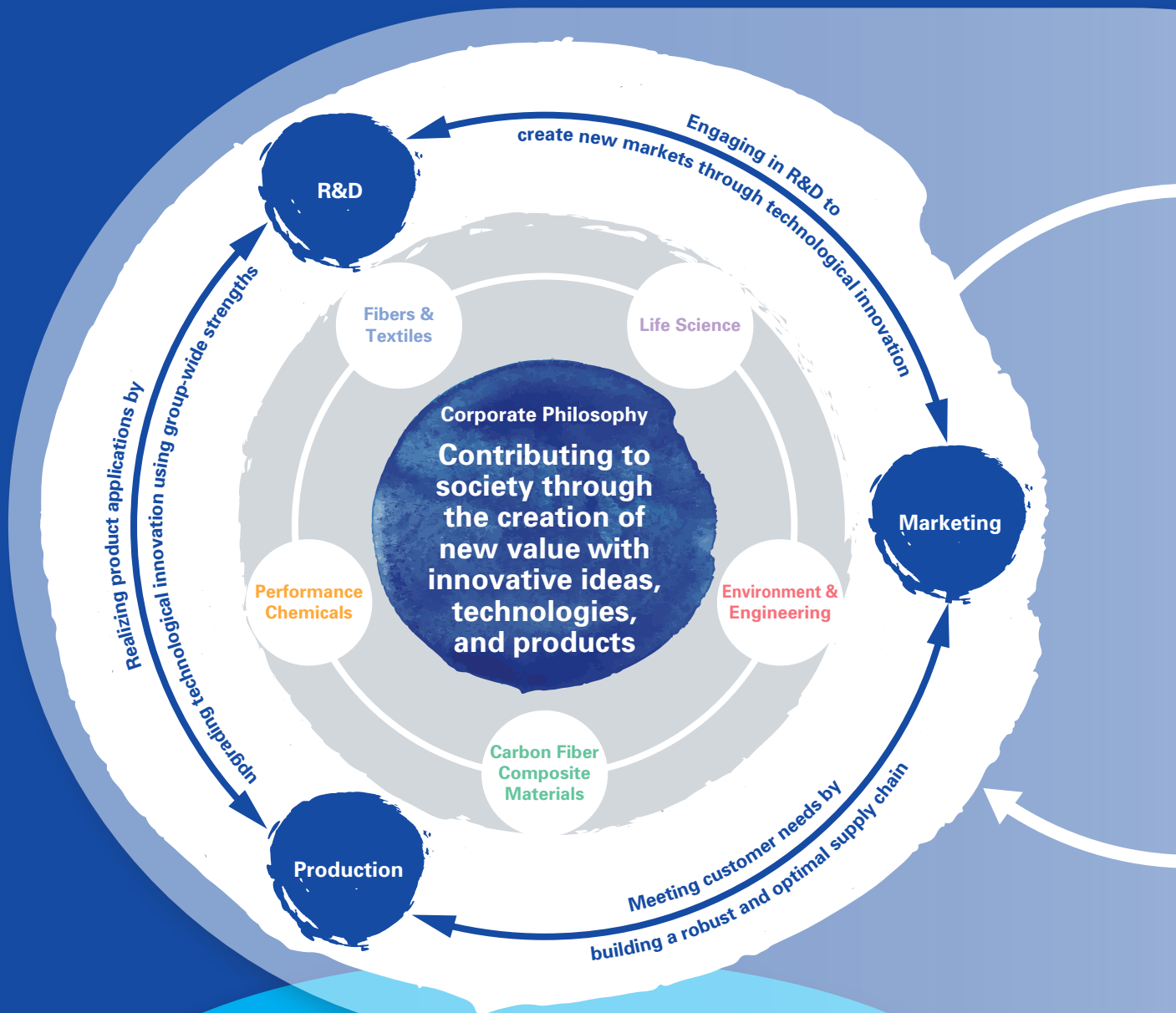


Toray's Value Creation Process

that enable it to "Contribute to society through the creation of new value with innovative ideas, technologies, and products"

Toray Group has continued to place the utmost importance on efforts aimed at contributing to society through business activities. While management from a long-term perspective that best reflects the requirements of the times, the Group has also engaged in people-centric management. Drawing on each of these core values since our foundation, we have worked diligently to pursue a process of co-creation with every customer that makes up the supply chain while ensuring mutual collaboration between our inherent R&D, marketing, and production strengths. Through these means, Toray Group is endeavoring to crystallize the four features of the world envisioned under its Sustainability Vision.

VALUE CREATION

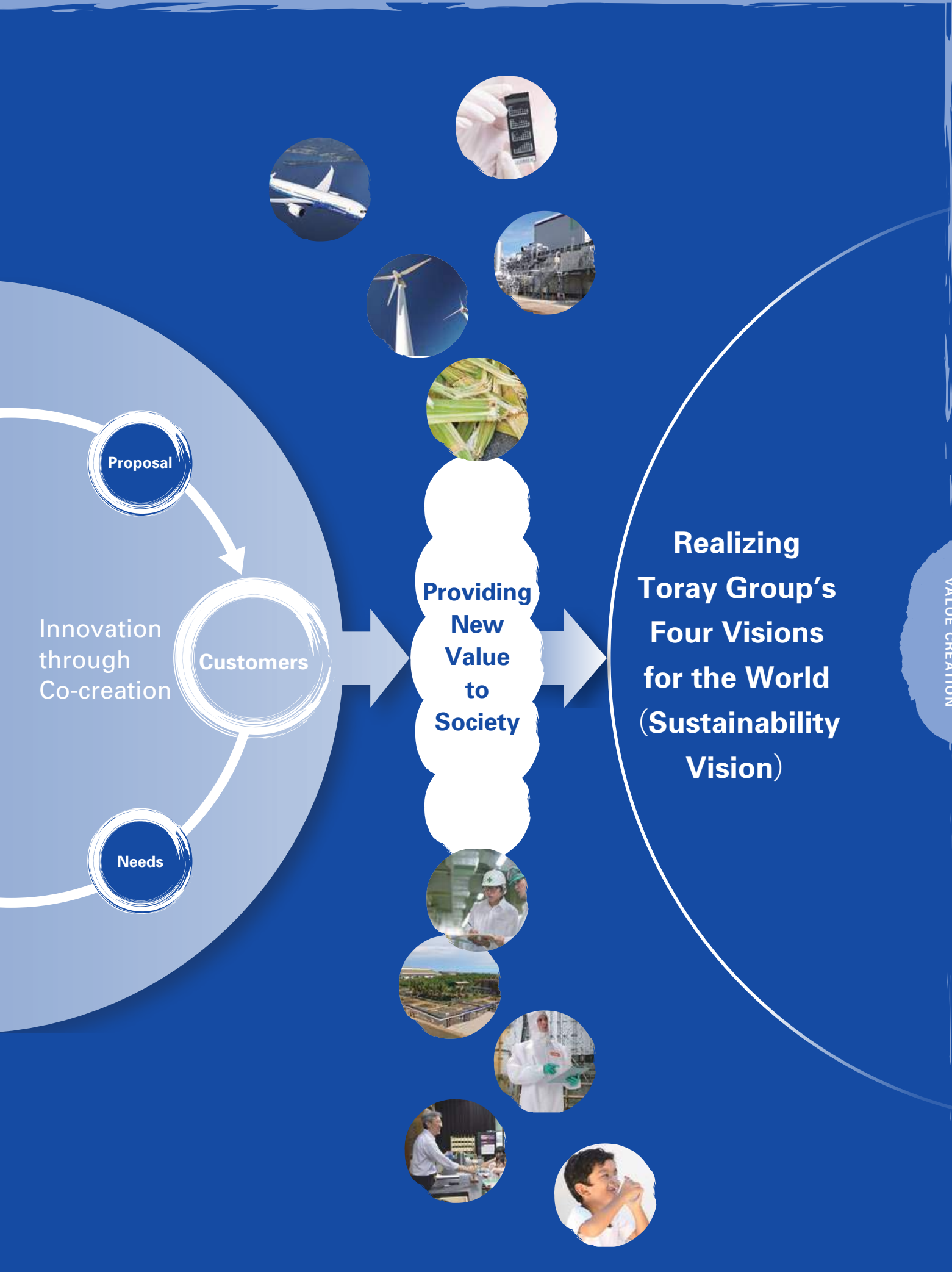


Value that we cherish as management Core Value

Contributing to society through business activities

Management from a long-term perspective

People-centric management (employees shape the destiny of a company)



Innovation through Co-creation

Proposal

Customers

Needs

Providing New Value to Society

Realizing Toray Group's Four Visions for the World (Sustainability Vision)

VALUE CREATION

An Advanced Materials Manufacturer That Gives Shape to Advanced Industries

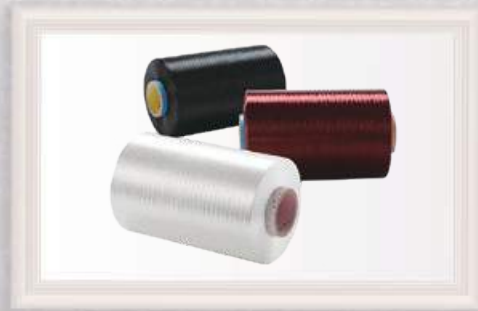
Since our establishment, we have positioned “contributing to society” as the focus of our existence. Carrying this focus into our corporate philosophy of “contributing to society through the creation of new value with innovative ideas, technologies, and products,” we have created a succession of materials that bring unprecedented levels of value to the world and forged a globally leading presence as an advanced materials manufacturer that gives shape to advanced industries.

1926

Began as a manufacturer of viscose rayon

The former Mitsui & Co.* was an importer of rayon yarn from Courtaulds PLC of the U.K. for sale in Japan. Mitsui established Toyo Rayon Co., Ltd. based on the national policy promoting Japanese industrial manufacturing. At the inaugural meeting on January 12, 1926, Yunosuke Yasukawa—at the time a managing director of Mitsui & Co.—acted as a representative of the incorporators and stated his hopes that the company would generate “major benefits for the national economy.”

* Note that the former Mitsui & Co. was a completely different corporate entity with no legal connection to the present-day Mitsui & Co.



1941

Succeeded in the synthesis and melt spinning of Nylon 6 fiber using proprietary technology

Developed using proprietary technology, “Nylon 6” has created new markets as a new fiber that can be applied in fishing nets as well as apparels such as stockings.

Polyester Film
Global Share
No.1



1959

Manufacture of LUMIRROR® polyester film began

Toray was the first company in Japan to industrialize polyester film. Positive steps have been taken to address market growth and to adapt to changing conditions and circumstances while gaining a share across a wide range of fields such as video tapes, industrial materials, specialty products, and others.

1955

Company principle established

“Toyo Rayon contributes to society” was identified as the Company’s original principle. Shigeki Tashiro, the Company’s chairman at that time, states “Just like individual people, companies have a social responsibility to improve the society in which they live.”

Luxury
Non-woven
Fabric with
Suede Texture
Global Share
No.1



Carbon Fiber
Global Share
No.1



1971

Marketing of ESCAINE®, ultra-microfiber non-woven fabric with suede texture, began

ESCAINE® is a non-woven fabric with suede texture using ultrafine microfibers. It was highly acclaimed as a fashion material for its lightweight and excellent chromogenic properties. Currently, it is being used in such areas as automobile interiors and furniture.

1971

Manufacture and marketing of carbon fiber TORAYCA® began

High-performance carbon fiber TORAYCA® features light weight, high tensile strength, and high stiffness. Sales activities commenced under the registered trademark “TORAYCA” from 1971.

1976

Marketing of TORAYCON® PBT resin began

Featuring outstanding long-term heat-resistance, chemical-resistance, weather resistance, and electrical characteristics, TORAYCON® is widely used in various connectors and other automobile parts, bobbins, coil cases, and other electronic and electrical components, and precision parts for office equipment.





RO Membrane
Global Share
No.1

1980

Marketing of ROMEMBRA® reverse osmosis membrane elements began

Research began in 1968 with ongoing development as a water treatment membrane. ROMEMBRA® enabled the production of ultra-pure water for the semiconductor industry and the desalination of sea and brine water.

'TORAY'

1986

The declaration of "A new founding" and a corporate philosophy was established to commemorate 60 years in business

We reviewed the Company principle and established a new corporate philosophy: "Contributing to society through the creation of new value with innovative ideas, technologies, and products." At the same time, we established our new corporate symbol as further commemoration of 60 years in business.



1990

TORAYCA® carbon fiber prepreg certified as a primary structural material for U.S. Boeing passenger aircraft

Initially the main applications of carbon fiber were fishing rods, golf shafts, and other sporting goods. Through improved technology and quality, the Company built up trust in this product as a secondary structural material in aircraft applications. In 1990, Toray prepreg was certified for the first time as a primary structural material (for structural parts where damage is directly linked to a crash) for the Boeing 777.

'TORAY'

Innovation by Chemistry

2006

Corporate slogan formulated

In April 2006, Toray Group created a new, long-term corporate vision—"AP-Innovation TORAY 21"—and adopted the corporate slogan "Innovation by Chemistry," declaring its aspiration "to become a global top company of advanced materials," while focusing on Chemistry.



2006

Strategic partnership started with UNIQLO CO., LTD.

As a company that provides innovative technologies and materials that have the power to fundamentally change society, Toray Group entered into a partnership agreement with UNIQLO CO., LTD., a company that enriches people's lives through clothes. Under this partnership both companies provide products that deliver new value and unprecedented levels of performance and comfort to people all over the world. The two companies are now in the third stage of the strategic partnership agreement.

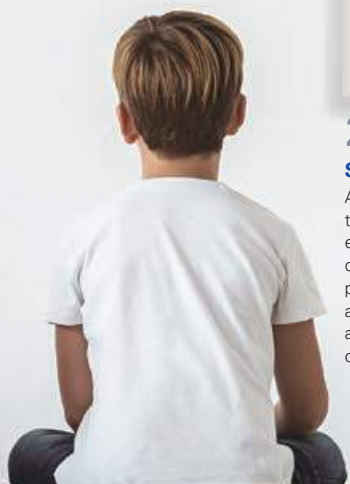


2016

Decided to establish the R&D Innovation Center for the Future as a project to commemorate the Company's 90th anniversary

Toray decided to establish the R&D Innovation Center for the Future at its Shiga Plant where the Company was founded, and will strengthen R&D to make people's lives better with *Kotozukuri* and value creation, which utilizes the strengths of advanced materials.

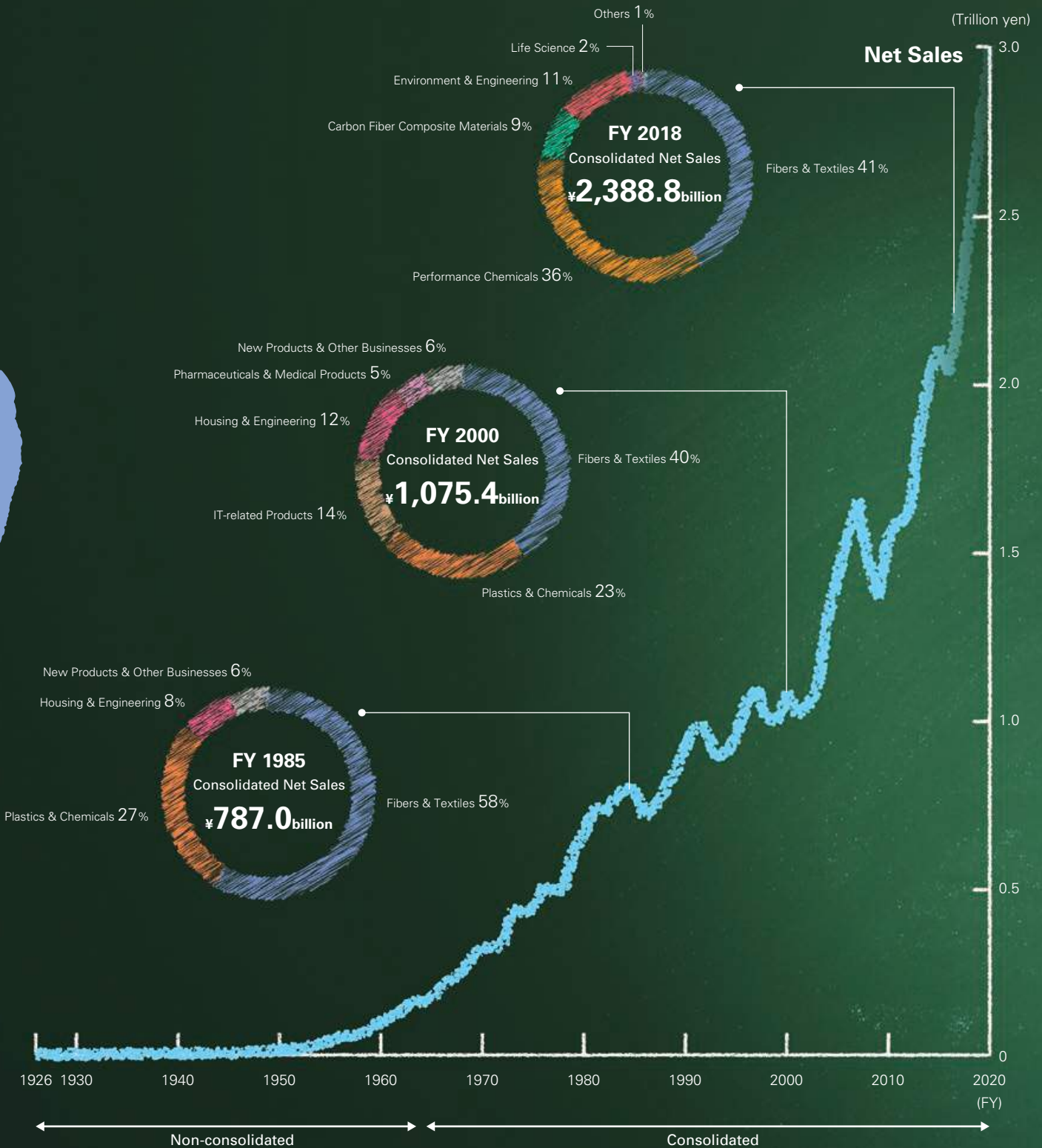
VALUE CREATION



Enhancing Long-term Corporate Value

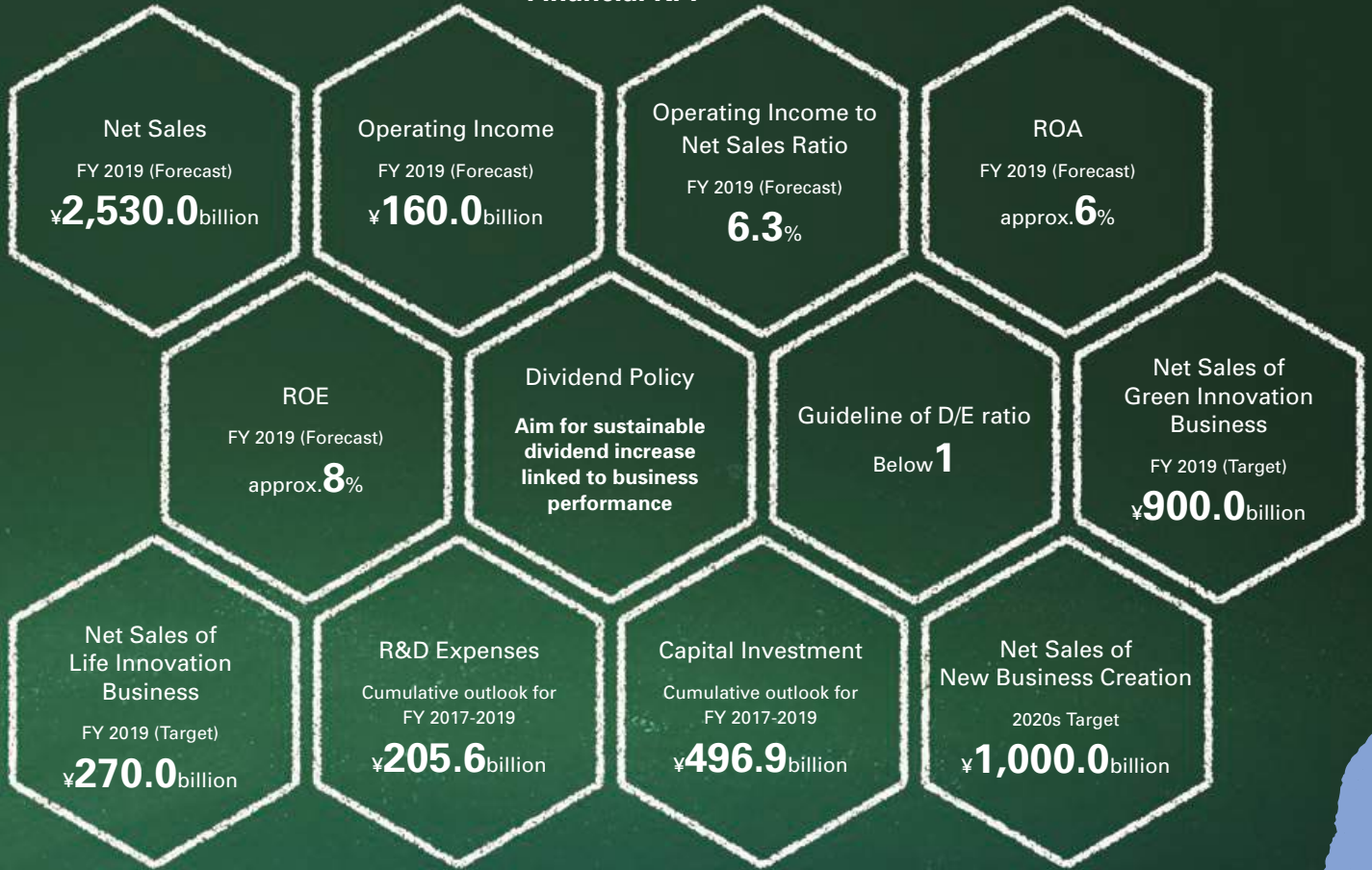
Toray Group began as a manufacturer of viscose rayon in 1926. On top of all three major synthetic fibers, nylon, polyester, and acrylic, the Company has continued to develop innovative technologies while creating a host of advanced materials and high value-added products in a broad range of films, chemicals, plastic resins, carbon fiber composite materials, pharmaceuticals and medical products, water treatment, and environmental fields. With an eye toward how society will evolve in 2050 and how innovative technologies and advanced materials may be utilized as a driving force, we will adopt a long-term perspective toward enhancing our corporate value.

VALUE CREATION



"US GAAP" for 1964 - 1983, "Japanese GAAP" after 1984

Financial KPI



Sustainable Related KPI (excerpt) FY 2020 Target



For more details, please refer to the following website (KPIs on promoting CSR):

Toray website > Social Responsibility > CSR Road Map and Progress on Key Performance Indicators

Inheriting the Ideas of “Long-term Continuity” and “Pursuit of the Ultimate Limits”

The phrase, “The Deeper, the Newer,” has been passed down as a key phrase at Toray Group, and has become part of the Group’s DNA. The concept underlying this is that when you dig deep into something and pursue it to its ultimate limit, the result will be new discoveries and inventions. An example of this would be the pursuit of the ultimate limits of film surface formation technologies. In the past, inorganic particles were added to the entirety of the film to create random projections on the surface, but Toray Group developed a technology that thinly laminates particle-based polymers on the film surface, with the particles aligned and the protrusion height carefully controlled. This technology contributed greatly to the success of the Company’s high-quality resolution video film business. While the appearance of DVDs signaled the end of the videotape market, the technology itself has been applied to other applications, including for data tape film and in support of the manufacturing process for polarizers and ceramic capacitors. Our focus on

Cultivating Business Seeds with the Potential to Create New Value

VALUE CREATION

Toray’s
Strengths

01

Research and Development

pursuing advanced technology stems from our belief that over time, the most advanced technology will likely be used in an increasing number of applications.

While it is true that it takes a certain amount of time to develop and commercialize advanced materials, the steadfast commitment to long-term continuity which is inextricably linked to the pursuit of the ultimate limits has become a hallmark of Toray Group. As an example, reverse osmosis membranes used in water purification and carbon fiber composite materials, which are among the Company’s mainstay products, took nearly a half century from initial research to large-scale market formation.

The strength of our R&D stems from the ability of the Group to recognize the long-term value of materials and the will to follow through, i.e., adhering to the concept of long-term continuity and the pursuit of the ultimate limits. This focus is the source of our hard-to-imitate competitive advantage and the wellspring of true innovation.

Toray Group has continued to invest in R&D without regard to fluctuations in the economy, and for many years has seen no substantial change in R&D costs as a percentage of sales, which serves to illustrate that innovation at the Group is based on the idea of long-term continuity and pursuing the ultimate limits.

Technology Center

Technical departments in
Business Divisions

Development Center

New Projects
Development Division

Technical departments in
Manufacturing Division

Engineering Division

Research & Development
Division



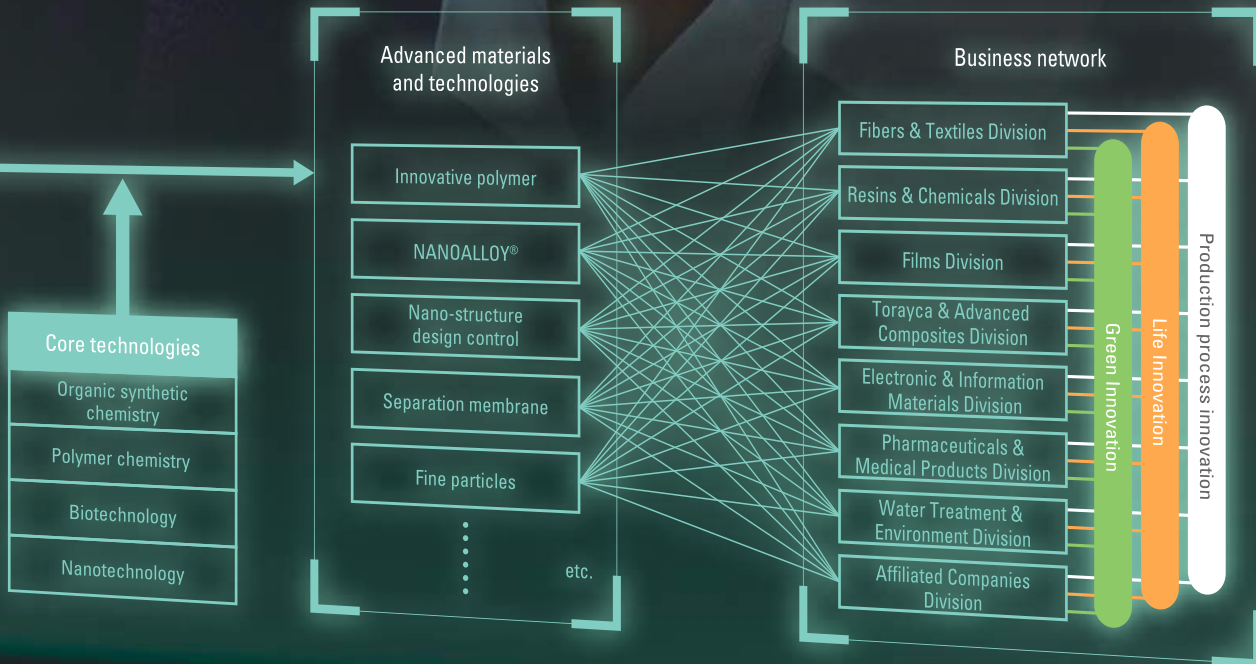
Curiosity-driven Research Producing the Seeds of New Technologies

Research for innovative new materials starts with the creation of themes in “fuzzy front end” (it literally means vague and uncertain world, and here defined as the period between when a product is first considered and when it is formally judged ready to enter development) . Somewhat similar to trying to dig a well in the vast desert first, it is important in this process not only to have a strong will, but also to have a system that promotes research activities that respect the creativity of those conducting the research.

Toray Group has since its founding encouraged independent research. At present, we believe about 20% of research time should be spent on curiosity-driven research, with each person focused on original basic research with the aim of creating a large-scale theme. This system has been effective in motivating research and has resulted in the creation of a variety of technologies. Researchers focused on this kind of curiosity-driven research were also one of the main reasons Toray Group was able to identify the value of carbon fiber before others and move into full-fledged research in the field. Curiosity-driven research also contributed to the development of highly profitable mainstay products such as thin layer laminated polyester film and artificial leather.

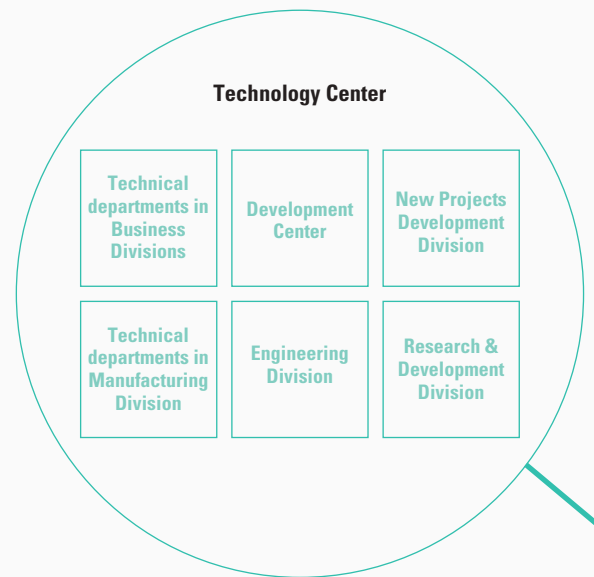


VALUE CREATION



Everything Derived from “four core technologies”

At first glance, it could appear that Toray Group business portfolio is diversified across a wide range of segments. However, all of these segments are built on our four core technologies. In addition to the organic synthetic chemistry, biotechnology, and polymer chemistry technologies the Company has focused its efforts on since its founding, Toray Group has added nanotechnology, the pursuit to the ultimate limits, as a fourth core technology. Using these four technologies, Toray Group is promoting greater depth and fusion of fundamental technologies such as polymerization, spinning, fibers application processing, film processing, and organic synthesis. The Group is also creating advanced materials and developing businesses in the fields of textiles, films, resins, chemicals, electronic & information materials, carbon fiber composite materials, pharmaceuticals, medical devices, and water treatment. All of these products have the four core technologies in common, which contributes to the likely emergence of technological synergies, and Toray Group is able to produce materials with even higher added value thanks to its various businesses combining the innovative technologies and advanced materials derived from these four core technologies.

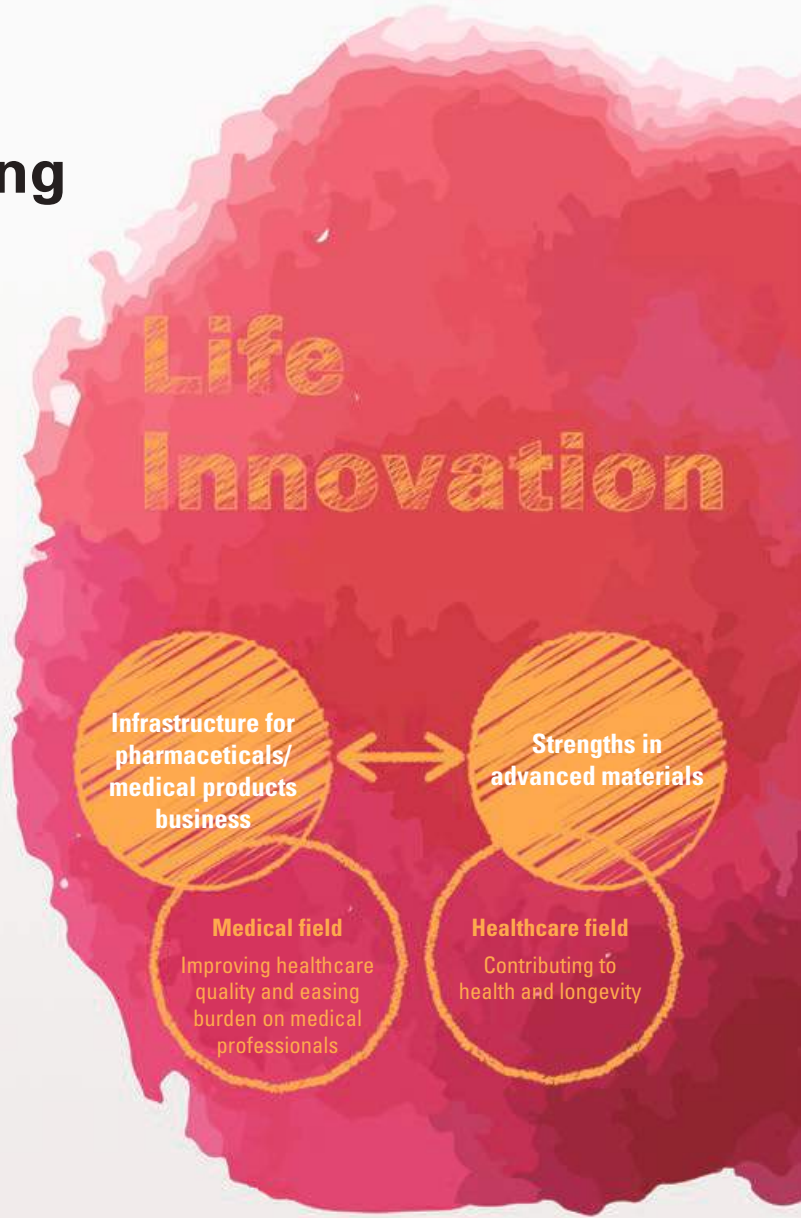


Solving Problems Using the Results from Core Technology Research and Development

An Undivided R&D Organization

Toray Group has centralized all of its R&D functions into a single organization called the Technology Center. Bringing together specialists from many fields in this undivided R&D organization makes it easier to create new innovations by integrating technologies. Moreover, the system enables the Group to exhibit combined strength by actively exploiting techniques and knowledge from many fields to solve problems in a single business area. It also enables various advanced materials and technologies to rapidly apply to multiple businesses.

With a focus on solving some of the issues facing the world, we are also developing Green Innovation Business and Life Innovation Business as Group-wide projects, based on the fusion of technologies. Using a one-package system centered on the Technology Center as a hub, we are focused on promoting the use of innovative technologies and advanced materials derived from our four core technologies in other fields, with the goal of maximizing returns on annual R&D investment of about ¥70 billion.



Green Innovation

Creation of Non-petroleum Materials

High-efficiency in Energy Use

New Energies

Water Treatment Membranes

Organic Synthetic Chemistry

Polymer Chemistry

Core Technologies

Nanotechnology

Biotechnology

VALUE CREATION

In addition to commercializing innovative materials, Toray recognizes the critical need to put forward proposals that dramatically increase the value of customers' products. With this in mind, Toray Group moves beyond the simple supply of materials, and works diligently to advance solutions that address customers' issues on the back of commonly shared visions.

Toray began the full-fledged production of commercial carbon fiber in 1971. Given the absence of carbon fiber market when we started, it was imperative that we take steps to create the market from scratch, while developing processing and molding methods, either on our own or in collaboration with customers. At the outset, we focused on the sporting and leisure fields, where a certain level of demand could be expected if the performance of products was high even when materials were a little expensive. As a result, we were successful in creating the market in the fields of fishing rods, golf clubs, and tennis rackets.

In contrast aircrafts, an area Toray Group targeted for carbon fiber sales in the long run, was hit by the first oil crisis in 1973. This set off the ongoing search for lighter weight, energy efficient materials by aircraft manufacturers, demand for carbon fiber reinforced plastic (CFRP) gradually increased for the use in the secondary structures of aircrafts, such as rudders. Based on the track record, The Boeing Company adopted plans to apply CFRP as a primary structural material (for structural parts where damage is directly linked to a crash) in its Boeing 777 in 1980,

Sharing Visions with Customers while Creating Markets

Toray's Strengths

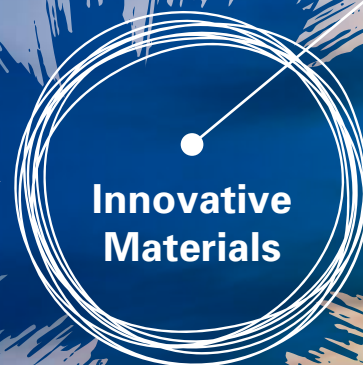
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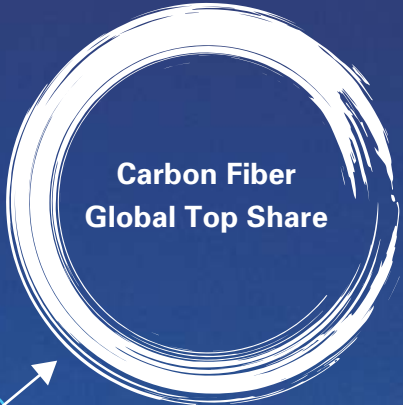
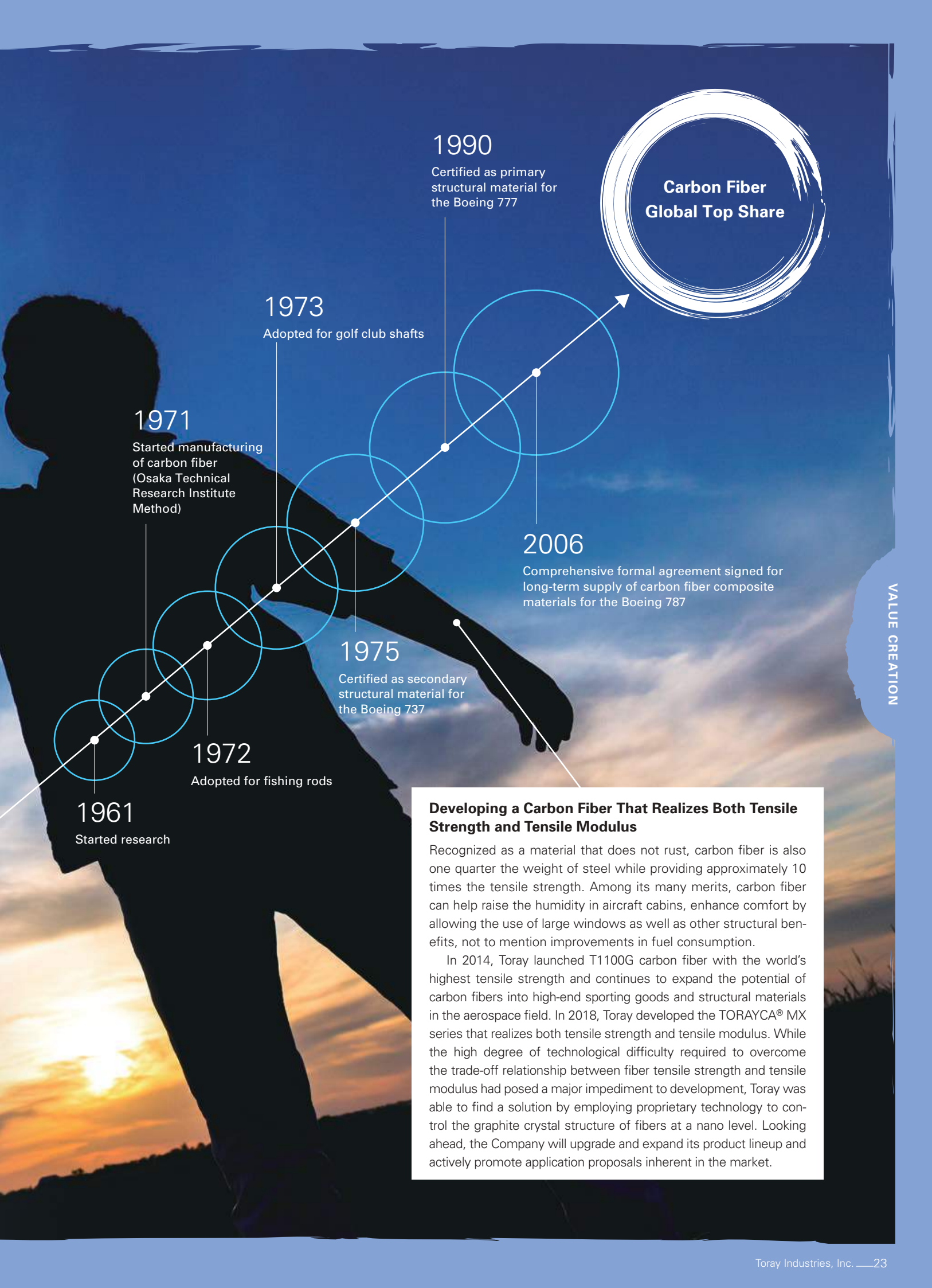
Marketing

and requested global manufacturers to step up their development of high-performance carbon fibers as well as CFRP. Against the backdrop of an increasingly competitive environment in the development of new technologies by each company, our product was certified as the world's first and only product which cleared the specification requirements put forward by The Boeing Company in 1990.

Our product has been recognized for its reliability as a material used in the manufacture of aircrafts, as well as for its stable supply and cost performance. Through a process of interactive technology exchange, Toray and The Boeing Company have continued to engage in the development of next-generation aircrafts, while nurturing strong ties of mutual trust. In 2003, both companies commenced the joint development of a CFRP for use in the next-generation medium-sized passenger aircraft the Boeing 787. After executing a fundamental agreement for the supply of materials in 2004, the companies concluded a long-term 16-year comprehensive supply contract in 2006. Spurred by the hope that carbon fiber would be adopted as a core material in the manufacture of all aircrafts, Toray has continued to engage in development. In a major step toward crystalizing visions of Toray Group and The Boeing Company, the Boeing 787, for the first time in the world, entered service across domestic flights in Japan in 2011. Over the ensuing period, the Boeing 787 operations have been expanded to service routes around the world.

Indicative of the widespread growth of the carbon fiber market, and our strong belief that materials have the power to bring about fundamental transformations in society, we are sharing visions with customers while providing broad solutions that help realize those visions as our inherent strength. As a result of these endeavors, we are expanding manufacturing markets in which materials play a leading role.





1990

Certified as primary structural material for the Boeing 777

1973

Adopted for golf club shafts

1971

Started manufacturing of carbon fiber (Osaka Technical Research Institute Method)

2006

Comprehensive formal agreement signed for long-term supply of carbon fiber composite materials for the Boeing 787

1975

Certified as secondary structural material for the Boeing 737

1972

Adopted for fishing rods

1961

Started research

VALUE CREATION

Developing a Carbon Fiber That Realizes Both Tensile Strength and Tensile Modulus

Recognized as a material that does not rust, carbon fiber is also one quarter the weight of steel while providing approximately 10 times the tensile strength. Among its many merits, carbon fiber can help raise the humidity in aircraft cabins, enhance comfort by allowing the use of large windows as well as other structural benefits, not to mention improvements in fuel consumption.

In 2014, Toray launched T1100G carbon fiber with the world's highest tensile strength and continues to expand the potential of carbon fibers into high-end sporting goods and structural materials in the aerospace field. In 2018, Toray developed the TORAYCA® MX series that realizes both tensile strength and tensile modulus. While the high degree of technological difficulty required to overcome the trade-off relationship between fiber tensile strength and tensile modulus had posed a major impediment to development, Toray was able to find a solution by employing proprietary technology to control the graphite crystal structure of fibers at a nano level. Looking ahead, the Company will upgrade and expand its product lineup and actively promote application proposals inherent in the market.

Since the dawn of the synthetic fibers market shortly after the end of the Second World War, Toray Group has not only supplied materials to primary users such as spinning companies and fiber merchants, but has also focused its energies on promoting the use of new material brands, including “Nylon” and “Tetoron” throughout the supply chain, from wholesalers to distributors. As the market for ready-made garments from brand-name apparel manufacturers increased in the 1960s–1970s, Toray organized its domestic production team, largely in Hokuriku manufacturing region, for the weaving, spinning, dyeing, fiber processing, and knitting segments, contributing to the establishment of an integrated fiber and textile business model.

The Group moved to accelerate global operations in the 1980s and 1990s, advancing the establishment of an integrated production system that covered everything from fiber to dyeing, in Southeast Asia and China.

The turn of the century saw strong growth in SPA (specialty store retailer of private label apparel) and fast fashion businesses. The SPA business model is very different from the traditional product-out business model, in which production is maintained at a constant level at each stage. In the SPA business model, production immediately reflects consumer behavior based on data collected at the store, bypassing interim distributors and allowing companies to completely sell out products while avoiding both excess inventories and lost sales opportunities.

Building a Supply Chain Unrivaled in the World with Our Powerful Partners

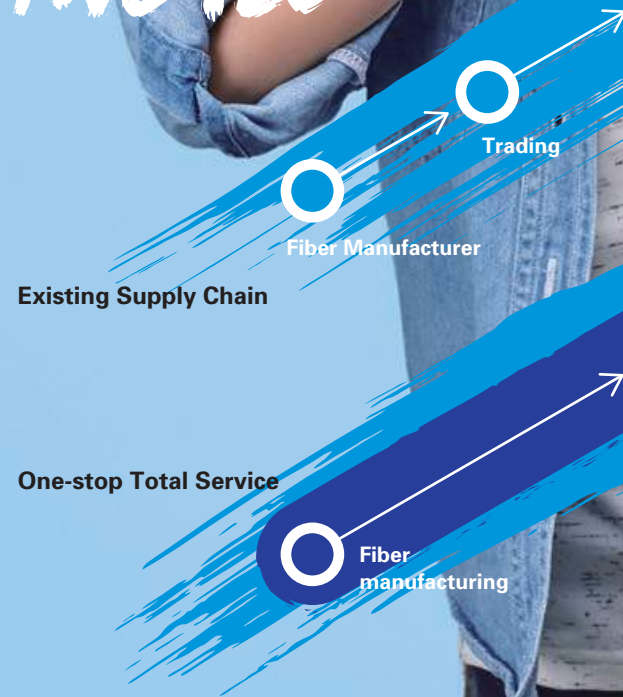
VALUE CREATION

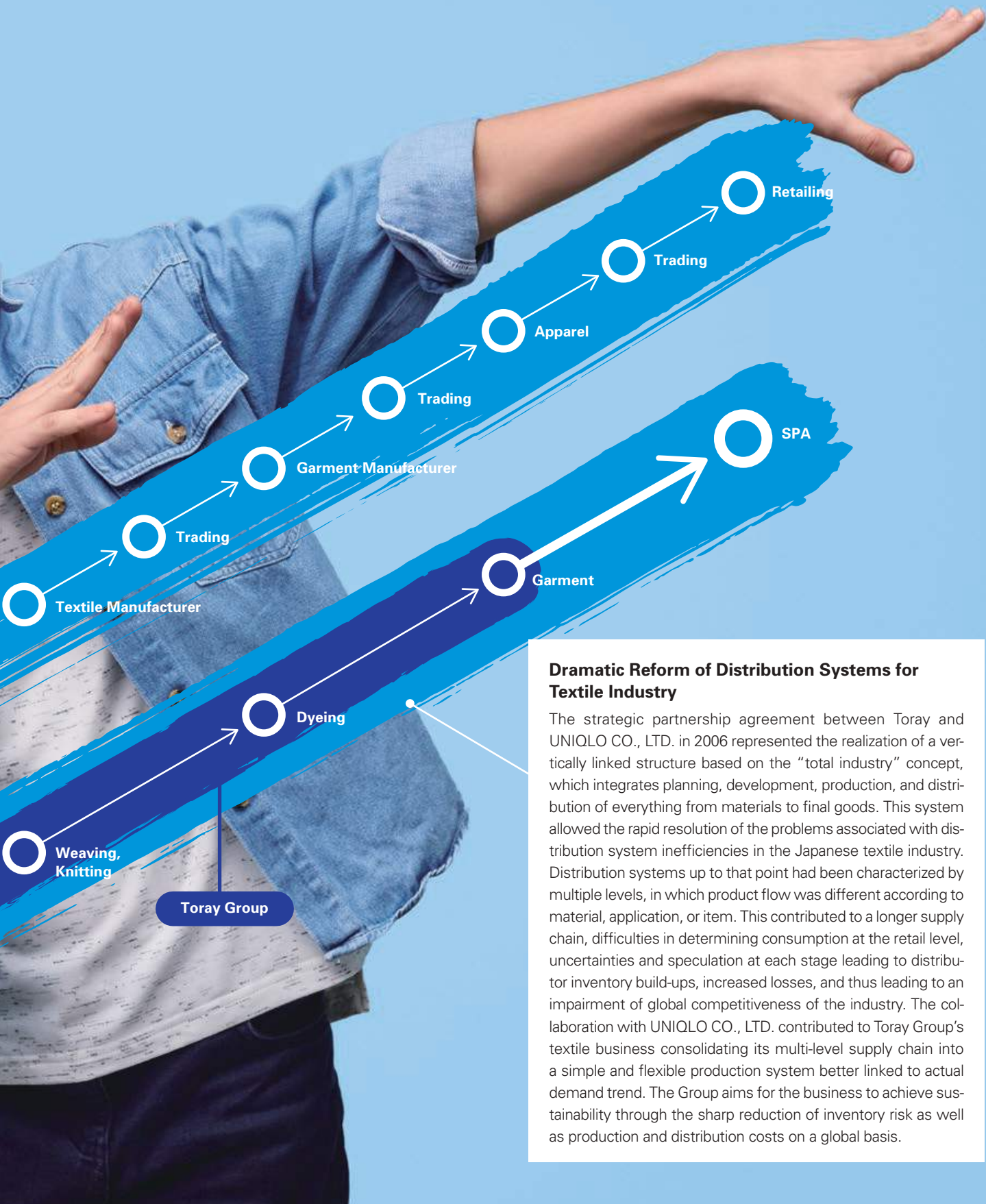
Toray's
Strengths

03

Supply Chain Management

Toray Group had the production technology capable of mass producing high-quality products, as well as a strategy for the global textile business that was well suited to the SPA mechanism. The Group also had a robust R&D system for the development of new and unique products. The Company in 2006 agreed to a strategic partnership with UNIQLO CO., LTD. and thereafter reformed the distribution system for fibers & textiles. The two companies moved to bridge the boundaries between a material manufacturer and a specialty store retailer of private label apparel (SPA), establishing an unprecedented business model in the world in which the two operated together as a virtual company that handled planning, development, production, and distribution for everything from raw materials to finished products. This contributed to the establishment of a global supply system, with production bases being located not only in China, but also in the ASEAN countries and Bangladesh. The Company has since continued to expand its integrated fibers, textiles, and garments business. Toray remains focused on building and operating a global supply chain network that can organically tie together a variety of processing stages and quickly deliver products with identical levels of quality thanks to the optimally located, efficient, and cost competitive production bases. Toray's building of a supply chain system unparalleled in the world contributed to the radical transformation of distribution systems in Japan, and appealing Japanese technology to the world, which has added new value to the textile industry.





VALUE CREATION

Dramatic Reform of Distribution Systems for Textile Industry

The strategic partnership agreement between Toray and UNIQLO CO., LTD. in 2006 represented the realization of a vertically linked structure based on the "total industry" concept, which integrates planning, development, production, and distribution of everything from materials to final goods. This system allowed the rapid resolution of the problems associated with distribution system inefficiencies in the Japanese textile industry. Distribution systems up to that point had been characterized by multiple levels, in which product flow was different according to material, application, or item. This contributed to a longer supply chain, difficulties in determining consumption at the retail level, uncertainties and speculation at each stage leading to distributor inventory build-ups, increased losses, and thus leading to an impairment of global competitiveness of the industry. The collaboration with UNIQLO CO., LTD. contributed to Toray Group's textile business consolidating its multi-level supply chain into a simple and flexible production system better linked to actual demand trend. The Group aims for the business to achieve sustainability through the sharp reduction of inventory risk as well as production and distribution costs on a global basis.

Guided by our basic policy of global management that emphasizes the need to take root over a long period in order to contribute to the economic development of the countries and regions where we operate our businesses, Toray Group's overseas production activities began with the establishment of a subsidiary in Thailand to provide integrated spinning, weaving, and dyeing of polyester-rayon fabric in 1963. As a Japanese company, Toray engaged in local production from an extremely early period. Beginning with Southeast Asia during the 1960s and 1970s, the Company's global network expanded to Europe and the U.S. in the 1980s, and then to the Republic of Korea and China in the 1990s. The Group has established production bases for such items as films and carbon fiber, in addition to fibers and textiles. Today, every effort is being made to promote organic collaboration among Group bases in Japan and overseas. Through these means, Toray is building an optimal global production and supply structure that adapts flexibly to changes in the business environment in line with market, foreign currency, and other trends. Furthermore, successful steps are being taken to create a production system that can supply high-quality products on a stable and continuous basis in any region.



Working to Secure Sustainable Growth on a Global Scale through Organic Collaboration Among Production Bases

VALUE CREATION

Toray's Strengths

04

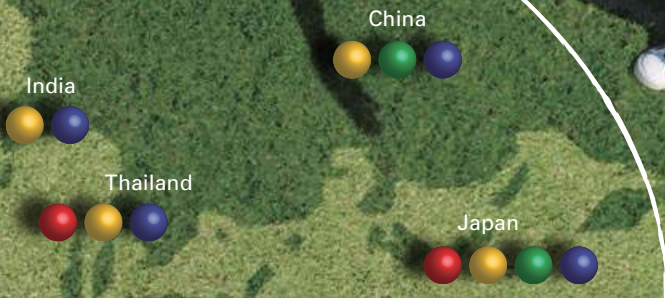
Global Production System

As of the end of fiscal 2018, Toray Group's network expanded to 26 countries worldwide. Accounting for 55% of the Group's total revenue, overseas sales amounted to roughly ¥1,300 billion. In contrast, the Group's overseas production ratio substantially exceeds its sales ratio. More than 75 to 80% of such principal products as fibers and textiles, resins, films, and carbon fibers are manufactured outside of Japan. Drawing on its global production system as a source of considerable strength, Toray Group is implementing a sustainable growth cycle. In specific terms, we are undertaking cutting-edge innovative research and development at our mother plant in Japan, while at the same time adopting a strategy to establish local production systems swiftly and flexibly from the perspectives of demand and cost competitiveness. Complementing these endeavors, we are also promoting the development of applications that cater to local needs at each production base. This in turn enables us to capture new profit opportunities.





Asian Airbag Textile Market



- Fiber Production and Sales 3 countries
- Textile Production and sales 6 countries
- R&D Center 2 countries
- Marketing 8 countries

Americas Airbag Textile Market



Working to Secure the Leading Position in Airbag Textile through a Global Integrated Production System

The airbag market is exhibiting rapid growth due to upswings in the number of automobiles sold in emerging countries as well as installation rates. In its airbag fibers & textiles business, Toray Group began the integrated production of a wide range of products from fibers to textiles in Mexico from 2018 as a part of efforts to further reinforce its global production system. Currently, Group companies manufacture airbag fibers in three locations and airbag textiles in six locations worldwide, respectively, under the global production system that is capable of providing airbag textiles of a uniform quality in a timely manner across the Group's entire network. As a result of these efforts, Toray Group is highly praised from a business continuity plan (BCP) perspective. Going forward, we are aiming to secure the top market share in the global airbag textiles market where strict quality control and reliability of products are required.

VALUE CREATION

Special Feature
R&D Dialogue



First of all, please tell us about your points of contact between Toray and science.

Abe | It really is an honor to be able to talk science with you Dr. Noyori, a recipient of the Nobel Prize in Chemistry. The results of your research into chirally catalyzed hydrogenation reactions became useful technologies that are widely used in the production of compounds, including pharmaceuticals. I have heard that your contacts with Toray date back a very long time.

Noyori | My family has long had a connection with Toray, or Toyo Rayon as it was back then. My grandfather and Asahiko Karashima, the company's future second chairman, were relatives and childhood friends from the same hometown, and I recollect hearing from my grandmother words that Mr. Karashima reportedly said, "If you lick it, rayon melts like glue."

What sparked my interest in science was Dr. Hideki Yukawa becoming the first Japanese Nobel laureate in the impoverished period right after the end of the Second World War. Many young boys held on to aspirations of emulating Dr. Yukawa, and I, at that time, an elementary school pupil, was one of them. Then, just prior to entering junior high school, my father, who was a researcher at a major chemical company, took me to a presentation on Toyo Rayon's nylon product development, where the president back then, Kikuo Sodeyama, introduced nylon as "an epoch-making product that is made from coal, water, and air." Since that was a time when people had nothing, I was impressed to learn even then that "chemistry is just like alchemy in that it can turn something worth nothing into things of value." This "Nylon Incident" gave me added impetus that led me to get enthusiastic about studying science. Added to

We All Dreamed About

which, as I always used to hear my father say at mealtimes, "The companies with money depend on overseas technology, and that is no good. To get back on its feet, Japan should focus on developing domestic technologies." As I grew up in such an environment, I aimed for and entered Kyoto University Faculty of Engineering, which has strengths in chemistry. I had thought that someday I would like to aim to become a researcher at Toyo Rayon. When

Koichi Abe

Executive Vice President and Representative
Member of the Board
Chief Technology Officer (CTO)
Toray Industries, Inc.

Born in 1953

Completed Master's Degree (Physical Chemistry),
Graduate School of Engineering Science, Osaka
University

1977 Joined the Company (Films & Film Products
Research Laboratories)

2005 Vice President and General Manager of
Research & Development Division

Since 2014 Executive Vice President and
Representative Member of the Board

I entered graduate school, however, I was enthusiastic about research and, having been recommended by the professor supervising my work, chose the path of remaining there with the aim of becoming a researcher. But, after having bounced around from one place to the next, I have become deeply involved with Toray as an outside director over the past four years, so my dream came true, and I am finding it very rewarding.

Abe | What led me to have an interest in science was not some lofty motivation like that of Dr. Noyori, but the *Astro Boy* manga series. A child of science, jet propulsion, 100,000 horsepower, a nuclear-powered hero fighting for justice...I received strong messages that science exists for and contributes to society, and vaguely wanted to somehow contribute to society myself through science when I was older. Later, I attended a public high school where I could choose a mathematics and science course from the first grade. The science classes there were not centered on classroom lectures, but a repetitive experience of experimenting by replacing basic principles with macro models. My teacher at that time would give fervent speeches about famous sayings from Nobel Prize winners, and I remember one that seemed to resonate with me in particular was something that Pasteur is supposed to have said: "Chance favors the prepared mind." I interpreted this as "Lady Luck smiles on those who continue to be aware of problems," and that is still my motto. Also, when the teacher gave us a problem of estimating the number of soybeans packed into a plastic case, you run out of time if you try to calculate it properly. I was taken aback by this. In fact, it taught the importance of intuition. Those kinds of unconventional courses aroused my curiosity about science all the more.

In my university days, as a researcher, I had knowledge hammered

Becoming a Scientist

into me, such as "Predict the answer before experimenting. The experiment provides confirmation," "Before conducting an experiment, think carefully about whether the experiment is really necessary," and "If you conduct a two-hour experiment, take at least twice as much thinking time in the laboratory." One day, by changing an experiment's procedure, a phenomenon completely different from the conventional prediction had occurred, and the professor supervising my work told me "We are having a company to file a patent application for your research." That company was Toray.

It was with that kind of relationship that I joined Toray and was initially assigned to the Films & Film Products Research Laboratories. Here too, little things I became aware of and an awareness of problems when conducting one research theme provided hints for setting the next theme. At Toray, key phrases like "The deeper, the newer" and "Pursuit of the ultimate limits" have been handed down over the years, but the result of having instilled them in me was that we developed the thin film lamination technology for magnetic tape, New Surface Topography (NEST), for which we won an Okochi Memorial Production Prize.



Ryoji Noyori

Outside Director, Toray Industries, Inc.

Born in 1938

Graduated from Kyoto University

Doctor of Engineering, Distinguished Professor, Nagoya University

2000 Received Order of Culture from Japanese Government

2001 Received Nobel Prize in Chemistry for the development of chirally catalyzed hydrogenation reactions

Since 2015 Outside Director, Toray Industries, Inc.



Intense tenacity is a strength based on a typically Japanese trait, and this the biggest barrier to entry for new market entrants.



In what areas do Toray's R&D fortes lie?

Abe | First of all, Toray doesn't express research and technological development as the one combined term in Japanese, unlike such as R&D in English, and always puts a break in between, research and technological development. Research is like creating one from zero, in other words akin to digging a well, whereas technological development is recognizing that you will fabricate a target quality product in a fixed time for a fixed cost. Having made the distinction between research and technological development in this way, we build one-package systems in which these elements are not divided into two and that I manage in my capacity as general manager of the Technology Center or CTO.

Secondly, at Toray, we identify the value of materials with a broad vision of the times and have that culture of persistently pursuing the ultimate limits with a focus on basic research attitude. In global competition, this intense tenacity is a strength based on a typically Japanese trait, and I consider this the biggest barrier to entry for potential new market entrants. As exemplified by carbon fiber, which became the main structural material for aircrafts more than half a century after the start of research, the culture of commitment to the "Pursuit of the ultimate limits" has built up a host of successful experiences and we continue to reap the benefits to this day.

Finally, the reason why we have a Technology Center is to integrate Toray's research and technological development functions and bring together experts from a variety of fields. The existence of this organization enables the development of advanced materials created in one field to be deployed in other fields. Occurrences of fusions of technologies are also facilitated. One example is the "DNA Chip," which is expected to detect various types of cancer from a small amount of blood and was created by the shared knowledge of biotechnology and nanotechnology experts. Also, to solve the problems associated with carbon fiber and water treatment membranes, we are demonstrating our

comprehensive strengths by utilizing technologies and knowledge from different fields to solve issues in one business field, such as the medical-field researchers who are lending their support to organic synthetic chemistry technologies.

Noyori | Toray has earned a very high level of trust from society by having each of its businesses provide products based on proprietary technologies. It might well be that Toray's comprehensive strengths, in which a wide range of knowledge and technology can bring about innovation across businesses, are a feature unrivaled by other companies. However, in unforgiving competition with European and U.S. companies, which always follow bold selection and concentration policies, and Asian companies with their low-cost production capabilities, Toray must be careful not to expand its business domain too far so that its relative competitiveness is not lost.

Abe | I agree with you. If researchers were to be given a free rein in the setting and management of research themes, management resources would be scattered and research efficiency would decline, making it impossible to win against fierce competition. Having said that, in maintaining technology-based management having an environment that draws out the free ideas of researchers is of absolute necessity. This we thus call "underground research," and at Toray, researchers are encouraged to spend about 20% of their working hours conducting discretionary preliminary experiments and investigations without reporting them to their supervisors. Carbon fiber and my development of NEST arose from underground research.

However, when moving from the research stage to the development stage, because we will create a pilot plant and need a lot of raw materials and people, it is impossible to do everything. Deciding what to invest in is the real thrill of management, but since it is a very hard decision to make, I make a point of making a judgment after trying as much as possible to quantify the extent of its value. Moreover, since this is an age in which our integral technologies are being caught up in the blink of an eye, we carefully examine whether it is a theme that would enable us to demonstrate Toray's strengths in the years to come, not just transiently. Priority is also given to those themes that have a high affinity with Toray's business and technological foundations and that cannot be built overnight. I call this "appropriateness for the Company" and is something to which I attach great importance. We are advancing to development stages when we can build up an exact picture of where to get value for money from the technology, where we could earn income in the value chain and how to build a business model that minimizes risk and maximizes return.



It is said that it is difficult for innovation to happen in Japan. What are your thoughts on this issue?

Noyori | Japanese companies are often said to "win in technology and lose in business." Since projects do not advance to the development stage despite their high potential and are poorly converted into value, Japanese R&D expenses tend to be perceived as costs rather than investments. Just because a project did not reach the commercialization stage, however, does not necessarily mean that the technological level was inferior, and there are many "premature inventions"

that the times have not caught up with. If, a few years later, an idea were to undergo huge transformation outside the company that had first thought of it, that would be a story of extreme wasted effort.

We should not be passive with regards to markets, but instead gather information, look out across the world and proactively make proposals that make use of our inventions and technologies. Japanese companies have keen “insect eyes” to view one thing intensely and precisely, but I think we have more of a need to develop “bird’s eyes” to have a panoramic, bird’s-eye view of things and “fish eyes” to sense as yet unrevealed phenomena and signs.

Then, as we enter the age of “value co-creation” on a worldwide basis, there is another problem in that Japanese people are not aware of the differences between groups and teams. A group has the meaning of a “flock” that occurs spontaneously based on homogeneity, whereas a team is an “organization” that has an artificially defined purpose. Since the traditional Japanese spirit of “doing something while maintaining precious harmony” has its origins in flocks, this exerts great influence in social stability and in the execution of routine tasks. However, the power of multiplication to create new value does not emerge from a homogeneous group. Solo musicians and vocalists are good in music, but in an orchestra format you have to bring together virtuosos for performances on a variety of musical instruments. And it will take an excellent conductor to hold them together. Unlike tug-of-war competitions, baseball and rugby games need players with different roles in order to win, and team lineups that are rich in diversity are essential. To speed up innovation, Japanese companies in particular should be aware that selecting different people, not closed groups, forms winning teams. Because Silicon Valley is able to do that, startups succeed. They benefit from investing in innovative ideas, bring together diverse talent from around the world with that capital, and create the strongest teams.

Another thing I would like to add is that I think science and technology also requires art, or perhaps I should say, an element of sensitivity. At advanced technology universities, not only in Europe and the United States but also in Asia, there is an increasing number of art departments that inspire sensitivity. There are many Toray researchers with excellent STEM (Science, Technology, Engineering, Mathematics), but having added Art, the people who possess a sense of STEAM will become indispensable for future business development.

Naturally, company research should be conducted not for solving immediate problems but for creating new value for the future. Society is vast. Researchers and engineers tend to attack a research theme with established logic, but unless they possess the “creativity” to provide “imagination,” they will not be able to create things the world wants. In that sense, the approach that says an expert will realize something with the ideas from an amateur is also important. Isn’t it also important, however, to adopt various sensibilities and think about innovation with soft ideas, such as from sales and marketing departments that are in contact with customers on a daily basis, people who are sensitive to life or employees who attended art schools who possess more keenly developed intuition and “feel”?

Abe | To respond to Dr. Noyori’s suggestions, Toray is now in the process of building the R&D Innovation Center for the Future and is aiming for its completion in December 2019. The Center



To win in business, Japanese companies should be aware of forming winning teams rather than closed groups.

will consist of an integrated research building, which will fulfill an ideas creation function, and an experimental research building that will promote the prototype production, assessment and demonstration of products developed on the basis of those ideas. The plan is for the Advisory Board to also welcome people from the areas of humanities and social sciences. Instead of the Center serving just as a technological development base for *monozukuri* (manufacturing), we are exploring the functions and mechanisms necessary for the future society and trying to conduct *kotozukuri* (the creation of added value) using the strengths of materials. The Center will also fulfill an innovation hub function, such as an international conference hall, exhibition/demonstration area, and open lab, and accelerate strategic open innovation through exchange, fusion, and collaboration with academia and important partners in various fields.



Please tell us more about the importance of open innovation.

Noyori | The days when a company could singlehandedly undertake everything, from research to technological development, have passed. In the pharmaceutical industry collaboration with external research institutes and startups has become commonplace. Innovation has a difficult birth from the traditional large companies with entrenched organizations. What is effective instead is an “ecosystem” in which various structural elements function cyclically and efficiently, like the ecosystems in the natural world. In other words, as a strategy, it is important for Toray to regard its own technologies as the core, to create high value-added products while utilizing external technologies and capital, and build the mechanisms to continuously generate revenue. The Toray Technology Center is not a place to lock up the accumulated knowledge and technology in a safe. To bring about innovation, Toray should actively promote not only internal use but also the integration of technologies with the outside, and I think that Executive Vice President and CTO Abe’s role, in the control tower overseeing operations, is of great importance.

Abe | I think Toray originally had an ethos of what we now call open innovation, but around the year 2000, the Company was particularly concerned about self-sufficiency. However, in the fiscal year ended March 2002, when Toray (unconsolidated) recorded a loss in operating profit, we earnestly reflected on that particular commitment and established the New Frontiers Research Laboratories in 2003. However, looking back, the basic invention of carbon fiber was that of Dr. Akio Shindo of the Osaka Technical Research Institute (now the National Institute of Advanced Industrial Science and Technology (AIST) Kansai). Toray quickly realized its value, received a patent license, and has persistently continued research and technological development. I think this is exactly what open innovation is all about. I would like to reaffirm that kind of activity and thereby bestow a meaningful function on the R&D Innovation Center for the Future.



In the sense of science for solving social issues, the marine plastics pollution issue is coming under intense scrutiny. Please tell us about the efforts that Toray is making in this regard.

Abe | Resolving the marine plastic pollution issue is positioned as a priority theme at Toray. However, just because something is made from biodegradable plastic, it does not mean that it will easily biodegrade when thrown away into seawater. The misunderstanding that plastic immediately biodegrades may conversely encourage more dumping. Giving consideration to such possibility, Toray is focusing on recyclability. For example, most packaging bags commonly used in supermarkets are plastic films but they are made in combination with multiple materials. By reducing the material to one type of film, we believe that recycling would be greatly encouraged.

Noyori | There is an increasing demand for materials that contribute not only to innovative functions, but also to a recycling economy. This is because the more useful the product, the more its negative impact, such as in the form of environmental problems, tends to increase. Research to efficiently produce oil-derived structures that realize breakthrough functionality will continue to be important. On the other hand, since Toray is a company that provides materials to all industries around the world, I think that it has a social obligation to make effective proposals for environmental problems, including marine plastic pollution, by the power of materials. In addition, because Toray advocates that “materials can change our lives,” as a Toray supporter, I would like the Company to formulate and address “what should be done,” not at the level of doing “what can be done,” but in a leading role in solving these global issues.



What are your thoughts on human resource development that contributes to the world with the power of science?

Abe | Researchers and engineers who have made great achievements at Toray are not passive, have a high sense of purpose and mission, and are able to actively think and work, but they also are “people with extensive expertise backed by basic scientific capabilities.” However, the recent trend

at universities is that specialized fields have become limited and more extensive, but even after completing a master’s program in polymer chemistry, it seems that the basic scientific ability to see the entire picture, including the surroundings—the “bird’s eyes” that Dr. Noyori mentioned—seems to have declined. In the meantime, it has become no longer possible to create major new products from a single technology, and it remains difficult to produce significant results from research conducted in isolation. Moreover, the major subjects at universities and research themes at companies do not always coincide. Thus, people who can see things with “bird’s eyes,” who possess multiple areas of expertise, even if they are not the same depth, and who know the key points to look for when approaching unknown fields, are producing great results. These are the types of human resources on which we are focusing development.

To create a climate where one could concentrate on research and technological development for a long time, and in which young researchers could work hard to become “research professionals,” Toray established a Research Fellow System in 1992, and an Engineering Fellow System in 1998. We bestow the titles of Research Fellow or Engineering Fellow on research and technological development engineers who have achieved breakthroughs that have contributed to the Company or have demonstrated their professional leadership in either of those fields. As an effect of this, there are people with proficient skills at Toray. We have also compiled a collection of successful cases called “How I Proceeded with My Research,” about how breakthroughs have come about, and are making efforts to pass them on.

Noyori | People are drawn to people. Rather than learning what kind of a product was made, people are more interested in the routes taken to bring about success. I think it’s very good to pass on the efforts of successful people.

In my experience, the owner of an original idea is not necessarily an excellent student who can do anything, or a student with high academic grades. Rather, the ideas and behavior of honors students are said to be similar. It is a problem if everyone is outside the norm, but in making something that does not yet exist, you cannot ignore the ideas of eccentrics and stubborn researchers. I think that non-standard ideas will arise from those who have been self-taught since they were young and are in the habit of self-study. For that reason, it is not easy for them to abandon pet theories and they tend to be isolated in an organization, but regardless of that I think that it should be Toray that trains the non-conformists of this world.

In addition, it is clear that we are heading to an era in which data will be known as the second oil resource, and AI and big data will exert their influence. In that respect, it has become important to secure and train human resources who are strong in mathematics and statistics. As far as researchers are concerned, there was an awareness that digital technology is a means to do things efficiently, and that digitalization and systemization are somehow alien to a world of steady manual labor like chemistry. But this belief should be revised. The evolution of IT has enabled exploration with orders of magnitude and speed. In 10 years’ time, the chemical industry map will be filled with the colors of the



If you want to become a researcher, you will need the spirit to make a big hit.

Koichi Abe

companies that are data driven. Throughout the Company, Toray should aim to be the market leader in the new information-oriented society.



Finally, as a message to the researchers and engineers who will be leading the coming era, please tell us what kind of human resources Toray is seeking.

Abe | In the words of our late honorary chairman, Katsunosuke Maeda, Toray is seeking for human resources who “have a discerning eye for change and possess the power to see through the essence of the matter” and are capable of “independently tackling their own issues head-on.” This has not changed and will not change. On top of that, I think that even a company with sales exceeding ¥3 trillion will start to decline if it loses its spirit as a collective of startups. To be honest, in the past, I was researching films with the spirit of “making a big hit.” I still feel that pioneer in me saying, “I will change Toray with my own strength. I will change the world with my own strength.” I would like everyone to possess that degree of fearlessness.

Noyori | I would like young people who are full of intelligence and sensibility to fully recognize the current trends in a world where the way things are in modern civilization are being questioned, to fully utilize their talents upon coming to Toray. Toray is aiming for global recognition as an excellent company. Based on Toray’s philosophy that is similar

I would like scientists to live in a world they themselves have created.

Ryoji Noyori

to CSV (Creating shared value), which balances economic profit activities and the creation of social value, the company is staking its future on the Green Innovation Business Expansion Project and Life Innovation Business Expansion Project. What is meant by life here?

Toray should aim not only for innovation for life but also for innovation of livelihoods and lifestyles. These will become possible only after reflecting the will of society. There is a host of opportunities for Toray to do that.

I know from personal experience that science makes great contributions to society and is a truly rewarding life occupation. I would like young scientists who are breaking new ground toward the future, to live in a world they themselves have created, not one given to them by others. Possessing that spirit, I hope that they can depict the future society the way it should be, by cooperating with a variety of people.

As one of the Company’s directors myself, I am aware of my responsibility to those who will be responsible for the future of Toray. Yoshikazu Ito, who himself developed a nylon manufacturing method utilizing photosynthesis, and changed the company name from Toyo Rayon to Toray after taking office as president, and focused on developing business in the non-textile sector, said, “It is easy to just improve business results over the short term. The president’s job is to sow the seeds for the generation after next.” This spirit of management has been passed down to Toray’s current president, Akihiro Nikkaku. I, too, would like to support management with that kind of spirit.