1.2 Japan's Scientific and Technological Capabilities and Their Level

As a comprehensive framework for Japan's scientific and technological policy, the Science and Technology Basic Law was enacted in 1995, and the "Science and Technology Basic Plan" was formulated as a five-year plan based on this basic law (first period: from 1996; second period: from 2001). The current Second Basic Plan encompasses expansion of government investment in R&D, strategic priority setting, and reform of the science and technology system for increasing Japan's scientific and technological capabilities.

Accumulation of such policies and resource investment is expected to bring about "creation of new knowledge," "creation of vitality based on the knowledge," and "creation of an affluent society based on the knowledge" in Japan as a result.

This chapter overviews the scientific and technological achievements in Japan in recent years, people who are making these achievements, the Science and Technology Basic Law, and the First and Second Science and Technology Basic Plans based on the basic law. Lastly, it clarifies Japan's scientific and technological level through comparisons with other countries.

1.2.1 Japan's Scientific and Technological Achievements

1.2.1.1 Scientific and Technological Achievements and Spillover Effects

Japan's scientific and technological achievements cover extensive fields, so it is difficult to overview all of them. Nevertheless, "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan" ("Study for Evaluating the Achievements of the S&T Basic Plans in Japan"(NISTEP Report, no. 89, March 2005)) compiled by the National Institute of Science and Technology Policy analyzes case examples in the eight fields specified in the Second Science and Technology Basic Plan and cites examples of effects that have been already generated over the past ten years or so, as shown in Table 1-2-1.

This section looks at the achievements and spillover effects of science and technology mainly based on case examples in the four priority fields and the other four fields that were taken up in the above report.

(1) Economic effects

Economic effects include "creating or expanding markets and employment," "reducing costs," "reducing economic risks," and "enhancing international competitiveness."

(Creating or expanding markets and employment)

The development of new technologies through R&D and subsequent technological progress have, when applied to products and services, an effect of creating or expanding the markets of these products and services, as well as creating or expanding related employment. Based on a creative research achievement of a Japanese researcher, the high-intensity LED was commercialized for the first time by a Japanese company in 1994. Today, Japanese companies command an 80% share of the world market for high-intensity LED. The world market size for overall high-intensity LED exceeded 100 billion yen in 2003, and is expected to grow further in the future. Examples of this type of effects are listed in Table 1-2-2.

Table 1-2-1 Examples of the Effects Generated by Science and Technology

Category	Type of effects	Examples of specific effects
Economic effects	Creating/expanding markets (employment)	- Creating new product/service markets - Expanding related markets - Giving rise to venture companies
	Reducing costs	- Shortening the R&D period, reducing test production costs - Improving efficiency of physical distribution, reducing inventory costs - Reducing energy costs, reducing costs for environmental measures
	Reducing economic risks	- Averting business risks - Preventing/reducing damage from disasters - Preventing a decline in product prices
	Enhancing international competitiveness	- Contributing to technological progress through scientific research - Enhancing international competitiveness through infrastructure development - Enhancing international competitiveness through pioneering efforts
Social effects	Addressing environmental problems	- Reducing greenhouse gas emissions - Preventing air pollution (dioxin, SOx, NOx, particulate matter) - Preventing water/soil pollution (PCB, lead, cadmium), reducing waste
	Addressing energy/resource problems	- Saving energy - Thermal/material recycling - Improving energy security
	Addressing the aging of the population	- Facilitating social participation of the elderly and the disabled - Reducing the burden of nursing care on society - Achieving a society of healthy longevity
	Improving social infrastructure/disaster prevention measures	- Improving the physical disaster prevention measures of structures - Preventing disasters in advance or reducing damage through information transmission - Improving the safety and reliability of social infrastructure, reducing traffic accidents
	Other	- Making international contributions - Influencing culture and policies
Effects on people's lives	Securing the lives /livelihoods of the people	- Reducing loss of lives at times of disasters - Overcoming deadly diseases
	Maintaining/ recovering people's health	- Preventing deterioration of the living environment (air, water, soil, noise, vibration) - Improving therapeutic effects to combat diseases
	Improving convenience /comfort for the people	- Reducing the burden on household budgets - Increasing convenience through reducing the size and weight of electronic equipment - Facilitating access to various services
	Changing people's awareness/lifestyles	- Increasing energy-saving/recycling awareness - Improving disaster-prevention awareness - Changing lifestyles through altering the concept of distance and time

Source: National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

Table 1-2-2 Examples of Creating or Expanding the Domestic Market and Employment

Type of effects	Case example	Field	Effects
Creating a market	Processing technology using lasers	Manufacturing	Processing equipment market: approx. 300 billion yen → approx. 600 billion yen (2010)
	Home photovoltaic power generation systems	Energy	Photovoltaic power generation system market: approx. 150 billion yen (the highest in the world) → approx. 400 billion yen (2010)
	Technology to increase the density and extend the life of lithium batteries	Nanotechnology/ materials	Put to practical use ahead of the rest of the world Lithium-ion secondary battery market: 250 billion yen
Expanding related markets through development of systematization technologies	Intelligent transport systems (ITS) (car navigation, VICS, ETC)	Information and communications	Related markets: approx. 881.4 billion yen → approx. 7 trillion yen (2015) Employment creation: 1.07 million persons (2015)
Creating/expanding related markets through development of elemental technologies	Photocatalytic materials	Nanotechnology/ materials	Related markets: approx. 40 billion yen

Source: National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(Reducing costs)

The developed technologies not only have economic effect as goods or services, but also have the effect of improving efficiency or reducing costs for the individual users or society as a whole through use of the products or services applying those technologies.

The technology for local weather forecasting has made progress, and it is used for cutting costs through reduction of inventory in a wide range of business types in which sales are easily affected by weather, such as the energy industry and convenience stores. In addition, the introduction of intelligent transport systems (ITS) (car navigation, VICS, ETC) has contributed to improving traffic efficiency and reducing traffic congestion. It is expected to reduce social costs by about 1 trillion yen through the easing of congestion and other effects.

(Reducing economic risks)

The developed technologies cannot only be comprehended in economic terms; they also have the effect of reducing economic risks such as reducing opportunity losses and stabilizing the market.

Development of a testing method to predict the possibility of carcinogenicity or long-term toxicity of chemical substances on the human body made it possible to discover such hazardous chemical substances in advance. It has had the effect of preventing the recurrence of damage caused by chemical substances, such as the Kanemi oil poisoning and Minamata disease, and reducing the business risks of the related companies.

(Enhancing international competitiveness)

The developed technologies enhance the international competitiveness of the industries that use those technologies through various routes.

Such base technologies as the "Earth Simulator" and "SPring-8" have promoted scientific research and contributed to the progress of diverse technologies. In addition, pioneering efforts were made ahead of the rest of the world in developing technologies to produce and use alternatives to chlorofluorocarbon (CFC) and halon, which are ozone-friendly and have a minimum impact on global warming, and in spreading the use of home photovoltaic power generation systems. Due to these efforts, the air-conditioner industry and the photovoltaic power generation industry respectively took measures to meet the emission regulations earlier than the relevant industries in other countries, so their international competitiveness was strengthened.

[Column 7]

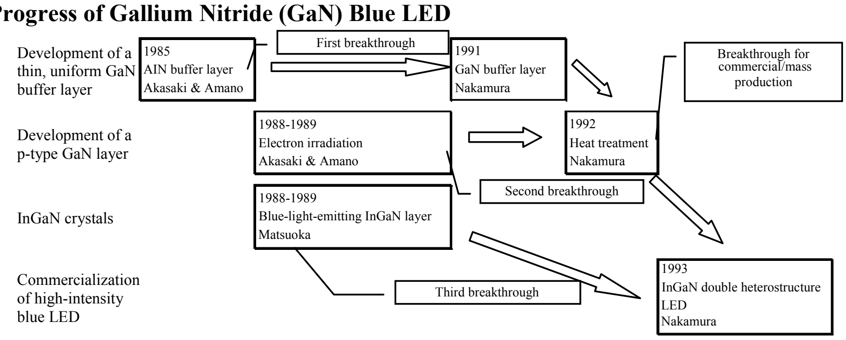
Researchers Devoted to the Study of Gallium NitrideSearch for Blue Light Emitting Diode

Recently, traffic signals that use light emitting diodes (LED) are installed at every corner and junction, so that drivers can easily identify the colors of signals even in strong light. This improvement in traffic signals owes greatly to the Japanese researcher who discovered the blue LED.

The blue LED was tested for the first time in 1971 in the United States by using gallium nitride. For the MIS-type LED that uses gallium nitride, the then Ministry of International Trade and Industry (MITI) conducted research under the Blue Light Emitting Devices Development Project for three years from 1975, and Japanese companies made sample shipments of flip-chip LEDs in 1980. But in making a single crystal of gallium nitride, its surface tends to become uneven or even cracked. As it was difficult to produce p-type semiconductors, which are indispensable for diodes, researchers tried continuously to test other materials such as zinc selenide, silicon carbide and so on.

At the time, there were some Japanese researchers who continued to focus on gallium nitride.

Technological Progress of Gallium Nitride (GaN) Blue LED



Source: Surveyed by MEXT

Then Nagoya University professor Isamu Akasaki (currently a professor at Meijo University), who spearheaded the sample shipment of metal–insulator–silicon (MIS) LED using gallium nitride while working for a private company, and Meijo University professor Hiroshi Amano, who was a graduate student at the time, succeeded in 1985 in making a high quality gallium nitride crystal by a low temperature buffer layer technique that used aluminum nitride as the buffer layer. This was the first breakthrough in the development. Then, they were jointly commissioned along with other private companies for four years from 1987 to develop "gallium nitride blue LED production technology" by the Research Development Corporation of Japan (currently Japan Science and Technology Agency). In 1988, they discovered that they could make a p-type semiconductor by applying an electron beam to gallium nitride blended with magnesium. Though emitting ultraviolet light, a pn junction LED with gallium nitride was made for the fist time. This was the second breakthrough in the development.

Gallium nitride emits ultraviolet light by itself. Tohoku University professor Takashi Matsuoka, who worked at NTT's Atsugi R&D Center at the time, considered indium gallium nitride (InGaN) to be the best material to emit blue light. And he succeeded in making a single crystal of it in 1988. This was the third breakthrough.

Around 1991, Shuji Nakamura, who worked for Nichia Corporation at the time, and is currently a professor at the University of California, Santa Barbara, succeeded in making a uniform crystal by using gallium nitride as the buffer layer, and discovered that a p-type semiconductor could be made through heat treatment of a crystal. This was the breakthrough for its commercialization and mass-production. In 1992, he developed the high-intensity blue LED by using a gallium nitride layer mixed with indium, which created a new market.

The use of the blue LED has spread from electric lights illuminating towns, traffic signals, large-sized screens, and it is now expected that the white LED derived from blue LED will replace white lamps and fluorescent bulbs.

The global market size of the gallium nitride LED in 2003 was estimated at over 100 billion yen, of which three Japanese companies occupy more than 80% of the total market share. Professor Akasaki and other researchers had received an accumulated amount of 3.6 billion yen as license fees as of 2003.

We should be proud that Japan has these researchers who took on the challenge of this difficult subject and succeeded in commercialization of the blue LED through their original approaches.

[Column 8]

ITS (Car Navigation, VICS, ETC etc.)
Aiming for Resolution of Road Transport Problems

Intelligent Transport Systems (ITS) are systems that seek to resolve road transportproblems such as traffic congestion, traffic accidents, environment deterioration caused by traffic and so on by combining people, roads and cars in an integrated system by making use of the state-of-art communication technology.

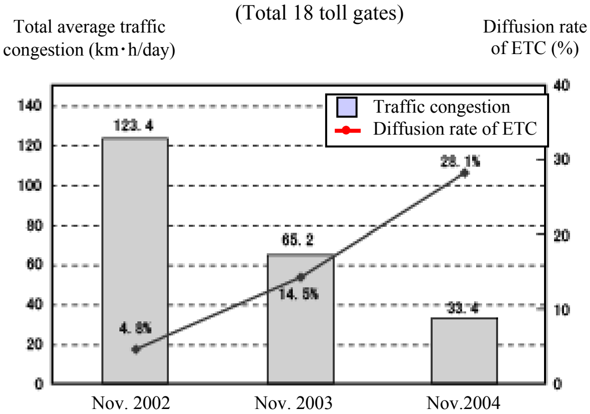
ITS in Japan have been promoted by four government ministries or agencies—the National Police Agency, the Ministry of Internal Affairs and Communications, and the Ministry of Economy, Trade and Industry, the Ministry of Land, Infrastructure and Transport—and extra-governmental organizations of the four ministries or agencies, such as ITS Japan, which represents the private sector. Since the formulation of the "Overall Plan regarding Promotion of Intelligent Transport Systems" by five related ministries in 1996, joint efforts were made by government organizations, universities and private companies to develop the systems and put them into practice in various fields. Among the elementary technologies, car navigation, the Vehicle Information and Communication System (VICS), Electronic Toll Collection (ETC) and others are already in practical use.

Car navigation was first invented by a Japanese company in 1981. Since then, new types of car navigation that use CD-ROM, DVD-ROM and hard discs have been put on the market in quick succession and their functions have been expanding in line with the development of large capacity storage. According to the Japan Automobile Research Institute, the accumulated number of shipments of car navigation systems is estimated to reach 25 million units at the end of 2005.

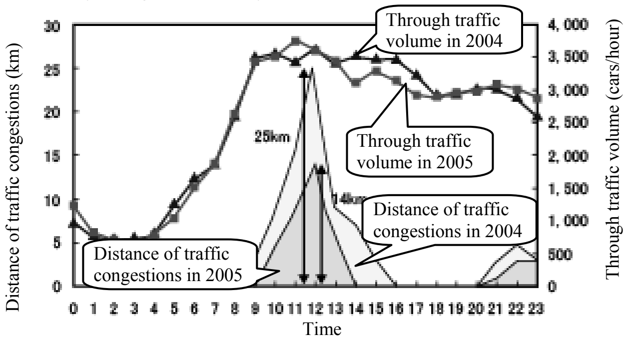
The VICS launched a service enabling drivers to acquire road traffic information, such as information on congestion and traffic control, in real time while driving. According to a survey conducted by the VICS Center, the total number of in-vehicle VICS units shipped exceeded 10 million in July 2003.

ETC is a system for collecting toll charges from cars without stopping them, by using radio communication for connecting ETC machines installed in cars to antennas located at toll booths. According to the Organization for Road System Enhancement, the accumulated number of cars that are equipped with ETC devices exceeded 5 million from the launch of the service in March 2001 to January 2005. Cars equipped with ETC devices account for 25.6% of the combined traffic volume of Japan Highway Public Corporation, the Metropolitan Expressway Public Corporation, the Hanshin Expressway Public Corporation, and the Honshu-Shikoku Bridge Authority for the period from December 24 to 30, 2004.

Metropolitan Expressway Toll Gates
(Total 18 toll gates)



Comparison of traffic congestion on two separate days with almost the same amount of daily traffic (January 2, 2004, and January 2, 2005)
Tomei Expressway: Traffic congestion on the stretch leading to the Tokyo Tollgate on the Tokyo-bound side



Through traffic volume per day	Diffusion rate of ETC
1/2/2004 ⇒ 59,800 cars/day	(approx. 15%)
1/2/2005 ⇒ 59,100 cars/day	(approx. 28%)

Source: Ministry of Land, Infrastructure and Transport, press release, "Diffusion rate of ETC exceeds 30%: About the recent diffusion rate of ETC," February 8, 2005

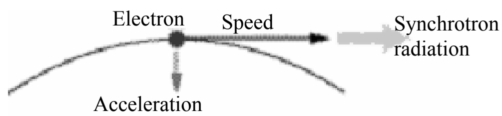
Since the 1990s, R&D for promotion of ITS has been implemented in Japan, the United States, and Europe. Japan leads the world in terms of R&D and system diffusion of individual elemental technologies constituting ITS, such as car navigation, VICS, and ETC.

[Column 9]

High-Power Synchrotron Radiation Technology (SPring-8)
Most Effective X-ray Generator in the World, 100 Million Times Brighter Than Conventional Generators

When the direction of an electron running straight at the almost same speed as that of light is changed by a material such as a magnet, electromagnetic waves are radiated. This wave is called synchrotron radiation.

As high-power synchrotron radiation technology is a basic technology, it is difficult to measure its direct economic effect. But there are several success cases of the application of synchrotron radiation. The duration of the use of catalytic agents for gas emission is extended by solving related problems by the application of synchrotron radiation and improvement in the lifetime of lithium-ion batteries is also made by clarifying the problems causing their degradation by the application of synchrotron radiation. Analyses of properties of minor components by using synchrotron radiation are applied to solve archaeological mysteries such as the Kofun Period geometrically-shaped convex copper mirror with a design of intertwined gods and beasts, as well as criminal investigations and so on.



▲Mechanism of emission of synchrotron radiation

Source: Japan Synchrotron Radiation Research Institute "Summary of SPring-8"

The higher the energy of an electron is, the brighter the synchrotron radiation that is generated and the better the directional characteristics of that radiation. And the greater the energy of an electron is and the greater the change of direction of movement that is made, the shorter the waves of the lights contained (e.g. X-rays) in the synchrotron radiation. As the brightness (luminance) of synchrotron radiation is very high with a wide range of wavelengths from X-rays to infrared radiation, detailed analyses of the kind, structure and properties of materials can be made by using synchrotron radiation.

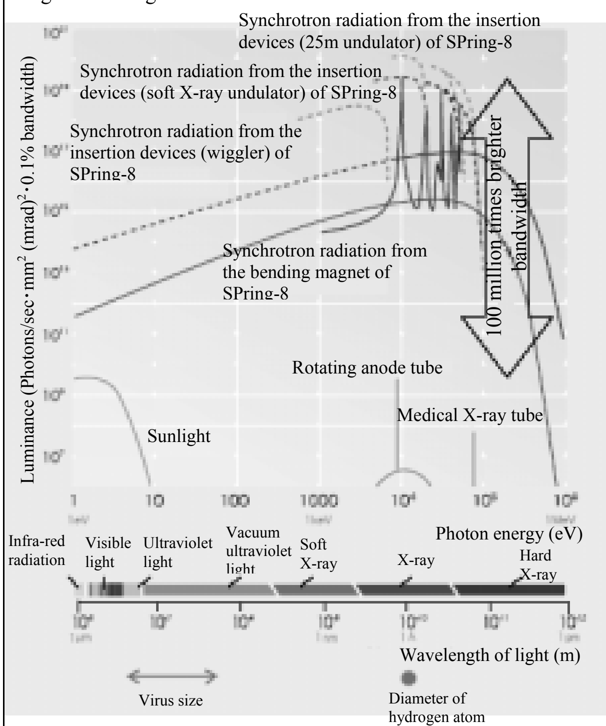
R&D on high-power synchrotron radiation generators has been undertaken by universities and public research institutes since the 1960s.

Now it is time for large third-generation synchrotron radiation facilities. SPring-8, which was jointly constructed by the Japan Atomic Energy Research Institute and the Institute of Physical and Chemical Research (RIKEN), is the most sophisticated experimental facility in the world. There are only two other facilities in the world that are of the same size and capacity as SPring-8: APS of the U.S. Department of Energy and ESRF, the joint facility of eighteen European countries.

Among the 48 beamlines—the experiment facilities that extract the synchrotron radiation—two shared-use beams and four exclusive-use beams are also made available for private use. As one thousand and several hundred researchers visit SPring-8 every year because of it boasting the highest performance in the world, it also contributes to international cooperation.

SPring-8 has already yielded the above-mentioned research results, and it is also expected to be applied further for industrial use.

Brightness of light source



Source: Japan Synchrotron Radiation Research Institute "Summary of Spring-8"

(2) Social effects

Social effects include "addressing environmental problems," "addressing energy/resource problems," "addressing the aging of the population," and "improving social infrastructure/disaster prevention measures."

(Addressing environmental problems)

Science and technology has the effect of addressing global environmental problems such as global warming and ozone depletion, as well as the effect of preventing air, water, and soil pollution and reducing waste.

As for technologies that have the effect of reducing greenhouse gas emissions, which cause global warming, CO_2 emissions are reduced by home photovoltaic power generation systems, and the greenhouse effect is reduced while internationally organized prevention of depletion of the ozone layer is also achieved by development of technologies to produce and use alternatives to chlorofluorocarbon (CFC) and halon, which are ozone-friendly and have a minimum impact on global warming.

(Addressing energy/resource problems)

Japan relies on imports for a large part of its energy and mineral resources. Therefore, by using them efficiently, Japan can achieve security in terms of energy and mineral resources.

Home photovoltaic power generation systems can be considered as domestic energy, since they recover the energy used for their manufacture in one year and a half to two years, and produce 10 to 13 times the energy used for their manufacture over the subsequent 10 years.

(Addressing the aging of the population)

Society will become more active by improving the medical technologies for the elderly, the disabled, and patients with various diseases. The achievements in the field of life science, such as cancer research, have lead to improving the therapeutic effects to combat diseases and increasing the possibility for a complete cure, and further effects are hoped for in the future.

(Improving social infrastructure/disaster prevention measures)

With regard to technologies for improving social infrastructure and disaster prevention measures, the technology to simulate the effects of earthquake motion on the behavior of structures has increased the safety of structures including roads, bridges, buildings, and houses, while development of a design method that enables early restoration at times of disasters has contributed to improving disaster prevention measures. In addition, development of the ITS is hoped to have such effects as reducing traffic accidents.

(Other social impacts)

SPring-8 had the effect of raising Japan's international status in the area of science and technology for possessing the world's highest performance facility, while it also made a cultural contribution to solving archeological mysteries with its analysis function and was applied to investigation of criminal offenses. Furthermore, the Earth Simulator had an impact on U.S. supercomputer R&D policy by achieving the world's fastest computation speed.

[Column 10]

The Earth Simulator (ES)
The Ultrafast Parallel Computer

Since 1997, the Earth Simulator (ES) has been developed in collaboration of the former Japan Marine Science and Technology Center, the former National Space Development Agency of Japan, and the Japan Atomic Energy Research Center, to create the world's fastest supercomputer. The ES has been operated by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) since March 2002. It is one of the greatest ultrafast parallel computer systems in the world. The ES aims to predict and investigate global phenomena including global warming, environmental changes, abnormal weather and tectonic movements, utilizing its highly precise simulation capabilities.

The ES recorded the world's best computing performance at 35.86 TFLOPS at the performance evaluation by the LINear equations software PACKage (LINPACK). The performance was approximately five times better compared to other supercomputers at the time. Consequently, it occupied first place in the world supercomputer performance TOP500 ranking, and did not yield it for approximately two and a half years until a supercomputer made in the United States took over first place in November 2004. For its research achievements utilizing the high performance of the ES, the JAMSTEC won the Gordon Bell Prize for three consecutive years from 2002, as well as the 21st Century Achievement Award in 2003.

Supercomputers including the ES were mostly utilized in scientific fields at first, but they are also expected to be applied in industrial areas such as the simulation of vehicular safety in collisions.

The U.S. Department of Energy listed supercomputers as the second-most important large-scale research equipment or facilities that should be developed in its report published in 2003. Additionally, in November 2004, the "Department of Energy High-End Computing Revitalization Act of 2004" was approved at the U.S. Congress.

Supercomputer competition between the United States and Japan has been becoming more and more intense.

(3) Effects on people's lives

Effects on people's lives include "securing the lives/livelihoods of the people," "maintaining/ restoring people's health," "improving convenience/comfort for people," and "changing people's awareness/lifestyles."

(Securing the lives/livelihoods of the people)

With respect to securing the lives/livelihoods of the people, progress in the technology for local weather forecasting and advancement of the technology to simulate the effects of earthquake motion on the behavior of structures have the effect of reducing damages based on better disaster prevention measures. The development of observation technology using satellites made it possible to gain a precise understanding of the status of damage at times of disasters, and contributed to speeding up recovery operations. Meanwhile, development of the helical CT technology—an effective means for early detection of lung cancer—enabled early discovery of lung cancer, which had been hard to discover and often advanced to the terminal stage.

(Maintaining/restoring people's health)

In terms of maintaining/restoring people's health, science and technology has the effect of preventing deterioration of the living environment and the effect of improving therapeutic effects to combat diseases. With regard to prevention of deterioration of the living environment, the development of photocatalysts and development of technologies to appropriately dispose of discarded cars and home electrical appliances have the effect of preventing air, water, and soil pollution as well as deterioration of the living environment. Improvement of therapeutic effects to combat diseases includes increasing the possibility of completely curing cancer through progress in cancer research.

[Column 11]

HIMAC (Heavy Ion Medical Accelerator in Chiba) Utilized for Cancer Therapy

From fiscal 1984 to 1993, the former Ministry of Education, the former Ministry of Health and Welfare, and the former Science and Technology Agency collaboratively promoted the "10-year Strategy for Cancer Control." Subsequently, since fiscal 1994, the three government offices have conducted the joint project "New 10-year Strategy for Cancer Control." Based on this strategy, many researchers belonging to universities, public research institutes and hospitals have worked closely together to carry out pioneering research, utilizing advanced technologies, and have achieved internationally distinguished results.

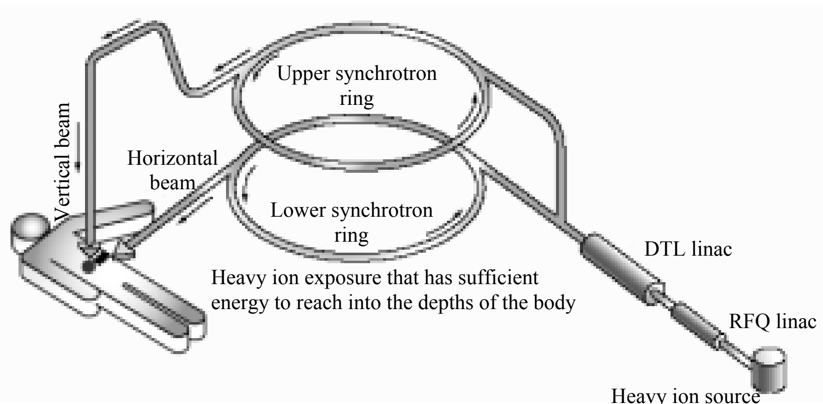
The Research Center for Charged Particle Therapy of the National Institute of Radiological Sciences (NIRS) has been conducting R&D utilizing the Heavy Ion Medical Accelerator in Chiba (HIMAC), which was established for the first time in Japan based on the "10-year Strategy for Cancer Control."

The HIMAC accelerates the heavy ions whose atomic number is 2 or more, e.g. proton and carbon ions, for exposure therapy for cancer focuses that are to be removed. Those heavy ions have the merit of reaching into the depths of the body, not diffusing like a shower. Consequently, the HIMAC can destroy cancer cells at some depth in the body, unlike X-rays, which harm healthy organs in front of or in the region of the cancer cells. It is expected that the HIMAC will be able to cure advanced cancers that exist very deep in the body and that were hard to remove in the past. Also, with the introduction of the HIMAC, the recurrence rate of cancer is estimated to drop sharply.

This is the tenth anniversary of the HIMAC, which was launched in 1994 as a project of the "10-year Strategy for Cancer Control." To date, the HIMAC has treated more than 2,000 cancer patients, proving the strong effectiveness of heavy ion beam therapy for cancer. In October 2003, the Ministry of Health, Labour and Welfare approved the HIMAC as a highly advanced medical technology, which was an important step for its diffusion as a therapy for the people.

The establishment and operation of a heavy ion medical accelerator for cancer therapy currently requires a large investment. For its diffusion as a therapy for the people, however, this cost should be decreased. In order to achieve such cost reduction, the optimization of the design for downsizing and R&D of parameter technologies are being conducted.

Conceptual illustration of heavy ion medical accelerator for cancer therapy



Source: NIRS, "Heavy ion beam: the novel ace for radiological therapy"

(Improving convenience/comfort for people)

With respect to improving convenience/comfort for people, science and technology has the effect of reducing financial burdens, such as reducing electricity charges due to the spread of home photovoltaic power generation systems and lowering recycling costs due to development of technologies to appropriately dispose of discarded cars and home electrical appliances.

Science and technology also has the effect of increasing convenience, such as easy access to various services through ITS, and the effect of increasing aesthetic appearances and comfort, such as antifouling tiles and antifog vehicle mirrors through the development of photocatalysts.

[Column 12]

Photocatalysis
Stain-proofing by UV Radiation

A photocatalyst is defined as a "substance that accelerates chemical reactions by receiving UV radiation, without changing itself." Because of its immutability, a photocatalyst can be used semi-permanently. In about 1968, Kenichi Honda (honorary professor at the University of Tokyo) and Akira Fujishima (the same) discovered the photoelectrochemical decomposition of water in UV radiation by using TiO2 and a platinum electrode. Their amazing discovery was presented to the world in *Nature* magazine in 1972. The photocatalytic effect of TiO2 was named the "Honda-Fujishima effect," after the discoverers.

About 1968
The "Honda-Fukushima effect" was discovered.

⇨

1990
Academia and industry cooperatively start studies on practical photocatalytic systems.

⇨

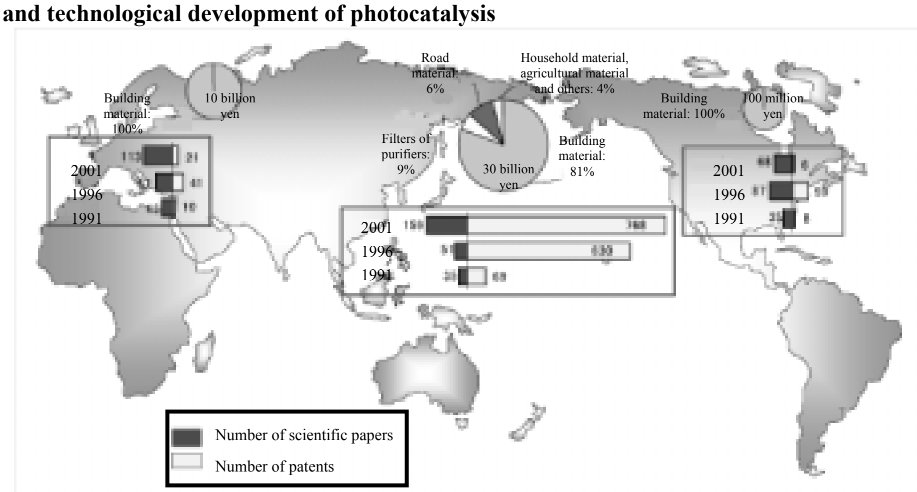
1994
Photo-assisted superhydrophilicity discovered in the cooperative studies.

In the beginning, it was expected that the photocatalytic system could be used for hydrogen composition technologies, but this was not disseminated. Later around 1990, the academic world and industry cooperatively started studies on TiO2 coating on various materials for stain-resistance, preventing bacteria and deodorization. Research groups supervised by Akira Fujishima and Kazuhito Hashimoto (professor) at the University of Tokyo lead the project, in collaboration with many businesses. It took several years to put photocatalytically-coated products on the market. The products have been gradually improved, in areas such as controllability of photocatalytic reaction, endurance and cost performance.

Additionally, in 1994, the collaborative study group of researchers at the University of Tokyo and businesses discovered the photo-assisted superhydrophilicity of photocatalysis, or in other words, that a surface coated with a photocatalytic product becomes highly hydrophilic on receiving UV radiation. Superhydrophilicity had not been common at all until the study group introduced it in *Nature* magazine in 1997. It contains the possibility of practical use in many fields. The self-cleaning effect, which is a combination of the oxidativity and superhydrophilicity of photocatalysis, has been already applied to building tiles, glass, and vehicles' sideview mirrors. The photocatalysis market is expected to expand dramatically in the future.

The following diagram compares Japan, the United States and Europe in terms of market scale (in 2002) and the number of patents and scientific papers (in 1991, 1996 and 2001) related to photocatalysis. It is clear that Japan is overwhelmingly the world leader in every aspect of the photocatalytic sphere.

Market scale and technological development of photocatalysis



Note: Figures for market scale are estimations for 2002. For 2003, the scale of the Japanese market is estimated at approximately 40 billion yen, the European market at 15 billion yen, and the U.S. market at 2.3 billion yen.
Estimation of market scale is based on the data provided by the Photocatalytic Products Forum.
Source: Japan Patent Office, "Research Report on Patent Application Trends: Photocatalysis (F.Y. 2003)."

(Changing people's awareness/lifestyles)

With regard to changing people's awareness, energy-saving awareness increased with the diffusion of home photovoltaic power generation systems, and recycling awareness increased with the spread of technologies for appropriately disposing of discarded cars and home electrical appliances. Furthermore, realization of ITS made it easier for users to make travel plans and changed their lifestyles through easing traffic congestion and providing appropriate information.

(4) Contributions of public R&D and support to scientific and technological progress

Contributions of public R&D and support to scientific and technological progress and achievement of results can largely be divided into two: direct contributions such as investment in R&D and indirect contributions such as procurement and development of research infrastructure. Direct contributions include public R&D and support on basic research and those implemented in line with the development and trend of technologies. Indirect contributions include public R&D and support on base technologies and technical infrastructure and contributions for tackling problems in coordination with policies other than R&D policy.

Table 1-2-3 evaluates the extent of such contributions of public R&D and support for some case examples from these perspectives. It suggests that indirect contributions such as procurement and development research infrastructure are also important as a role of the public sector.

(Public R&D and support on basic research)

The importance of public R&D and support on basic research is obvious from the contributions made by national universities in discovery of the phenomena and elucidation of the principles with regard to water decomposition by photocatalysts, decomposition of organic matter, and super-hydrophilc property. Various basic research conducted at public research institutes, such as universities, provide essential technology seeds for achieving results or produce unexpected results through continuance of diverse research. Through accumulation of scientific knowledge, they contribute to technological progress and the achievement of results.

(Public R&D and support in line with the development and trend of technologies)

Public R&D and support in line with the development and trend of technologies are also important. This type of R&D and support include the shortening of the period for achieving results by shifting to focused research or national projects in a timely manner according to the technological progress, and implementation of public R&D or support by clarifying the positioning and the aim of the technological development in each phase until the achievement of the effects, based on a long-term national vision. Examples of the latter include promotion of diffusion of home photovoltaic power generation systems in accordance with the Sunshine Plan and the New Sunshine Plan based on a 30-year long-term vision.

(Public R&D and support on base technologies and technical infrastructure)

Public R&D and support on base technologies and technical infrastructure may not be obvious as direct contributions, but the lack of such R&D and support may have made achievement of results difficult or reduced their effects. R&D and business activities by diverse users including the private sector become possible through standardization and development of databases by public research institutes. In addition, SPring-8, a sophisticated radiation facility boasting the world's most powerful radiation, has been developed by public investment as a facility for common use by industry, academia, and government, and it has been used for leading-edge research, such as analyses, in a wide array of scientific domains and for the measuring technologies and material technologies in industries.

Table 1-2-3 Case Examples of Public R&D and Support

(Contribution: large ○; moderate △)

		Public R&D and support on basic research	Public R&D and support in line with the development and trend of technologies	Public R&D and support on base technologies and technical infrastructure	Tackling problems in coordination with other policies
Life sciences	Helical CT technology effective for early detection of lung cancer	–	△	–	–
	Base sequence determination technologies for detecting individuals' gene polymorphism and their application (diagnosis and tailor-made medicine)	△	○	○	–
Information and telecommunications	High-speed parallel computers (Earth Simulator)	–	△	○	○
	ITS (car navigation, VICS, ETC)	–	△	○	○
Environment	Technologies to produce and use alternatives to CFC and halon, which are ozone-friendly and have a minimum impact on global warming	△	△	○	○
	Technologies to elucidate the impact of endocrine disrupting chemicals on the human body and living organisms	○	–	–	–
Nanotechnology and materials	Technologies to make higher-density, longer-life lithium batteries	–	–	–	–
	Photocatalytic materials	○	○	–	–
Energy	Home photovoltaic power generation systems	△	○	△	○
	Technologies to produce liquid fuels from natural gas and use them (GTL, DME)	△	△	–	–
Manufacturing	Technologies to appropriately dispose of discarded cars and home electrical appliances	–	△	–	○
	Processing technologies using lasers	△	○	△	–
Infrastructure	Technology for local weather forecasting	○	–	○	△
	Technology to simulate the effects of earthquake motion on the behavior of structures	○	–	○	△
Frontier	Satellite remote sensing technologies (technologies for analyzing and using data)	△	–	△	–
	High-power radiation technologies (SPring-8)	△	–	○	–

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(Tackling problems in coordination with other policies)

Problems have been tackled through coordination with policies other than R&D policy. For example, R&D was promoted as a result of deregulation or the introduction of regulations as represented by the home photovoltaic power generation systems, where grid connection allowing reverse power flow was also made possible besides technological development. Also, continuous technological development became possible through government procurement as represented by parallel computers with a high computing speed. In addition, early markets emerged due to the introduction of subsidy systems.

[Column 13]

Home Photovoltaic Power Generation Systems
Clean Energy

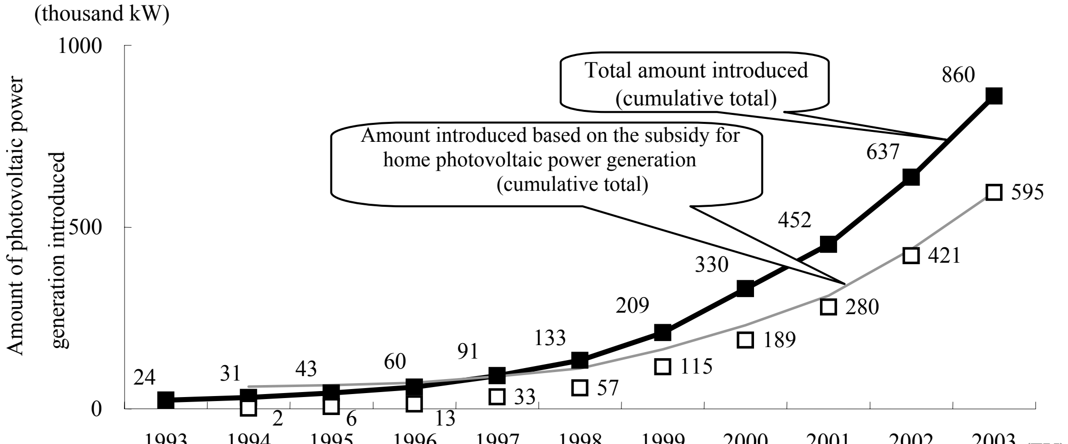
The bright sun on a clear day is an inexhaustible and semi-permanent source of energy. It is estimated that the total energy expended by the human race in an entire year is equivalent to the solar energy the earth receives in just 30 minutes. Additionally, the photovoltaic power generation system is clean, with no discharge of either greenhouse gasses or waste during the generation process.

Since 1999, Japan has been the world's foremost producer of solar cells. Nearly half of all cells produced in the world in 2003 were produced in Japan.

In the Sunshine Plan started in 1974, the home photovoltaic power generation system was treated as an important technology. Large-scale R&D was conducted jointly among industry, academia and government. The subsidy project for home photovoltaic power generation systems was taken over by the New Sunshine Plan since 1993, as well as by individual projects conducted by the New Energy and Industrial Technology Development Organization (NEDO).

One of the major factors behind the successful diffusion of the photovoltaic power generation systems was that the Japanese government promoted the projects with a long-term vision for 30 years, with the target set for the year 2000. The technologies for the mutual service system were developed on the assumption of the power generation systems being distributed among individual households. The system enables consumers to sell surplus energy to power companies, as well as to buy energy from power companies when it is insufficient. Other effective factors include the deregulation that approves the service of photovoltaic power generation system for individual households, and the establishment of the initial photovoltaic power generation system market supported with the subsidies for its establishment. It was a prominent example of policies not directly related to R&D (e.g. deregulation and subsidies) effectively promoting R&D.

Number of photovoltaic power generation systems installed



Source: METI, "New Vision of Energy Industry" (June 2004). The "total number of installations of photovoltaic generation systems subject to the subsidy project" for 2003 was surveyed by METI.

(Need for contributions of public R&D and support)

In the "Analysis of Socio-Economic Impact of Science and Technology Policy in Japan" ("Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)) compiled by NISTEP, a questionnaire survey was conducted on 2,154 researchers and technology users (persons responsible for the planning division or the market research division in companies). The survey results indicate how the samples saw the contributions of public R&D and support in various fields to date and the future need for such contributions (Figure 1-2-4).

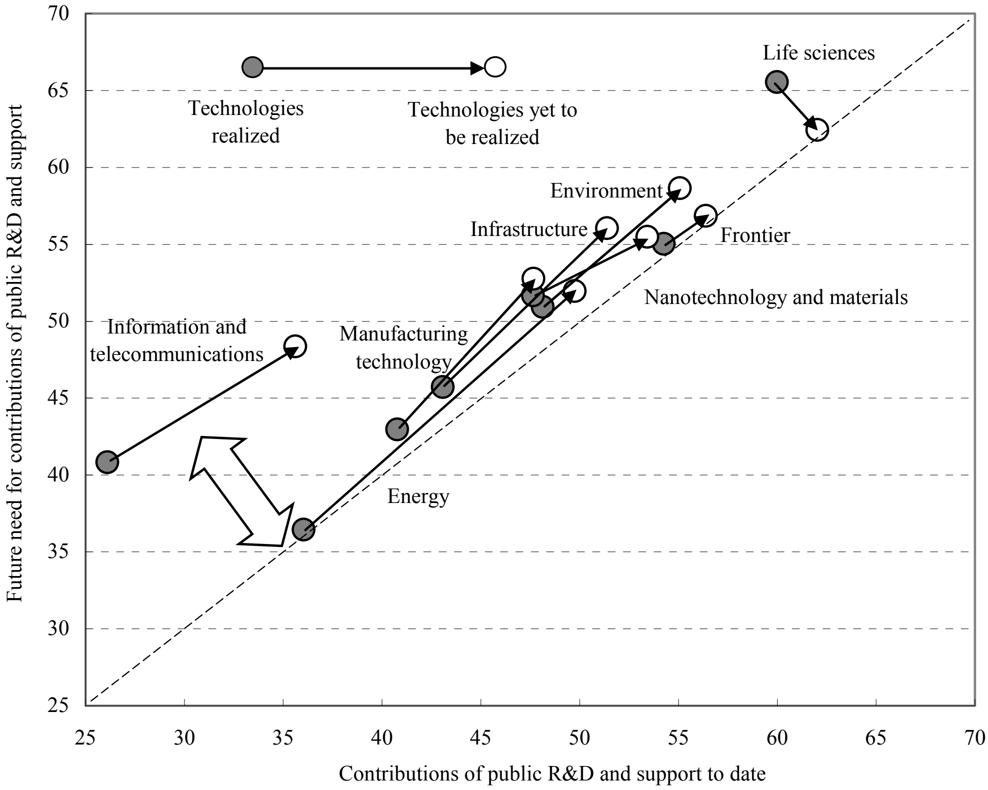


Figure 1-2-4 Contributions of Public R&D and Support in Various Fields to Date and the Future Need for Such Contributions

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

Looking by field, the respondents considered that large contributions have been made with respect to technologies realized (those that have been realized within the past 10 years or so and are already producing effects) in the fields of life sciences and frontier, followed by nanotechnology and materials, environment, infrastructure, and manufacturing technology. The respondents regarded that small contributions have been made to date in the fields of energy and information and telecommunications. On the other hand, looking at technologies yet to be realized (those that are likely to be realized and produce effects in the coming 10 years or so), the respondents viewed that larger contributions would be made in all fields compared to the contributions made for the technologies realized. The expected degree of contributions for technologies yet to be realized was particularly larger than that for technologies realized in the fields of information and telecommunications, energy, manufacturing technology, and infrastructure.

The same degree of contributions is generally being sought in the future, but an ever-larger degree of contributions of public R&D and support is being sought in the information and telecommunications field.

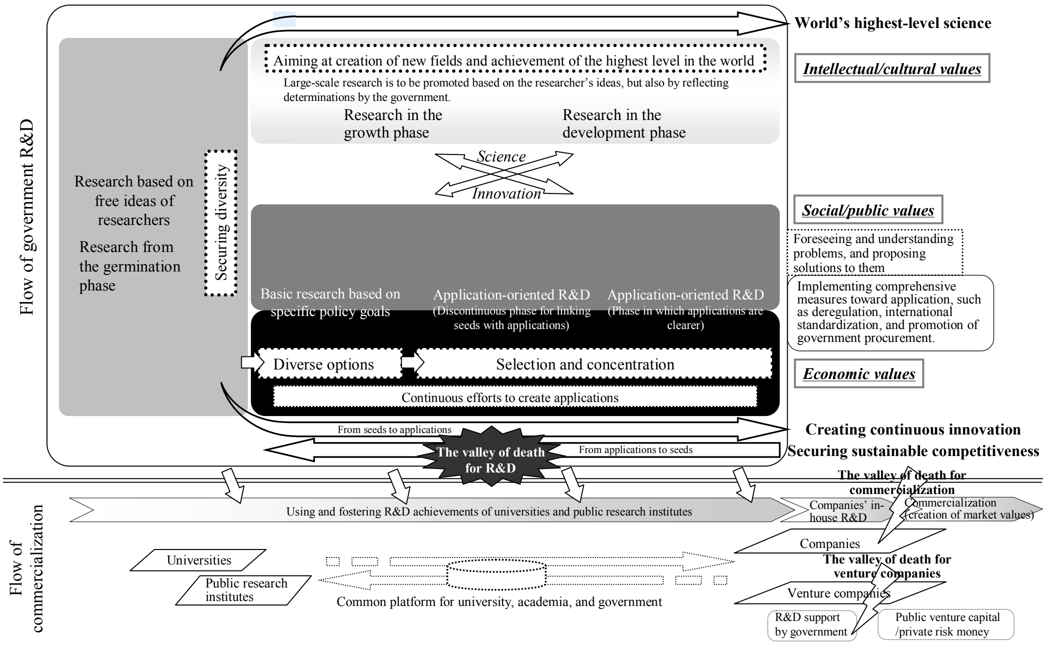


Figure 1-2-5 Development of Science and Creation of Continuous Innovation

Support for R&D should be provided in accordance with the development phase and the characteristics of the R&D. This figure overviews the concept where research based on free ideas of researchers lead to development of science and creation of continuous innovation toward generation of various values.

Source: Produced from materials of the Special Committee on Science and Technology Basic Plan, Council for Science and Technology, MEXT.

1.2.1.2 Turning Dreams into Reality by Science and Technology

Sometimes mankind encounters a phenomenon that overturns the conventional common knowledge of science and technology, and finds a new truth. Also, it devises a new verification measure, and discovers a new phenomenon by using that measure. Such efforts lead to new discoveries and inventions, and further to the progress of mankind and realization of dreams. This kind of progress has been driven by researchers' insatiable intellectual curiosity.

In 2000, Hideki Shirakawa, Professor Emeritus at the University of Tsukuba, and two other professors were awarded the Nobel Prize in Chemistry for the "discovery and development of conductive polymers." At the end of the 1970s, they made a unique discovery that polymers (plastics), which had been believed not to conduct electricity, sometimes indicated conductivity. Addition of this discovery to the original properties of plastics—being lighter, more flexible, more workable, and lower material costs than metal—broadened the possibilities for application areas, and later developed conductive polymers into an important research domain for chemists and physicists. This field also became important in practical use. For example, in industrial use, conductive polymers are being used or being developed to be used as polymer batteries, condensers, various electron devices, and light emitting elements. In Professor Shirakawa's research, a pioneering discovery was made from among down-to-earth research, and it vividly indicates that the continuation of basic research generates a significant achievement.

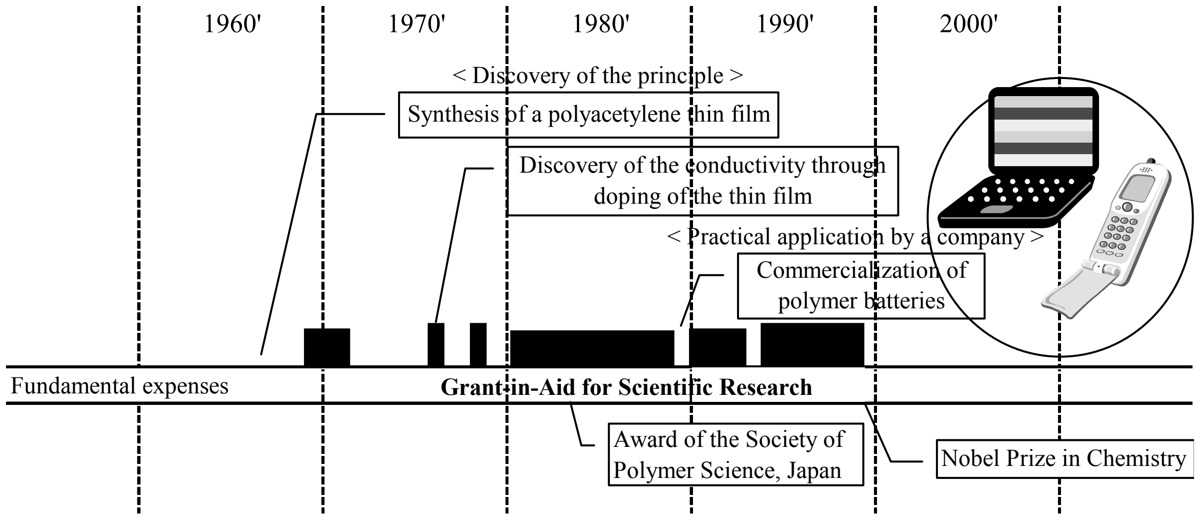


Figure 1-2-6 Achievements of Hideki Shirakawa and Public Support

Source: Surveyed by MEXT

In 2001, Ryoji Noyori, President of RIKEN, Japan, and U.S. chemists were awarded the Nobel Prize in Chemistry for their "work on chirally catalysed hydrogenation reactions." The term "chiral" originates from a Greek word for the "palm," and it refers to molecules that are in a mirror-image relation, just like the palms of the left and the right hands. These molecules are called enantiomers, and ever since they were discovered by Louis Pasteur, it had been a dream of mankind to develop a method to selectively synthesize one of these two. This was because many pharmaceuticals had enantiomers having different functions from each other. There were cases where one of the enantiomers was an excellent drug, but the other was a deadly poison. Noyori discovered a hydrogenation catalyst that synthesizes only one of the two enantiomers with high selectivity from among compounds that have various double bonds. The achievement of this long-term catalyst research, which germinated from around 1965 is today widely used in industrial production of pharmaceuticals, menthols, and other items.

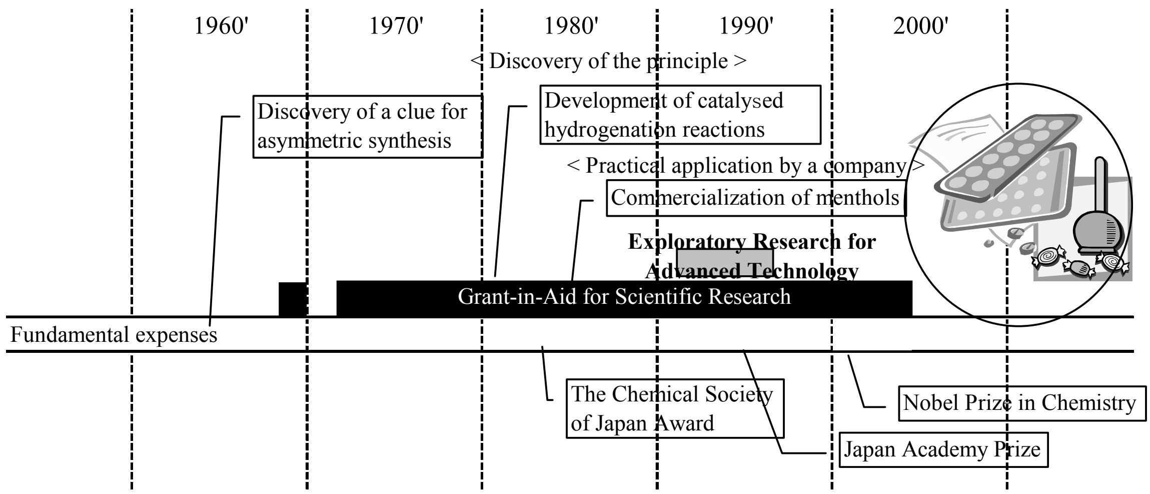


Figure 1-2-7 Achievements of Ryoji Noyori and Public Support

Source: Surveyed by MEXT

In 2002, Masatoshi Koshiba, Emeritus Professor at the University of Tokyo, was awarded the Nobel Prize in Physics "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos." He was highly commended for succeeding in detecting neutrinos from a faraway supernova explosion by using a gigantic detector called the Kamiokande, underpinning the theories on the mechanism of a supernova explosion caused by a gravitational collapse and the stellar evolution, and opening up a new research field called neutrino astronomy.

Also in 2002, Koichi Tanaka, fellow at Shimadzu Corp., was awarded the Nobel Prize in Chemistry "for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules." He developed the "soft laser desorption" technique in which proteins are crystallized by being mixed with a matrix (a mixture of multiple chemical substances) and are bombarded with laser pulses. This method, which conducts ionization without breaking up the protein molecule structure, made analysis of biological macromolecules possible.

Name	Category	Year
Hideki Yukawa	Physics	1949
Shinichiro Tomonaga	Physics	1965
Leo Esaki	Physics	1973
Kenichi Fukui	Chemistry	1981
Susumu Tonegawa	Medicine	1987
Hideki Shirakawa	Chemistry	2000
Ryoji Noyori	Chemistry	2001
Masatoshi Koshiba	Physics	2002
Koichi Tanaka	Chemistry	2002

Figure 1-2-8 Japanese Nobel Prize Winners (Natural Sciences)

Source: Surveyed by MEXT

The prize-winning by these persons of merit demonstrates to the world the high research standard of Japanese researchers, and is a great pride and encouragement not only for Japanese researchers, but for the entire nation.

(1) Unexpected achievements brought about by scientific and technological progress

Hideki Shirakawa, Professor Emeritus at the University of Tsukuba, is said to have made the achievement by, instead of considering an experiment with erroneous blending of catalysts as a mere mistake, continuing with the research by focusing on its outcome. Masatoshi Koshiba, Professor Emeritus at the University of Tokyo, also succeeded in detecting neutrinos by installing the Kamiokande for observing the process of proton decay, and encountering a supernova explosion. Furthermore, Koichi Tanaka, a fellow at Shimadzu Corp., is said to have discovered the clue for the formula that won the prize by mixing an erroneous chemical into the sample but continuing with the experiment.

In the realm of science and technology, an unexpected coincidence or a slight mistake often leads to a historic discovery. However, a coincidence is not sufficient to make such a historic discovery, but as Louis Pasteur said "chance favors only the prepared mind." Likewise, researchers' daily efforts and their insights based on those efforts are essential for turning a "coincidence" into a "discovery."

This also applies to scientific and technological achievements. There have been cases where effects that had not been intended in the basic research phase were achieved or came to be expected in the course of subsequent research (Figure 1-2-9).

Technology	Unexpected effects
Photocatalytic materials	They were originally intended for producing hydrogen, but due to their super hydrophilic property and the function to break down organic matter, they are used for antifouling/defogging and for air purification.
Base sequence determination technologies for detecting individuals' gene polymorphism and their application (diagnosis and tailor-made medicine)	They were intended for life-saving treatment against genetic diseases in the basic research phase, but there are hopes for realization of their application to tailor-made medicine.
Processing technologies using lasers	The laser light source for nuclear fusion research was applied to the light source for industrial laser processing machines.
Carbon nanotube device technologies	They were originally intended for mere structural materials, but there are growing expectations for their application as electronic devices.
Hydrogen storing alloy	In 1990, a nickel-metal-hydride battery was put to practical use by using a hydrogen storing alloy as the negative-electrode material.
System for disaster prevention before the arrival of seismic motion based on a nationwide seismic detection network	Basic research for earthquake prediction and installation of seismometers contributed to the system for taking disaster prevention measures before the arrival of the seismic motion.

Figure 1-2-9 Science and Technology which Produced or Is Likely to Produce Unexpected Effects in the Basic Research Phase

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(2) Time required from invention or discovery of a technology seed until achievement of results

Scientific and technological progress has had a large impact on the economy, society, and people's lives in diverse forms. However, the progress of individual science and technology does not immediately bear results, but has a considerable impact on the economy, society, and people's lives only when it is combined with other science and technology or when goods/services using the science and technology are diffused in society.

Scientific discoveries may be required but not sufficient for making innovations that have economic effects. The road from making a scientific discovery to achieving economic effects is long and tough. Only after accumulation of many people's failures and frustrations on top of a scientific invention does a new product appears on a market, and when it is accepted by the market, the innovation is complete. It is extremely difficult to predict the time required until the completion of this process. However, it is certain that no innovation will occur without action, and Japan will not develop if it leaves innovations to the efforts of others.

For example, the National Institute of Science and Technology Policy surveyed the time required from invention or discovery of a technology seed until its practical application regarding technologies for which the time of invention or discovery of the technology seed, the time of its practical application, and the time of achievement of results were relatively clear, including future prospects. As a result, it found that the time was very long and varying, ranging from about 10 to 40 years (Figure 1-2-10).

Technology	Period until practical application	1960 1970 1980 1990 2000 2010 2020 2030	Details of invention/discovery and practical application
Helical CT technology effective for early detection of lung cancer	Approx. 10 years		1982: Private company acquires a patent for helical CT (Japan) 1990: Helical CT put to practical use (Japan)
Vertical magnetic recording technology (for hard disk drives)	Approx. 30 years		1976: University invents the vertical magnetic recording technology (Japan) 2005: Hard disk using the vertical magnetic recording technology put to practical use (Japan)
Technologies to make higher-density, longer-life lithium batteries	Approx. 10 years		1979: Lithium cobaltate developed as a positive-electrode material (U.K.) 1991: Lithium battery using lithium cobaltate as the positive electrode put to practical use (Japan)
Photocatalystic materials	Approx. 30 years		1967: Photodecomposition of water discovered (Japan) 1994: Tiles and building materials using photocatalysts commercialized (Japan)
Home photovoltaic power generation systems	Approx. 40 years		1954: Solar battery created by Bell Labs (U.S.) 1994: Monitor users for home photovoltaic power generation systems invited from the public (Japan)
Processing technologies using laser	Approx. 20 years		1960: Theodore Maiman succeeds in ruby laser oscillation (U.S.) 1980s: Application of laser to processing technologies makes progress (Japan)

: From invention/discovery of technology seed to practical application

Figure 1-2-10 Period from Invention/Discovery of Technology Seeds Until Their Practical Application

Source:NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report, no. 89, March 2005)

(3) Pursuing dreams

In order to promote science and technology, it is also important to arouse people's intellectual curiosity and inquisitiveness so that the entire people increase their interest in and understanding of science and technology, and that the youth, who will lead in the next generation, can hold dreams and hopes in science and technology and develop science and technology oriented minds.

The outstanding performance of Japanese athletes at the Athens 2004 Olympic Games is still fresh in our minds, and the efforts and talents of each athlete deserve praise. Kosuke Kitajima is said to have carried out effective training and improved his swimming method based on scientific analyses at the Japan Institute of Sports Sciences (JISS). It has become necessary to scientifically analyze sports in order to compete for world records.

[Column 14]

Athens Olympic Games and Sports Science
Kosuke Kitajima's Brilliant Achievement Supported by Science and Manufacturing Technologies

Japanese swimmer Kosuke Kitajima won gold medals in the 100-meter and 200-meter breaststroke at the Athens Olympic Games in August 2004. He also broke the Olympic record in the 200-meter event. Although you might not know it, Kitajima's brilliant achievement was considerably supported by Japanese technology.

Kitajima was supported in his training in the aspect of sports medicine and science by the Japan Institute of Sports Sciences (JISS), which was established in 2001. JISS is the core institute for sports medicine, science and information in Japan. It is equipped with MRI, motion analyzers, video editing and analysis devices and facilities, and an altitude training room that can simulate the low-oxygen conditions at altitudes about 1,800 - 3,000 meters above sea level. Making good use of its leading facilities and devices, JISS provides a support system to athletes using objective digital information, converted from the subjective and emotional analogue information traditionally given by sports coaches.

To scientifically investigate inefficiencies in Kitajima's swimming, a group of specialists mainly composed of JISS staff examined the velocity curve (graphic data) of his swimming style filmed underwater. They thoroughly analyzed his stroke and kick. They also provided Kitajima with data beneficial for planning his altitude training schedule, showing the effects of hypoxic training based on physiological data on blood and blood lactic acid consistency. The data on Kitajima's diving angle proved that his starting posture was not perfect compared to other top swimmers in the world, and contained some room for improvement. Based on the data, Kitajima and his coaches made efforts to shorten his time over the first 15 meters, which is regarded as the first critical part of a race. Their efforts contributed greatly to Kitajima breaking the Olympic record.

Japan's excellence in manufacturing technologies also contributed to Kitajima's victory. To create the swimsuit Kitajima wore, a special-effects manufacturer gave support by creating a soft mannequin of Kitajima based on the 3-D measurements of his body. Much importance is placed onto how swimsuits fit, because if they do not fit perfectly, water will penetrate into the spaces between the swimsuit and body, creating resistance while swimmers are racing. Additionally, based on the analysis of water flow computation, various efforts were made to create a swimsuit with the least possible resistance under water, using a surface similar to sharkskin and stitches that are not resistant to water flow. It was a swimsuit made especially for Kitajima to wear at the Athens Olympic Games.

At the Athens Olympic Games, Kitajima successfully won two gold medals, which in the past seemed a mere dream for Japanese swimmers. Other Japanese athletes also had great success at the Olympics. The total number of medals won by Japanese athletes was 37, the highest number ever won by the Japanese team. Part of the amazing achievement by Kitajima and other Japanese athletes at the Athens Olympic Games was down to the contribution of Japan's technological excellence.

Have you ever gazed at a starry sky and wondered what the universe looks like and how it all started? By increasing such intellectual curiosity and inquiring mind, people can acquire the willingness to learn independently and the ability to learn on their own initiative, and as a result, they can develop scientific ways of thinking and looking at things.

Thirteen astronomic observatories gather from 11 countries around the world at the summit of Mauna Kea on the island of Hawaii, and compete their observation results. Japan also has the "Subaru" Observatory, which boasts the world's largest single-mirror reflecting telescope with a primary mirror diameter of 8.2 m, on Mauna Kea. A joint research group of the University of Tokyo, the National Astronomical Observatory of Japan, and other institutes announced in February 2005 that they had discovered a young cluster of galaxy in the universe of 12.7 billion years ago by using the Subaru Telescope. This means looking at the universe in its very early stages since the National Aeronautics and Space Administration (NASA) has estimated the age of the universe to be 13.7 billion years.

When the universe was formed, matter (protons, neutrons, and electrons) and antimatter (antiprotons, antineutrons, and antielectrons) had supposedly existed in the same amount. However, antiprotons, etc. cannot be found under natural conditions in the actual world. The KEK B Factory of the High Energy Accelerator Research Organization (KEK) is attempting to solve this mystery, and has empirically proved that the Kobayashi-Masukawa theory, which theoretically predicted the differences between matter and antimatter, is correct.

When thinking about these large research facilities, we tend to look solely at the research achievements made at these facilities, but we must not forget the science and technology required for building these large research facilities as well. The primary mirror of the Subaru Telescope has a diameter of 8.2 m, but it is only 20 cm thick, so the mirror would bend if no measurement were taken. Thus, the mirror has 261 actuators (shafts of which vertical movement is controllable) at the back to detect the bent of the lens with an accuracy of 0.01% and compensate the mirror surface by moving the actuators. Meanwhile, the rotating part of the dome, which is 20 m in diameter and weighs approximately 2,000 tons, is moved to make a round in six minutes. These are achievements of Japanese science and technology.

Achievements could also be made by using the Kamiokande because a Japanese company created a gigantic photomultiplier with a diameter of 50 cm.

Such large facilities and equipment used there could not have been created without Japan's science and technology, and this indicates the high scientific and technological level of Japan.

People will always aspire to reach new frontiers. The frontiers that exist today are the universe and the deep sea. In Japan, the Japan Agency for Marine-Earth Science and Technology owns the "Shinkai 6500," which is a manned research submarine that can dive to depths of 6,500 meters, "Deep Tow," which is a towing-type, deep-sea exploration system that can investigate the sea at a depth of about 4,000 meters, and "Dolphin 3K," which is an unmanned exploration vehicle with a self-navigation capacity that can dive to depths of 3,300 meters. The latter two have made achievements, such as investigating the Russian tanker "Nakhodka," which sank off the Oki Islands in Shimane Prefecture in 1997, as well as discovering the main engine of the first-stage rocket of "H-II Launch Vehicle No. 8," which fell into the waters close to the Ogasawara Islands in December 1999 and contributing to ascertaining the causes of the accident. As for their original task, which is deep sea investigation, they have discovered a large number of unknown creatures around "hydrothermal vents" where water heated by magma under the seabed spurts out like hot springs.

In the area of space, H-IIA Rocket No. 7 with Multifunctional Transport Satellite-1R (MSTA-T-1R) onboard successfully lifted off from the Tanegashima Space Center on February 26, 2005. The satellite has been named "Himawari 6" and will be used for weather monitoring and air-traffic control. Not only such practical use, but also the presence of Japanese astronauts working internationally in the challenging arena of manned space activities in cooperation with U.S. astronauts gives strength to many Japanese people, and such activities as the "Space Educational Program" in which astronauts in space give a direct lecture to young people on the Earth contribute to increasing people's awareness of science and technology.

[Column 15]

50 Years of Rocket Development in Japan

The pioneer of rocket development in Japan was Hideo Itokawa (Professor at the University of Tokyo), who started developing the "pencil" rocket when the ban on aerospace exploration was removed after World War II, and succeeded in an experiment on its horizontal launch in 1955. Various developments and experiments on rockets followed that, and finally in 1970, the Japanese first satellite "Osumi" was successfully launched by the L-4S, which was propelled by solid fuel. By the success of the L-4S, Japan became the fourth country where a satellite was launched with its domestic aerospace technologies. Japanese technologies of solid-fueled rockets for scientific uses were improved and taken over to the "M" series, reaching at the world-highest standard when the current M-V was developed.

The development of launchers for satellites with practical purposes was, on the other hand, not so smooth for Japanese scientists. They had to import U.S. technologies before developing their own technologies. It was 1994 when the test rocket H-II No.1, the first large-scale rocket completely developed in Japan, was successfully launched. The H-II series was improved and the H-II A, the base rocket for Japanese satellites with competence in the world market, was developed.

Although the launching of the H-II A had been suspended for more than a year because of the failure of Launcher No. 6, it was restarted on February 2005. The H-II A No.7 successfully launched MTSAT-1R (Himawari No. 6).

Fifty years ago, the 23-centimeter "pencil" rocket developed by Itokawa gave dreams and hope to young scientists in those days. Now the 53-meter H-II A is a symbol of the big results and capacity of Japanese technologies, which are brought about by 50 years of intellectual work and technical efforts by prominent scientists and engineers. Current rocket science technologies have given dreams and hopes to many scientists and youngsters in Japan, similar to the way the pencil rocket did 50 years ago.

1.2.2 Leaders of Future Science and Technology and Their Roles

The basis for scientific and technological activities is diverse human resources. The fostering and securing of such human resources have become an important issue common to various countries.

Due to the rapid declining of birthrate and aging of the population, Japan needs to make stronger efforts in the future to secure the quantity and quality of human resources such as researchers and engineers, and develop people's understanding of and interest in science and technology, including those of children.

This section looks at the current status and challenges concerning such diverse human resources for science and technology and their roles as well as activities for enhancing people's understanding.

1.2.2.1 Importance of Fostering/Securing Scientific and Technological Human Resources

(Worldwide competition for acquiring human resources)

In the "knowledge-based society" of the 21st century, the basis for all kinds of activities will be "people" who create and use knowledge. In particular, quality and quantity of "human resources" will be important for promoting and encouraging scientific and technological activities. Therefore, efforts for securing scientific and technological human resources have been strengthened in countries around the world.

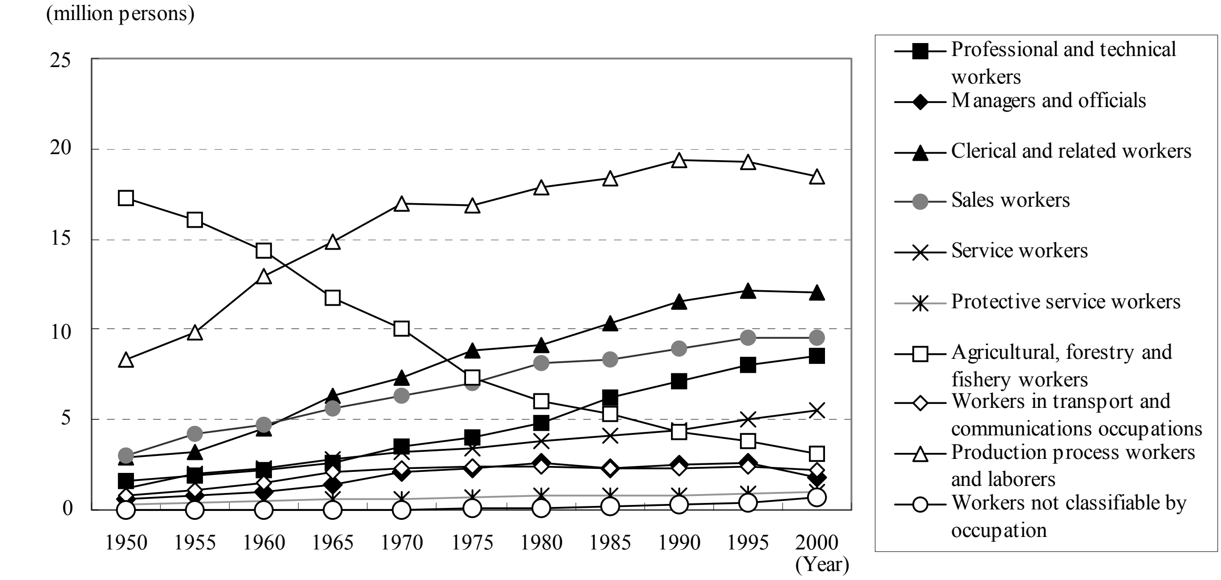
For example, human resources programs have been formulated in France and China. Also, because of the trend of globalization, cross-border competition for acquiring human resources with advanced skills and knowledge has intensified and some countries have taken measures to retain human resources or encourage their return from other countries due to a sense of a brain drain crisis (see Chapter 2 Section 4). "Innovate America" (commonly known as the "Palmisano Report") released by the U.S. Council on Competitiveness in December 2004 also mentioned "talent" as the first of the three recommendations for promoting the innovation policy. In addition, at the Meeting of the OECD Committee for Scientific and Technological Policy (CSTP) at Ministerial Level, "Improving the development and mobility of human resources in science and technology" was taken up as a theme, and discussions were made on issues including the brain drain, securing quantity and improving quality with respect to human resources development, support for students to pursue science and technology studies starting from elementary education, and expanding the participation of women.

Also in higher education, international competition among universities has intensified, for example in establishment of branch schools overseas, due to the increased international mobility of human resources such as exchanges of students and teachers, as well as movement of experts between countries.

In this manner, the fostering and securing of scientific and technological human resources has become an important challenge not only for developed countries, but also for rapidly developing Asian countries.

(Impacts of the declining birthrate and aging of the population in Japan)

Domestically, Japan's scientific and technological human resources have been constantly growing in terms of the number of "those engaged in specialized/technical jobs" and their proportion in all employees has also been increasing (Figure 1-2-11). The total number of researchers and the proportion of researchers in the working population have been growing as well (Figure 1-2-12).



Proportion of professional and technical workers to all workers	4.3	4.8	5.0	5.5	6.6	7.6	8.7	10.6	11.6	12.5	13.5

Figure 1-2-11 Number of Workers by Occupational Classification

Source: Statistics Bureau, MIC, "Population Census"

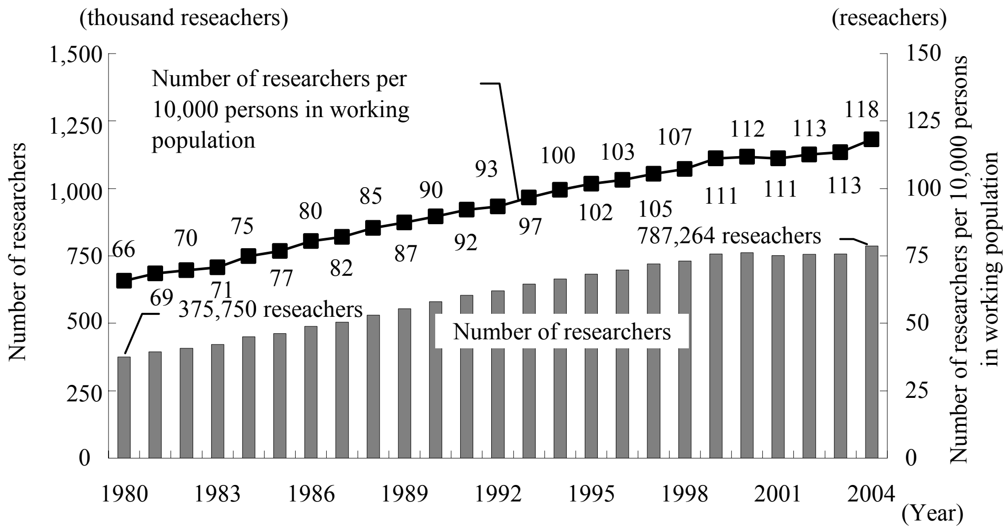
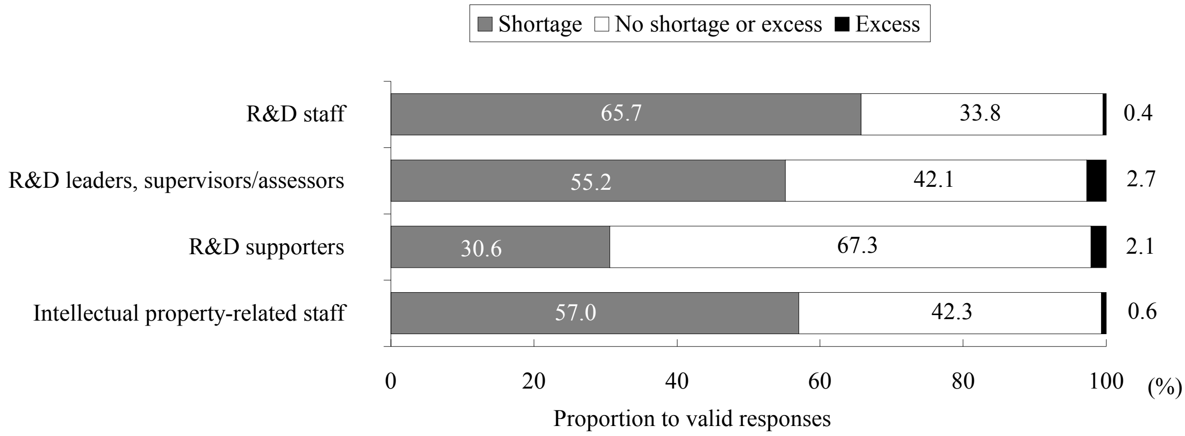


Figure 1-2-12 Number of Researchers per 10,000 Persons in Working Population

Notes: 1. Number of researchers includes those in social sciences and humanities.
2. Number of researchers is the value as of April 1, but that in or before 2001 is the value as of March 31. Working population is the value as of October 1.

Source: Statistics Bureau, MIC, "Survey of Research and Development," "Labor Force Survey."

However, according to the “Survey on Research Activities of Private Businesses” in fiscal 2004, shortage of talents, particularly R&D staff, R&D leaders, and intellectual property-related staff, was being perceived in companies engaged in R&D, especially in the fields of manufacturing technology, information and communications, nanotechnology, and materials (Figure 1-2-13).



R&D Fields of Researchers and Their Shortage

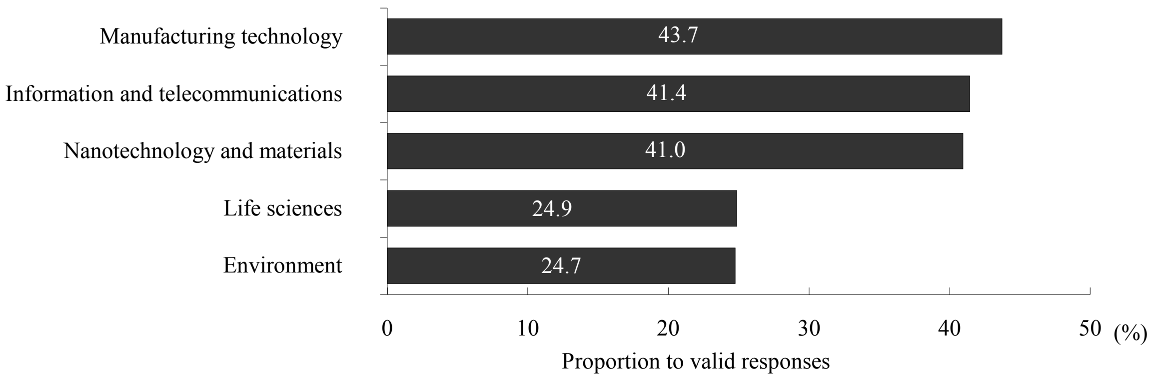


Figure 1-2-13 Shortage and Excess of Scientific and Technological Human Resources

Source: MEXT, “Survey on Research Activities of Private Companies (FY 2004)”

Furthermore, the declining birthrate and aging of the population are accelerating in Japan at an unparalleled pace in the world, so the working-age population began to decline after peaking in 1995, and the proportion of middle-aged and older people in those engaged in specialized/technical jobs has been increasing. There are concerns about the predicted lack of successors of manufacturing engineers and technicians, the difficulty of passing down technologies and expertise, and the outflow of technologies to Asian countries in line with the mass retirement of the “baby boomers” of the first post-war baby boom (the Year 2007 Problem) (Figure 1-2-14). Under such circumstances, there is a risk of being unable to secure sufficient supply of talented researchers and engineers for meeting the demand in the future, depending on the future industrial structure. There is an estimation that the number of researchers and engineers will be short by more than one million persons in the next 25 years.

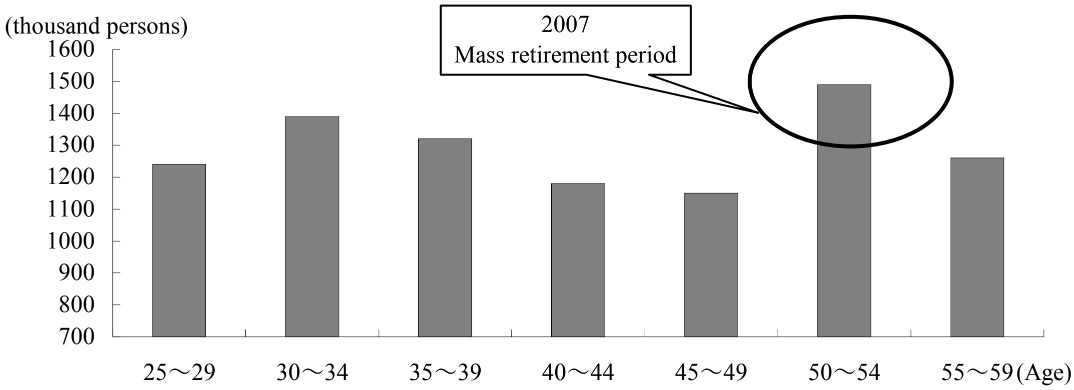


Figure 1-2-14 Number of Employees in the Manufacturing Industry by Age Group (2003)

Source: Statistics Bureau, Ministry of Internal Affairs and Communications, "Labor Force Survey (2003)"

In the field of science and technology, not only measures for increasing the quantity of human resources, but rather, measures for raising their quality would be important, such as increasing their creativity. A decline in vitality of younger generations may lead to a decline in scientific and technological potential. Since Japan will become a society with a declining population in the future, it will be important to attract talented human resources to the field of science and technology, and develop an environment where they can fully demonstrate their abilities.

Therefore, there is a need to implement comprehensive policies for developing and securing human resources by designing integrated measures for elementary and secondary education, undergraduate schools, graduate schools, and working people, while considering life cycles.

1.2.2.2 Diverse Human Resources Involved in Science and Technology

(Human resources involved in science and technology)

Today, the relations between science and technology and society are becoming closer and more diverse. Scientific and technological activities are carried out by people having diverse roles, such as those who create new knowledge (researchers), those who use achievements of knowledge in commercialization or services (engineers, technicians), those who engage in management (e.g., management of technology [MOT]), those who promote coordination between industry, academia and government in intellectual property-related projects or the like, and those who bridge between science and technology and the general public (science communicators) (Figure 1-2-15).

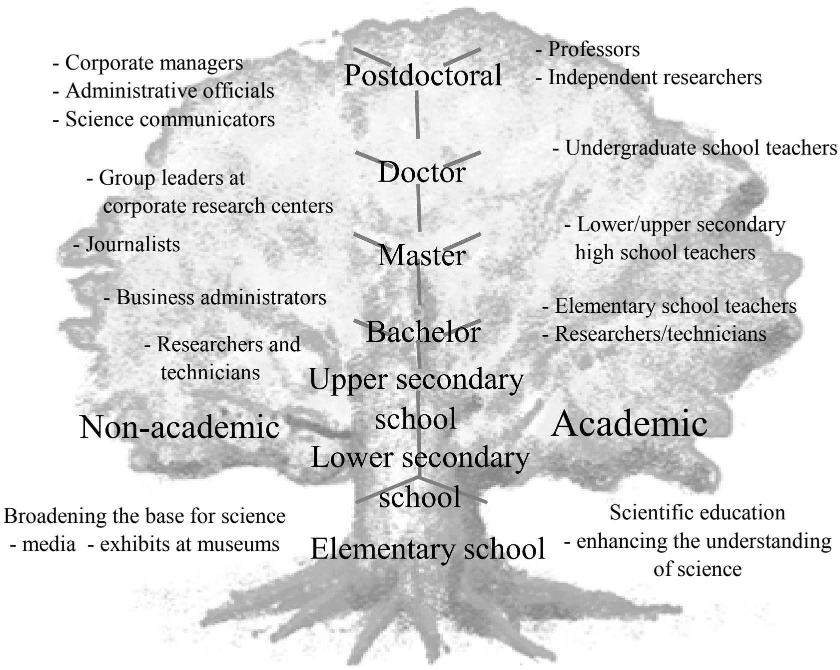


Figure 1-2-15 Example Career Paths of Scientific and Technological Human Resources

Source: Produced by MEXT based on the report of the Conference on International Training and Support of Young Researchers in the Natural Science Field (November 29-30, 2001 [France: Strasbourg]).

Conventionally, emphasis had been placed on measures for further raising the peak of knowledge creation (researchers). However, there will be a need to also focus on use of knowledge and establishment of the foundation for such use (broadening the base for science) in the future. Incidentally, according to NISTEP's analysis based on a questionnaire survey, about one-third of those with a doctor's degree in the United States get a job at profit-making companies, and conduct activities in wide-ranging fields including non-academic jobs. On the other hand, only about 17% of those with a doctor's degree in Japan get a job at profit-making companies, which is about half the percentage of those that do in the United States.

(Development of researchers and engineers)

Higher educational institutions such as universities and graduate schools are core research institutes that play a lead role in Japan's basic research as well as institutions for developing scientific and technological human resources such as researchers and engineers.

In Japan, graduate schools mainly focused on development of researchers and university instructors at the time when the graduate school system was established. However, in response to the growing needs for development of human resources for advanced, specialized jobs backed by rapid technological innovation as well as the sophistication and increased intricacy of society and economy, the professional graduate school system was established in fiscal 1999 and the professional school system was established in fiscal 2003. Due to the establishment of such systems and an increase in the number of graduate schools, the numbers of persons enrolled at, graduated from, and hired after graduating from graduate schools for natural science have been increasing every year.

However, a shortage of such human resources has been perceived by private companies for some job types and fields, while the problem of quality has also been pointed out. For example, when working researchers were asked about the qualities and abilities sought in an ideal researcher, many mentioned creativity, knowledge in the areaof expertise, the ability to set research themes, and an inquiring mind. However, while they highly evaluated young researchers as having knowledge in the area of expertise and cooperativeness, they made low evaluation of young researchers' creativity and ability to set research themes (FY 2002 "Survey of the State of Japan's Research Activities") (Figure 1-2-16). Meanwhile, private companies seek universities and graduate schools to develop the ability to think and extensive knowledge/interests of students, indicating that "the thinking power should be developed rather than providing knowledge" and "the method of the entrance examination should be changed from evaluation of the amount of knowledge to multidimensional evaluation of the ability to think, interests, and talent" (FY 2004 "Survey on Research Activities of Private Businesses") (Figure 1-2-17).

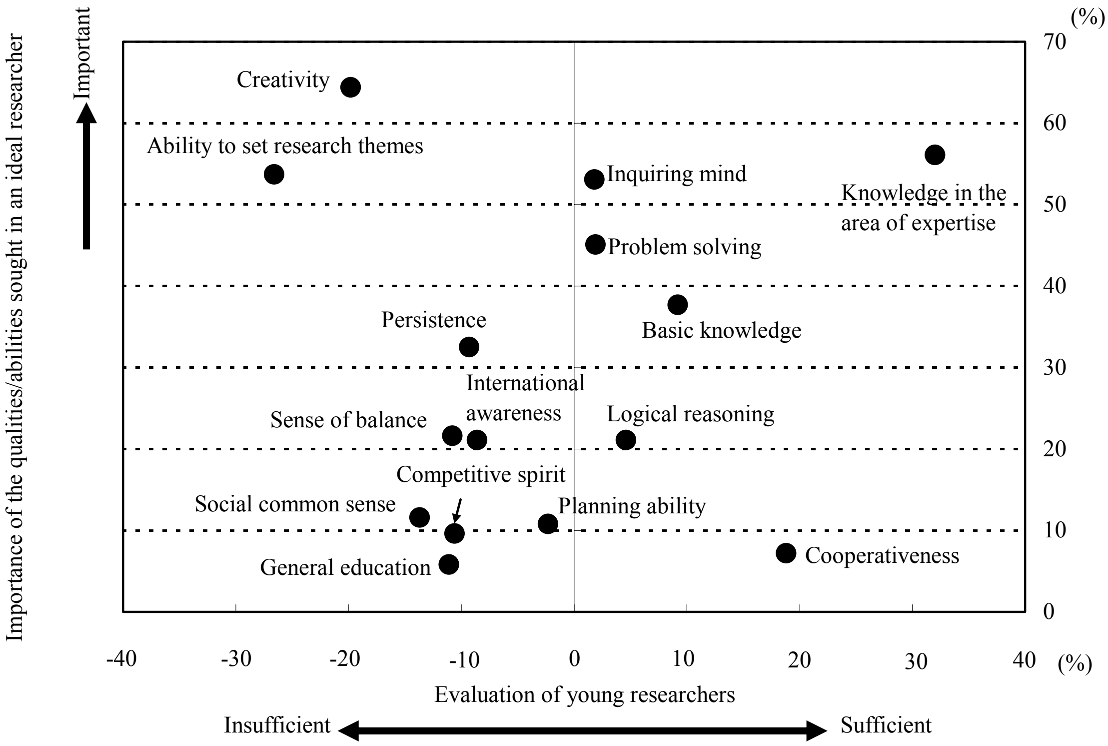


Figure 1-2-16 Importance of the Abilities Sought in an Ideal Researcher and Evaluation of Young Researchers

Source: Produced by NISTEP based on MEXT, "Survey of the State of Japan's Research Activities (FY 2002)"

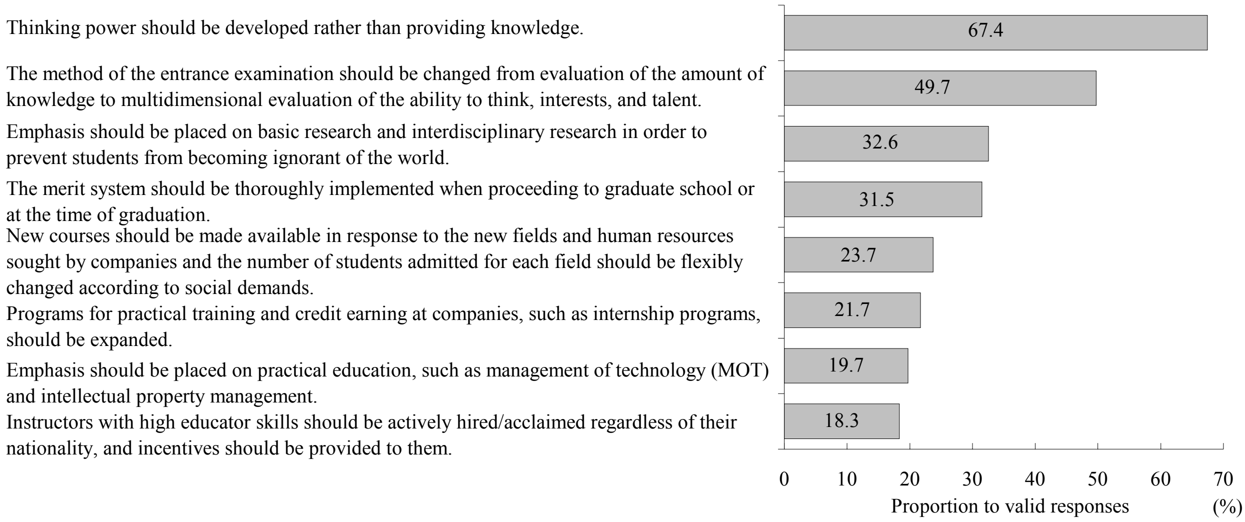


Figure 1-2-17　Matters Sought from Universities and Graduate Schools

Source: MEXT, “The Survey on Research Activities of Private Businesses (FY 2004)”

Accordingly, from the viewpoint of upgrading the abilities and qualities of researchers, there is a need to improve the educational content and methods at graduate schools, mainly those of doctorate courses, while also considering social needs.

Many engineers and technicians supporting Japan’s manufacturing field have graduated from specialized upper secondary schools such as industrial high schools, special training colleges, colleges of technology, junior colleges, and universities. In order to foster creative, high-quality engineers and technicians with an ethical sense, it is necessary to promote practical education at these institutions as well as make efforts to implement coordination between industry, academia and government in human resources development, such as internship programs, and to cultivate students’ outlook on careers.

Furthermore, due to the increased intricacy of scientific and technological activities, there are demands for persons who engage in management, so an increasing number of educational institutions are providing educational programs on management of technology (MOT). In addition, in order to use the scientific and technological achievements for economic activities, there is a need to develop and secure wide-ranging human resources including, coordinators of coordination between industry, academia and government, those with an expert eye who can discover technology seeds and match them with companies, those engaged in intellectual property affairs, and those who support start-ups.

(Allowing female and non-Japanese workers to demonstrate their abilities)

Due to the declining birthrate and aging of the population, there is a need to increase individuals’ abilities and productivity as well as to develop an environment in which diverse human resources can show good performance according to their abilities.

Firstly, the number of female researchers and their proportion have been gradually increasing (Figure 1-2-18), but the level is low compared to the proportion of females among school graduates (such as among those who earned a bachelor’s, master’s, or doctor’s degree), the proportion of females in all employees (more than 40%), and the situation in other countries.

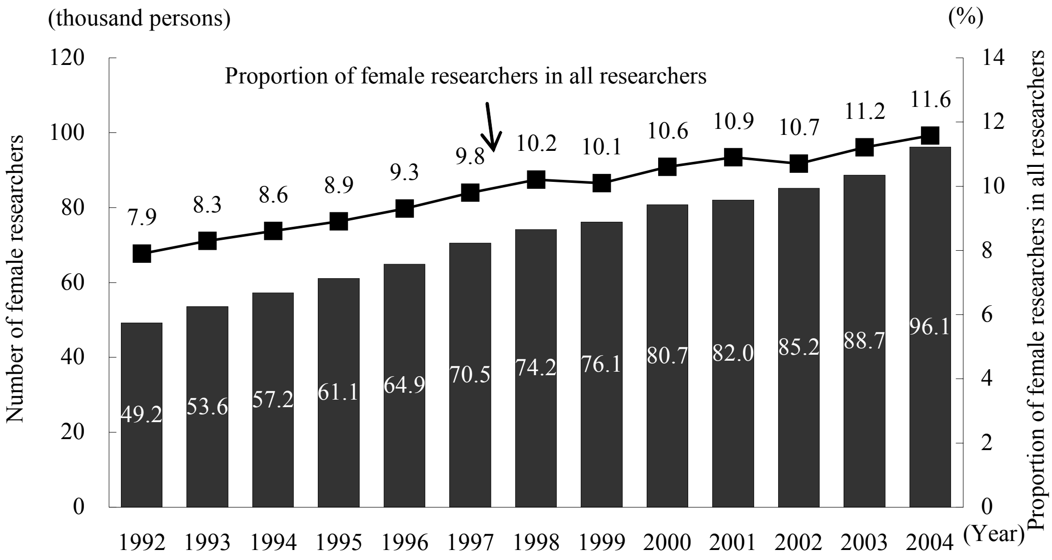


Figure 1-2-18 Proportion of Female Researchers in All Researchers

Note: Values are the number/proportion of female researchers including those in social sciences and humanities as of March 31 (as of April 1 for values up to 2001).
Source: Statistics Bureau, MIC "Survey of Research and Development"

Looking by sector, the proportion of female researchers in 2004 was relatively high for universities at 20.4% and the proportion has been gradually increasing, but that for companies was low at 6.6% and the proportion has remained at the same low level for the past several years.

The reasons include insufficient preparations to accept female workers particularly at private companies, and the problems of childbearing and childraising. It has been pointed out that it is tough to continue being engaged in R&D work.

According to the "Survey on Research Activities of Private Businesses" in fiscal 2004, the most companies stated "there are few or no applicants" as the reason for lack of increase in the proportion of female researchers, followed by "the company does not make special effort to increase the number of female researchers" (Figure 1-2-19). With regard to measures for encouraging female researchers to demonstrate their abilities, about 70% of the companies had taken some kind of measures, mainly in the area of providing systems for taking leave and allowing flexible working hours and working modes. As for measures to be implemented in the future, some companies, though still not so large in number, mentioned about setting numerical targets for female executives and researchers, in addition to expanding the fields and job categories for employing female workers. Thus, even more active measures are expected in the future (Figure 1-2-20).

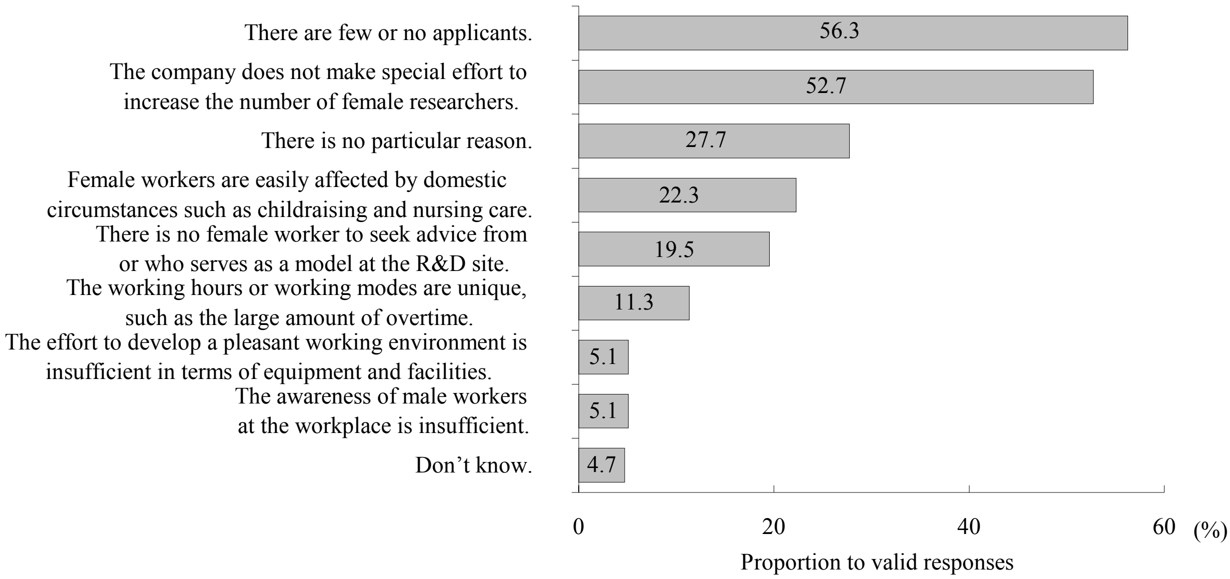


Figure 1-2-19 Reasons for Lack of Increase in the Proportion of Female Researchers

Source: MEXT, "Survey on Research Activities of Private Businesses (FY 2004)"

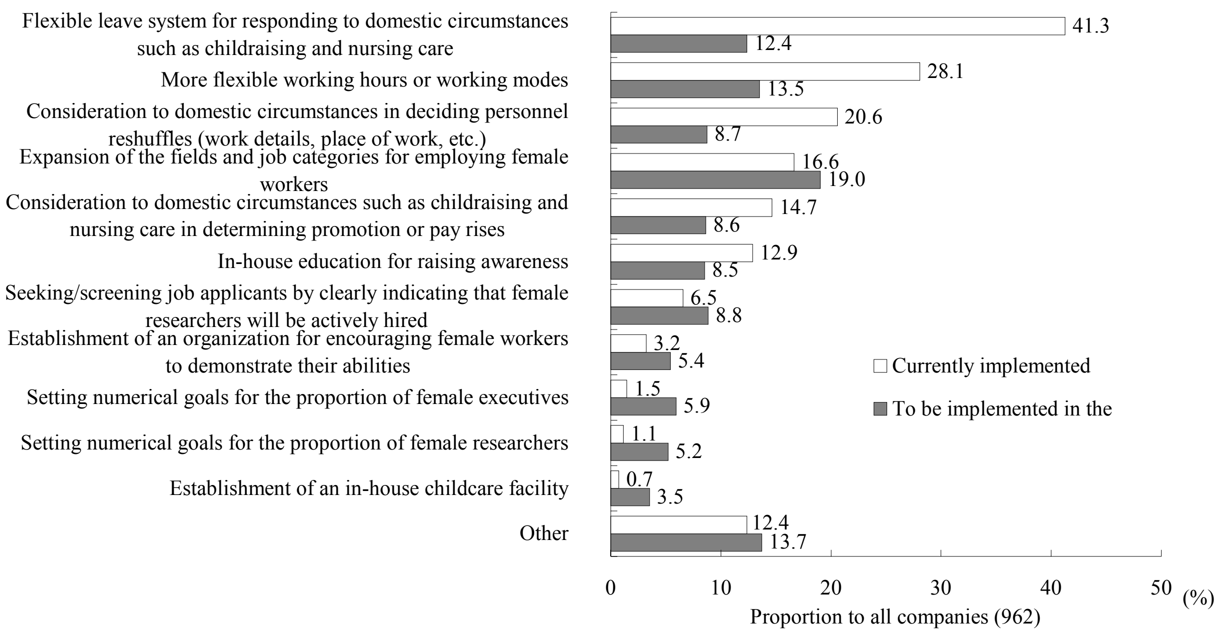


Figure 1-2-20 Specific Measures for Encouraging Female Researchers to Demonstrate Their Abilities

Source: MEXT, "Survey on Research Activities of Private Companies (FY 2004)"

Next, the number of non-Japanese researchers and their proportion have also been gradually increasing in recent years (Figure 1-2-21), but the influx of people engaged in technological/research work has been declining. Moreover, according to the "Survey on Research Activities of Private Businesses," the number of newly hired non-Japanese researchers has hardly changed for the past five years.

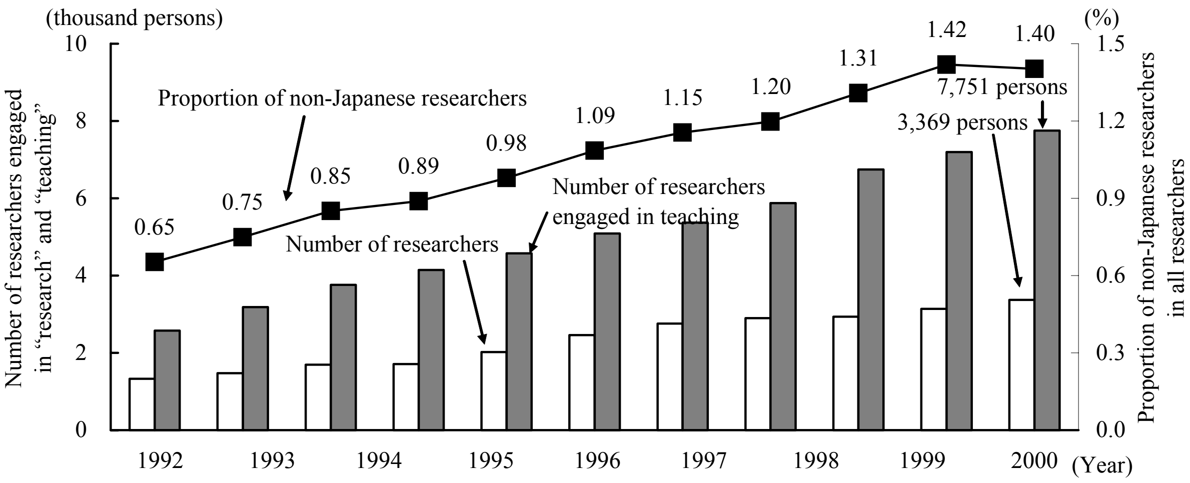


Figure 1-2-21 Number of Non-Japanese Researchers and Their Proportion in All Researchers

Source: NISTEP, "Science and Technology Indicators" (FY 2004)

Some of the reasons mentioned were communication problems, such as language problems, and the uncertainty of maintaining the employment contract. However, presence of talented non-Japanese researchers is important for intellectually stimulating Japan's research society, which tends to be regarded as being closed, and for building an international network. Therefore, measures should be taken to establish an environment that facilitates their stay and settlement in Japan.

Comprehensive measures will be required, also including use of elderly human resources and expansion of reeducation programs for workers.

(Improvement of treatment for scientific and technological human resources)

When comparing the average wage for jobs related to science and technology between Japan and the United States, a higher wage than average is paid for most jobs that require specialized skills or knowledge both in Japan and in the United States. In Japan, however, the payment is not particularly high for most jobs related to science and technology, except for "aircraft pilots" and "doctors." In contrast, a high wage corresponding to professional ability is paid for technological jobs in the United States (FY 2002 "Annual Report on Promotion of Science and Technology")

Meanwhile, according to a survey on private companies that engage in R&D, most companies (67.3%) mentioned that there is no difference in average wage between researchers and other workers, while a larger percentage of companies (49.4%) provided the same or almost the same starting salary to those with a doctor's degree as for those with a bachelor's or master's degree than companies (45.8%) that paid more to those with a doctor's degree (FY 2002 "Survey on Research Activities of Private Companies").

This indicates that, in Japan, technological workers who tend to have received long years of education with rich curriculums do not enjoy a particularly good wage. Although treatment of workers cannot be measured merely by their wages, which only indicate one economic aspect, it will be desirable to guarantee treatment that matches the advanced knowledge, skills, and ability in securing excellent scientific and technological human resources and allowing them to demonstrate their potential.

1.2.2.3 Fostering Understanding of and Interest in Science and Technology

(Scientific and technological literacy)

In order for society to appropriately determine what is ideal science and technology and to take necessary measures, the level of scientific and technological literacy of the people becomes important.

People enjoy scientific and technological achievements in various forms. In the future, however, it is hoped that they will participate in forming policies of the national or local government instead of merely being one-sided beneficiaries. This is because the relation between science and technology and society is becoming closer and more intricate, and individuals have come to be inevitably involved in both the "positive" and "negative" effects of scientific and technological development, as well as because enormous amounts of national expenditure (tax) are directed to science and technology.

However, cutting-edge science and technology has become more and more sophisticated and complicated—becoming something like a black box—scientific and technological achievements have penetrated so deeply into people's lives that they often go unnoticed, and Japan has attained economic affluence in general. Due to these reasons, people's awareness of science and technology has lowered compared to the previous survey. The decline was particularly notable for younger generations under age 30 (Figure 1-2-22).

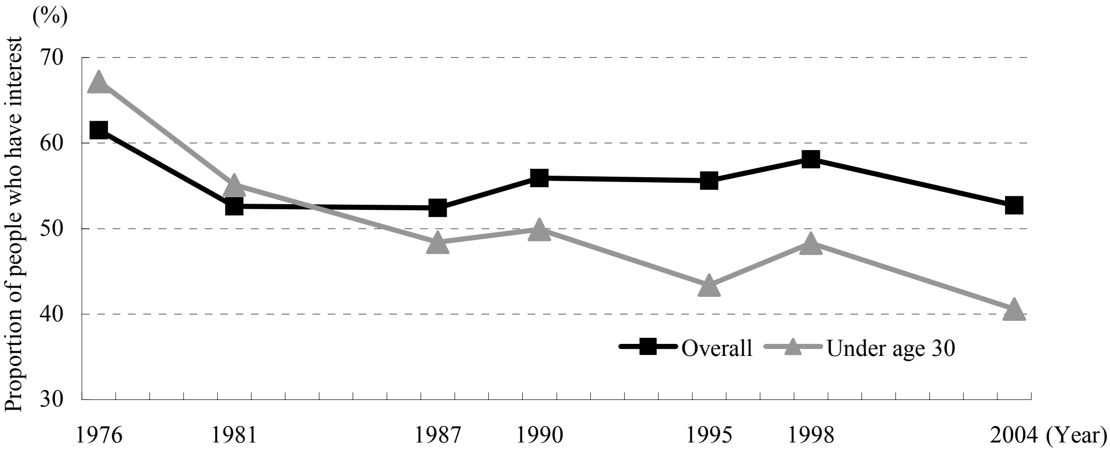


Figure 1-2-22 Interest in News and Topics of Science and Technology

Source: Cabinet Office, "Public Opinion Poll on Science and Technology and Society."

According to a survey that internationally compared the degree of understanding of basic scientific and technological concepts of adults aged 18 or over, Japan ranked low among the surveyed countries.

People's loss of interest in science and technology may invite a decline in the intellectual level of Japan as a whole, a decrease in the number of young people wanting to pursue a career related to science and technology, as well as diminishing of scientific and technological human resources.

The survey results show that adults' interest in science and technology is affected by whether they liked or disliked science when they were children. Therefore, in order to raise adults' scientific and technological literacy, it will be beneficial to increase schoolchildren's interest in science and technology as well to implement wide-ranging measures such as encouraging them to acquire an attitude for voluntary learning instead of one-way provision of knowledge and information.

(Measures to develop children's academic abilities and to enhance their interest in the science class)

In December 2004, the results of two international surveys on academic abilities were released. The surveys were the "Programme for International Student Assessment (PISA 2003)" conducted by the Organisation for Economic Co-operation and Development (OECD) targeting children aged 15 (first-graders of upper secondary school) and the "Trends in International Mathematics and Science Study (TIMSS 2003)" conducted by the International Association for the Evaluation of Educational Achievement (IEA) targeting fourth-graders of elementary school and second-graders of lower secondary school (Figure 1-2-23).

According to the results, the overall academic standard of Japanese children ranked high in the world, but in the PISA 2003, the reading ability has been declining to the same level as the OECD average, and is not at the world's top level. In the TIMSS 2003, the overall academic abilities ranked high in the world, but the scores for science achievement of elementary school students and mathematics achievement of upper secondary school students were lower than those in the previous survey. Looking at children's willingness and attitude to study, not many Japanese students said they enjoy learning or they usually do well in mathematics or science. The time spent on study outside of school was at the lowest level among the participating countries, while the time spent on watching television and videos was long. The results indicated that there is much room for improvement with respect to children's willingness to study and study habits.

Programme for International Student Assessment (PISA) 2003
(Conducted by the Organisation for Economic Co-operation and Development (OECD))

○ The overall academic abilities of Japanese students ranked high in the world. (Targeting first-graders of upper secondary school)
○ However, reading ability is declining, so Japan is not at the world's top level.
○ Japanese students have a good attitude about taking lessons, but there are problems regarding their willingness to study and study habits.

1. International comparison of average scores (40 countries/regions)

Performance in mathematics (ranking highest in the previous survey)	Top ranking group: Hong Kong, Finland, South Korea, Netherlands, Liechtenstein, Japan (sixth)
Performance in reading (ranking eighth in the previous survey)	Same level as the OECD average (14th)
Performance in science (ranking second in the previous survey)	Top ranking group: Finland, Japan (second), Hong Kong, South Korea
Performance in problem solving (introduced this time)	Top ranking group: South Korea, Hong Kong, Finland, Japan (fourth)

2. Results of the questionnaire survey

○Willingness to study

	Students interested in the things they learn in mathematics
Japan	32.5%
OECD average	53.1%

○Time spent on studying outside of school

Japan	6.5 hours/week
OECD average	8.9 hours/week

○Students' attitude in taking lessons

	The teacher has to wait a long time for students to quieten down.			
	Always	Mostly	Sometimes	Hardly ever
Japan	3.9%	9.6%	34.8%	50.4%
OECD average	12.0%	19.2%	41.5%	24.8%

Trends in International Mathematics and Science Study (TIMSS 2003)
(Conducted by the International Association for the Evaluation of Educational Achievement (IEA))

- ○The academic abilities of Japanese schoolchildren ranked high in the world.
  However, the scores for science achievement of elementary school students and mathematics achievement of upper secondary school students were lower than those in the previous survey. (Targeting fourth-graders of elementary school and second-graders of lower secondary school)
- ○There are problems in children's willingness to study and study habits.
- ○The time spent watching television and videos was long while the time spent doing jobs or chores at home was short.

(1) Japan's scores

(i) Mathematics achievement

	Elementary school	Lower secondary school
1964 (First survey)	Not implemented	Second place/12 countries
1981 (Second survey)	Not implemented	First place/20 countries
1995 (Third survey)	Third place/26 countries	Third place/41 countries
1999 (Third survey-repeat)	Not implemented	Fifth place/38 countries
2003 (Fourth survey)	Third place/25 countries	Fifth place/46 countries

(ii) Science achievement

	Elementary school	Lower secondary school
1970 (First survey)	First place/16 countries	First place/18 countries
1983 (Second survey)	First place/19 countries	Second place/26 countries
1995 (Third survey)	Second place/26 countries	Third place/41 countries
1999 (Third survey-repeat)	Not implemented	Fourth place/38 countries
2003 (Fourth survey)	Third place/25 countries	Sixth place/46 countries

(2) Awareness of mathematics/science

	I enjoy learning		I usually do well in	
	mathematics	science	mathematics	science
Lower secondary school	39%	59%	39%	49%
World average	65%	77%	54%	54%

(3) Things students do outside of school

	I do my homework	I watch television and videos	I do jobs or chores at home
Lower secondary school	1.0 hour/day	2.7 hours/day	0.6 hours/day
World average	1.7 hours/day	1.9 hours/day	1.3 hours/day

Figure 1-2-23 Outline of the Results of PISA and TIMSS

Source: MEXT

Meanwhile, according to the "Research on Curriculum for Primary and Lower Secondary Schools" conducted by the National Institute for Educational Policy Research in fiscal 2001 and fiscal 2002, the proportion of schoolchildren who agreed with the opinion, "I like studying the subject," for science and mathematics tended to be lower for students in higher grades.

Therefore, in the area of elementary and secondary education, necessary reform must be promoted for overall compulsory education, including the educational content, the teaching method, and the quality of teachers, in order to "cultivate solid academic capabilities" targeted by the current Courses of Study, to develop intellectual curiosity as well as an attitude to learn and think voluntarily, and to achieve the world's top-level academic abilities.

In particular, in order to enhance the understanding of and interest in science and technology of children who will lead Japan in the future, MEXT implements diverse projects concerning science education such as the "Science Literacy Enhancement Initiatives" including designation of Science Literacy Enhancement Schools (elementary and lower secondary schools) and Super Science High Schools (upper secondary schools), as well as creation and distribution of "White Paper on Science and Technology for Kids" (See Part 3).

Measures will also be required in higher education such as universities to develop the science literacy of students who do not specialize in science and technology, and to ensure that students majoring in science and technology acquire extensive knowledge, application abilities, and literacy that are not limited to their major field.

[Column No.16]

International Science Olympiads and Inter-High School Tournament of Science

In July 2004, the International Mathematics Olympiad (IMO) for high school students was held in Athens, Greece—the place where Japanese athletes won many medals, exciting viewers of the Olympics throughout Japan. The six winners of the domestic preliminary rounds participated in the IMO as Japan's representatives. Their excellent performances were rewarded with 2 gold and 4 silver medals. The International Chemistry Olympiad was also held in Germany in the same year, and a Japanese participant won a gold medal for the first time.

The International Science Olympiads (ISO) is an annual competition with six divisions (mathematics, chemistry, physics, informatics, biology and astronomy) for high-school students or below. All the competitions originated in Eastern European countries in the former Communist bloc, and have spread to Western bloc countries.

The aims of the ISO are as follows: (1) promotion of learning activities for students who are interested in science and technology: (2) cultivation of learners' creativity and inspiration; and (3) establishment of friendship between participants through international exchange. It is also effective in attracting public attention to science and technology.

Japan has participated in the Olympiads' Mathematics (since 1990) and Chemistry categories (since 2003). Japanese participants in these Olympiads are selected through tightly-contested domestic preliminary rounds, which are supported by the related academic societies, teachers and volunteers.

The number of Japanese participants in the ISO has been increasing, although there is concern that it will decrease in the future because of the trend of fewer children and the unpopularity of science. The increasing number of participants could be due to increased name-recognition of the ISO, and to the Japan Science and Technology Agency (JSTA) introducing the ISO support system in fiscal 2004. JSTA subsidizes the expenses of overseas trips by participants and their supervisors, as well as of domestic training camps. Japan will also participate in the Biology Olympiad from the Beijing competition in 2005 and in the Physics Olympiad from the Singapore competition in 2006. The people involved the Physics Olympiad have been preparing for Japan's first participation. In August 2005, for example, the "Physics Challenge 2005" will be held in Okayama Prefecture, partly as the domestic elimination rounds of the Physics Olympiad.

Inside Japan, the first Super Science High School event was held at Tokyo Big Sight in August 2004. Science lovers from high schools throughout Japan gathered in the meeting to present their research. In the "Inter-high-school Tournament of Science," the 72, which were designated as "Super Science High Schools" in fiscal 2002, participated, and 26 of them presented the results of their studies over the last three years. The Honorable Mention by the Minister of Education, Culture, Sports, Science and Technology was awarded to students of the science and mathematics seminar at Hiroshima Kokutaiji High School, Hiroshima Prefecture, for their study "Genetic Analysis of the Great Salamander." For the first time in the world, high school students succeeded in analyzing the DNA of the great salamander, the world's biggest amphibian, which is designated as a special national treasure in Japan. As their study was so outstanding, they had an opportunity to present it at the meeting of the Society of Evolutionary Studies, Japan, in the same month, and received high praise from the specialists.

Such efforts to cultivate young people's intellectual curiosity and inquisitive spirit are highly beneficial, not only for nurturing world-class scientists and engineers, but also for stimulating other students and school education. Despite the trend of unpopularity of science and technology, events such as the ISO and the Super Science High School are expected to become more popular.

(Building channels between researchers and society)

Scientists and engineers play a significant role in enhancing people's understanding of science and technology and encouraging children to take up a career in science or technology in the future.

However, there is a considerable gap in awareness between the general public and scientists. For example, according to the "Survey of the State of Japan's Research Activities" in fiscal 2003, which targeted researchers, those who answered that people's impression of researchers seemed to have "improved" or "slightly improved" accounted for 42.3% of all respondents, which is a considerable increase from the 9.2% in the same survey in fiscal 1999 (Figure 1-2-24). The reason mentioned by nearly 80% of these respondents was "Japanese people winning famous scientific prizes such as the Nobel Prize." On the other hand, in the "Public Opinion Poll on Science and Technology and Society," which was conducted on the general public at around the same time, about 15% answered "agree" or "slightly agree" with the statement, "scientists and engineers are a familiar and close presence," while more than 70% answered "disagree" or "slightly disagree" (Figure 1-2-25).

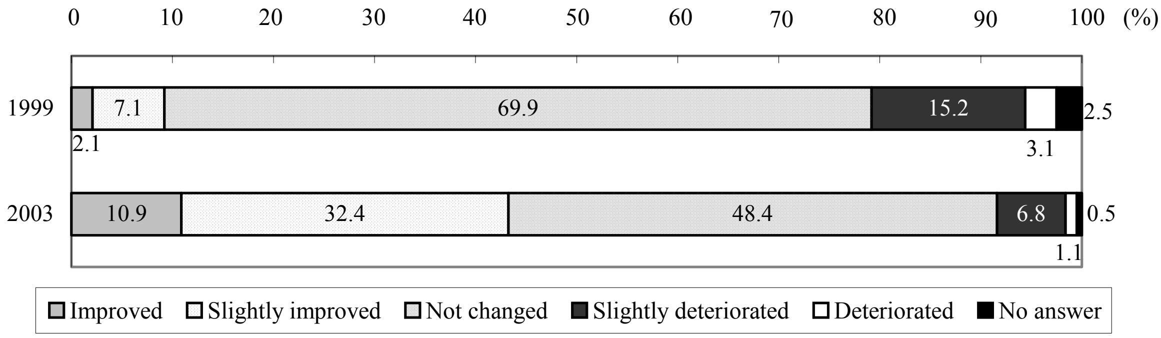


Figure 1-2-24 Changes in Society's and People's Impression of Researchers (Researchers' Awareness)

Source: MEXT, "Survey of the State of Japan's Research Activities"

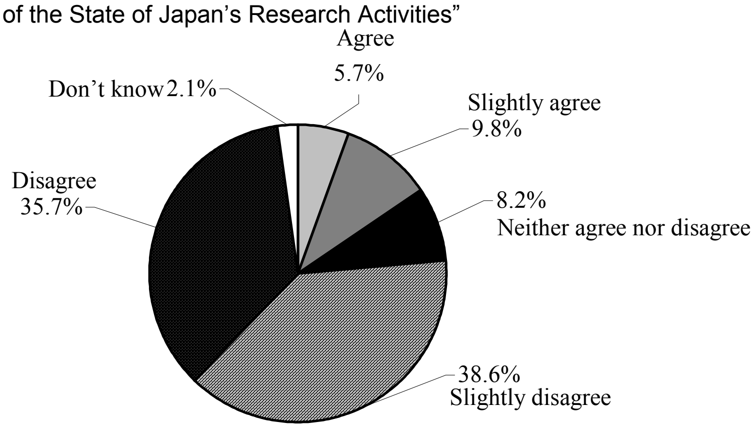


Figure 1-2-25 Sense of Closeness with Scientists and Engineers (People's Awareness)

Note: Figure indicates the respondents' opinions on the statement, "scientists and engineers are a familiar and close presence."
Source: Cabinet Office, "Public Opinion Poll on Science and Technology and Society (February 2004)."

Looking at the places that scientists and engineeers want to use for presenting their research in the FY 2003 "Survey of the State of Japan's Research Activities," the greatest number of respondents mentioned contribution of an article to a magazine for the public and lectures/lessons for the public. However, looking at how people access information on science and technology in the "Public Opinion Poll on Science and Technology and Society," the main means were television and newspaper. Such difference in awareness and practices seem to be causing a distance between scientists and the people.

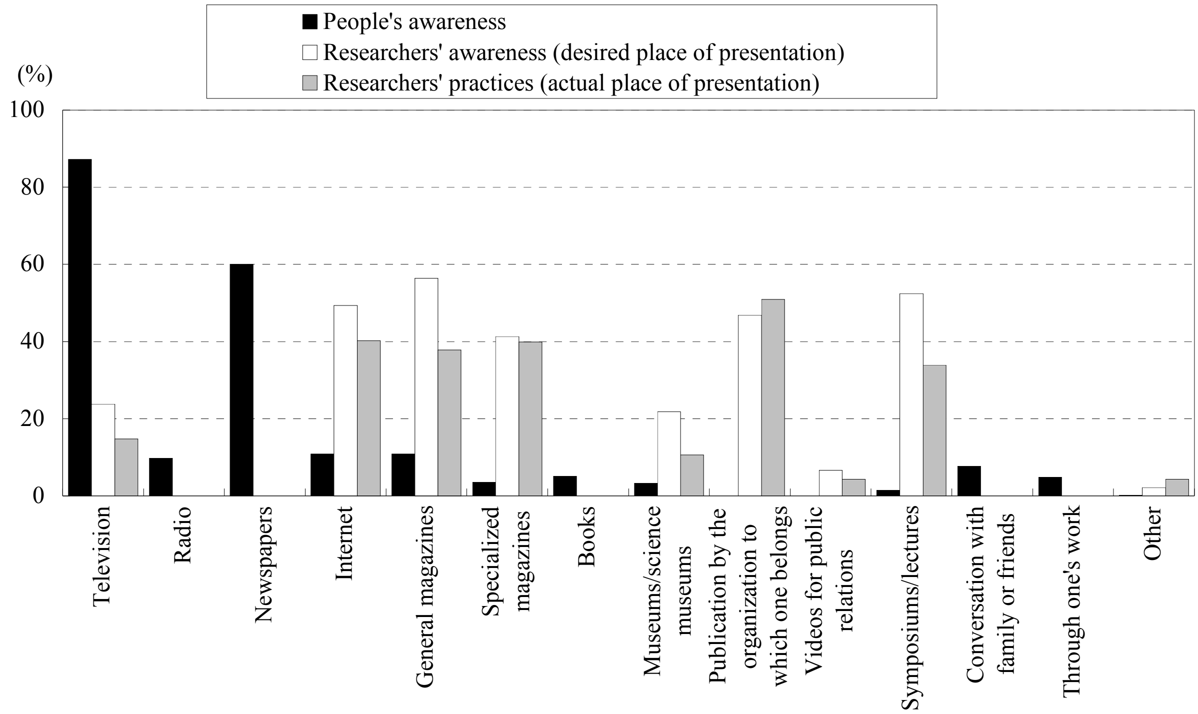


Figure 1-2-26 People's Means of Access to Scientific and Technological Information and Places Where Scientists Disseminate Information

Note: Results of the survey of the state of Japan's research activities were compared with the results of the public opinion poll by deeming the survey items to correspond to the following:
"mass media such as television and radio" as "television";
"Web sites on the Internet" as "Internet";
"contribution of an article to a magazine for the public" as "general magazines";
"activities of an academic society or association such as public relations" as "specialized magazines";
"demonstration of experiments and activities for experiencing science and technology at science museums" as "museums/science museums"; and
"lectures for the public and lessons at citizen's colleges" as "symposiums/lectures."

Sources: Cabinet Office, "Public Opinion Poll on Science and Technology and Society (February 2004)";
MEXT, "Survey of the State of Japan's Research Activities (FY 2003)."

Therefore, scientists and engineers and the organizations to which they belong should send out information and conduct outreach activities[1] more actively through the mass media and other diverse media.

Also, because science and technology is a specialized field, the vehicle for conveying the information to people in an understandable manner would be important, so science journalists should be developed and the public relations section of research institutes should be reinforced.

At the same time, museums and science museums are places where people of various ages, particularly children, can actually experience and observe science and technology, but while the number of these facilities is increasing every year, there is little growth in the number of visitors. Therefore, they are expected to contribute to enhancing children's interest in science education through adopting unique display styles and in coordination with school education.

1 Researchers join in the local community on their own initiative, interact with the community members, and provide them with learning opportunities.

1.2.3 The Science and Technology Basic Law and the Science and Technology Basic Plan

Research achievements derived from researchers ideas go through various twists and turns until they are put to practical use and reach consumers, and various public support becomes necessary in that course. Japan, which enacted the Science and Technology Basic Law in 1995, took a step forward toward becoming an advanced science- and technology-oriented nation. Based on this law, the First and Second Science and Technology Basic Plans were formulated to support the diverse R&D of universities, public research institutes, companies, and individual researchers, and to establish the foundation for producing many research achievements. This section focuses on the background of formulation of the Science and Technology Basic Law and the Science and Technology Basic Plans as well as the status of their attainment.

1.2.3.1 Enactment of the Science and Technology Basic Law

(Expectations for science and technology)

The bill for the Science and Technology Basic Law was submitted to the Diet by a cross-party group of Diet members in order to make the promotion of science and technology as one of Japan's top priority issues, and to achieve an "advanced science-and technology-oriented nation." The bill was unanimously approved, and the law was promulgated and entered into force in November 1995. For a long time, people had held high expectations for enactment of the Science and Technology Basic Law, which indicates the roadmap for the country's science and technology policy, and the government submitted the bill to the Diet in 1968. However, the bill was repealed as a result of not being approved by the end of the session, due to considerable differences in the ideas of people concerned regarding coordination between industry, academia and government and the handling of universities.

Nevertheless, nearly 30 years later, enactment of the Science and Technology Basic Law gathered momentum again due to considerable changes in the domestic and international situations. Japan grew to become the world's second largest economic power. Japan was no longer in a catch-up era, but it was time for it to make challenges in unexplored fields of science and technology and open up a path for the future by demonstrating creativity as a front-runner. At the same time, because Asian countries were making efforts to catch up with Japan by making use of their inexpensive labor, there were growing concerns about a possible hollowing out of industry in Japan, such as the percentage of overseas production of the Japanese manufacturing industry increasing from 6.0% in 1991 to 8.9% in 1995. Thus, development of new technologies was also necessary for creating conditions that make companies remain in Japan. Furthermore, Japan had come to be expected to make scientific and technological contributions to the world in addressing energy and environmental issues as one of the front-runners.

(The situation of science and technology in Japan at the time)

The situation of science and technology in Japan at the time of enactment of the Science and Technology Basic Law was a matter of concern. First of all, public funds were considerably lacking. While the percentage of R&D funds to gross domestic product (GDP) in Japan was at the highest level in the world, exceeding that of major western countries, the percentage of government-financed R&D funds to GDP was low at 0.59 in Japan when the percentage was 0.88% in the United States (1994) (Figure 1-2-27). Because R&D funds were mostly financed by the public sector in this way, research was not so active in areas of medium to long-term technology seeds, such as in the basic research field, which are indispensable for development of science and technology.

Furthermore, the amount of R&D funds per researcher was low, and research facilities, which support researchers' creative research activities, were becoming old. Facilities that were 20 years old or older accounted for 50% of the facilities of all national universities, which was 35% of the facilities of all national research institutes.

There was also a serious shortage of human resources for conducting research. Although there were demands for unique and creative researchers and engineers, such human resources were quite small in number in Japan in reality. In 1991, the number of persons who earned a doctor of science degree in Japan was 600 as compared to 9,700 in the United States, and the number of persons who earned a doctor of engineering degree in Japan was 1,000 as compared to 6,400 in the United States. Therefore, it was necessary to increase the number of postdoctorals and develop an environment for allowing them to get jobs with advantage also for expanding the researcher population and fostering creative researchers. Moreover, there was a need to form a research environment where talented young researchers are promoted and the principle of competition takes effect, so as to have researchers demonstrate their free creativity. However, researchers at universities and national testing laboratories lacked mobility since they were basically subject to lifetime employment, and the competitiveness of the research environment was insufficient. What is more, it was quite difficult to provide young researchers with appropriate places for engaging in research.

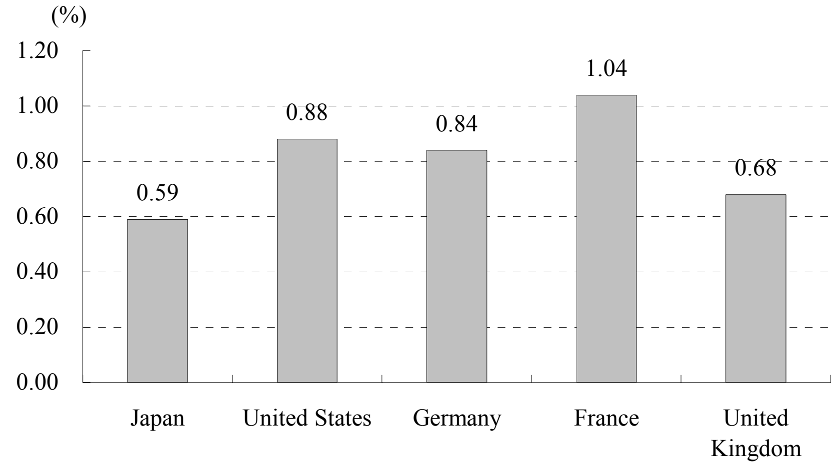


Figure 1-2-27 Percentage of R&D Funds to GDP (1994)

Source: Japan: Statistics Bureau, MIC, “Survey of Research and Development”;
United States: National Science Foundation, “National Patterns of R&D Resources”;
Germany: Federal Ministry of Education and Research, “Bundesbericht Forschung,” “Faktenbericht Forschung”;
France: “Project de Loi de Finance: Rapport Annexe sur l’Etat de la Recherche et du Development Technologique”;
United Kingdom: Office for National Statistics, “Gross Domestic Expenditure on Research and Development”

(Significance of the Science and Technology Basic Law)

The Science and Technology Basic Law indicates policies for the promotion of science and technology including harmonized development among basic research, applied research, and development research, and clearly states that the nation and local governments are responsible for actively promoting science and technology. In addition, it provides that the government should formulate a Science and Technology Basic Plan in order to comprehensively and systematically implement policies. Furthermore, it lists measures that should be implemented by the government, such as improving and securing researchers. In this manner, the Science and Technology Basic Law indicated a path for establishing the necessary research environment for the development of science and technology, and put forward the country’s basic attitude toward becoming an advanced science-and technology-oriented nation in Japan and overseas. The significance of establishing this law as a basic law instead of a mere promotion law was in declaring the direction for future promotion of science and technology and attempting to achieve a national consensus on the promotion of science and technology.

Outline of the Science and Technology Basic Law
- Guidelines for promotion of science and technology (Article 2)
- Responsibilities of the nation and local governments (Articles 3 and 4)
- Formulation of a Science and Technology Basic Plan (Article 9)
- Measures that should be taken by the nation (securing researchers, improvement of facilities, promotion of information intensive R&D, promotion of international exchanges, and promotion of learning on science and technology; Articles 10 to 19)

1.2.3.2 Formulation of the First and Second Science and Technology Basic Plans

(First Science and Technology Basic Plan)

In the year following the promulgation of the Science and Technology Basic Law, a Science and Technology Basic Plan was formulated in order to give shape to the principles of the law and systematically promote measures for promoting science and technology. The first key point of the First Science and Technology Basic Plan was institutional reform toward building a new R&D system, which was aimed at achieving a flexible, competitive, and open research environment. The specific measures included an increase of mobility of researchers through introduction of a tenure system for the researchers of national research institutes, the fostering and securing of researchers through accomplishment of the "Program to Support 10,000 Postdoctorals," promotion of coordination between industry, academia and government, encouraging acceptance of non-Japanese researchers, and impartial evaluation of researchers. The second point was an increase in government investment in R&D, which was the most important target of the Science and Technology Basic Plan. The plan required the doubling of government investment in R&D during the Basic Plan period with an aim of raising its percentage to GDP to match the level of major western countries by the beginning of the 21st century. The total expenditures related to science and technology that were to be required during the Basic Plan period to this end were 17 trillion yen. In addition, in order to establish desirable R&D infrastructure, the need for systematic improvement of facilities that are expected to become aged was pointed out.

Key Points of the First Science and Technology Basic Plan
- Promotion of institutional reform for building a new R&D system
  (Introduction of a tenure system, accomplishment of the "Program to Support 10,000 Postdoctorals," promotion of coordination between industry, academia and government, etc.)
- Increase in government investment in R&D
  (Overall amount of expenditures related to science and technology during the Basic Plan period: 17 trillion yen)

(Second Science and Technology Basic Plan)

The First Science and Technology Basic Plan achieved success in the areas of accomplishing the "Program to Support 10,000 Postdoctorals" and achieving a sum exceeding the 17 trillion yen, which had been indicated to be the necessary amount of expenditures related to science and technology, as government investment in R&D. The Second Science and Technology Basic Plan, which was formulated in 2001, indicated the following three goals for the future of Japan, while presenting a vision for the 21st century: "a nationcontributing to the world by creation and utilization of scientific knowledge," "a nation with international competitiveness and ability for sustainable development," and "a nation securing safety and quality of life." In order to attain these goals, the Basic Plan set up targets including efforts to increase government investment in

R&D to 24 trillion yen[2] so as to match the level of major western countries, achieve closer coordination between industry, academia and government, double the competitive funds in order to foster a competitive environment, and resolve the aging and overcrowding of university facilities and equipment. Furthermore, for making selective and intensive fund injections, "life sciences," "information and telecommunications," "environmental sciences," and "nanotechnology and materials" were chosen as the four priority fields that Japan should promote from the view-points of creating knowledge that will give rise to new development, achieving sustainable growth in the world market, improving industrial technical abilities, generating new industries and employment, improving people's health and the quality of life, ensuring national security, and preventing disasters.

Key points of the Second Science and Technology Basic Plan

- Indication of a clear vision of Japan
- Raising the total government investment in R&D to 24 trillion yen[3]
- Strategic priority setting in science and technology
  (Promotion of basic research, prioritization of R&D on national/social subjects, and focus on emerging fields)
- Reform of the science and technology system
  (Establishment of a competitive R&D environment, improving mobilization of researchers, improving self-reliance of young researchers, reform of evaluation systems, reform of coordination between industry, academia and government, development of environment for promoting science and technology in the region, human resources development and reform of universities, establishment of interactive channels between science and technology and society, and maintenance of infrastructure such as improving facilities of universities, etc.)

(Establishment of the Council for Science and Technology Policy and changes in the framework for promoting science and technology)

During the period of the First Science and Technology Basic Plan, there were great changes in the framework for promoting science and technology policy. In January 2001, the "Council for Science and Technology Policy" was established in the Cabinet Office as part of the central government reform. While the former Council for Science and Technology Policy only held a meeting once a year, the new Council for Science and Technology Policy holds a meeting once a month always with the participation of Prime Minister, and holds discussions among experts and bureaucrats. Specifically, the council plans and totally coordinates basic policies, and makes deliberation and evaluation of the direction for allocation of resources, such as budget. In addition, the national framework for administration of science and technology was restructured, such as the consolidation of the Ministry of Education, Science, Sports and Culture and the Science and Technology Agency into the Ministry of Education, Culture, Sports, Science and Technology (MEXT) for promoting science and technology policies and academic policies in an integrated manner. At the same time, in order to make national experimental and research institutes and national universities more diverse and unique by putting them in a more competitive environment, there was also a major change in the status of public research institutes and universities, such as a measure to turn national experimental and research institutes into independent administrative institutions (starting in fiscal 2001) and incorporating national universities (fiscal 2004).

2 The percentage of government investment in R&D to GDP during the Basic Plan period is premised to be 1%, and the nominal GDP growth during the same period to be 3.5%.
3 The percentage of government investment in R&D to GDP during the Basic Plan period is premised to be 1%, and the nominal GDP growth during the same period to be 3.5%.

1.2.3.3 Status of Accomplishment of the First and Second Science and Technology Basic Plans

(Transition and prioritization of government investment in R&D)

Although the financial circumstances had been severe and the budget for general expenditures had been cut or has remained at the same level throughout the periods for the First and Second Science and Technology Basic Plans, national expenditures related to science and technology steadily increased. The total science and technology related expenditures during the First Basic Plan period was 17.6 trillion yen, and during the Second Basic Plan, including local budgets, reached 21.1 trillion yen (until the initial budget for fiscal 2005) (Figure 1-2-28).

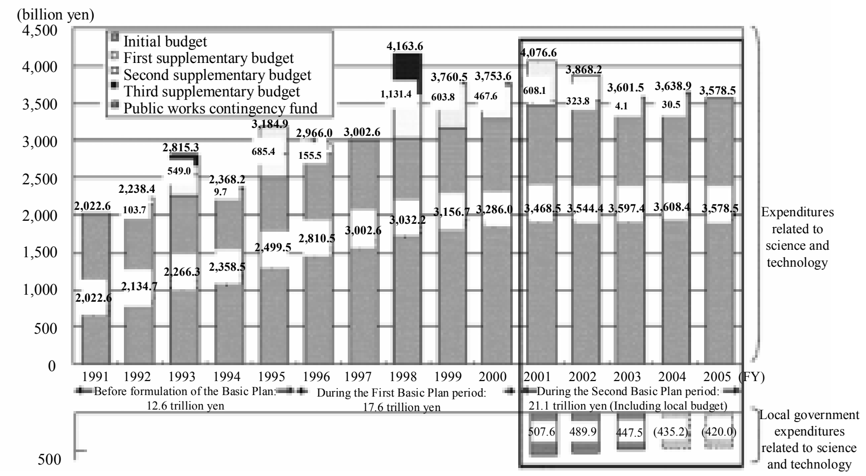


Figure 1-2-28 Expenditures Related to Science and Technology (on a Budget Basis)

Notes: 1. Initial budget for fiscal 2005 is a preliminary value.
2. Figure includes `local government expenditures related to science and technology (the values for fiscal 2004 and 2005 are estimated values).
3. Of the expenditures related to science and technology for 2004 onward, those related to national university corporations etc. are calculated based on the total sum of the operation subsidy and the subsidy for construction of facilities, which are national expenditures, and the corporation's own income (hospital income, tuition fees, amount received for entrusted projects). (This sum corresponds to the expenditures related to science and technology in the Special Account for National Educational Institutions before the incorporation of national universities, etc.)

Source: Surveyed by MEXT

According to an analysis by NISTEP,[4] the proportion of basic research in the research related expenditures increased during these periods from the five-year average of 33.8% prior to the formulation of the First Science and Technology Plan (pre-first period), to 37.1% in the first period, and to 38.5% in the second period(until fiscal2004). In the same manner, the proportion of the fourpriority fields, namely, life sciences, information and telecommunications, environment, and nanotechnology/materials also increased from 29.1% in the pre-first period, 37.6% in the first period, and to 42.1% in the second period, indicating that emphasis was placed on these fields.

4 Calculated based on the sum of the "research expenditures" in the expenditures related to science and technology plus the amount of the basic education and research school funds that is registered as expenditures related to science and technology, which corresponds to the research expenditures of independent administrative corporations (estimated based on data before incorporation) and those of national universities (research related expenditures).

(Increase of competitive funds)

The amount of the competitive funds extended increased dramatically. In fiscal 2000, the final year of the First Basic Plan period, the amount was 296.8 billion yen, or 2.4 times the amount in fiscal 1995, and in fiscal 2005, which was the final year of the Second Basic Plan period, the amount was 467.2 billion yen, or 1.6 times the amount in fiscal 2000. These funds fostered a competitive environment at R&D sites (Figure 1-2-29).

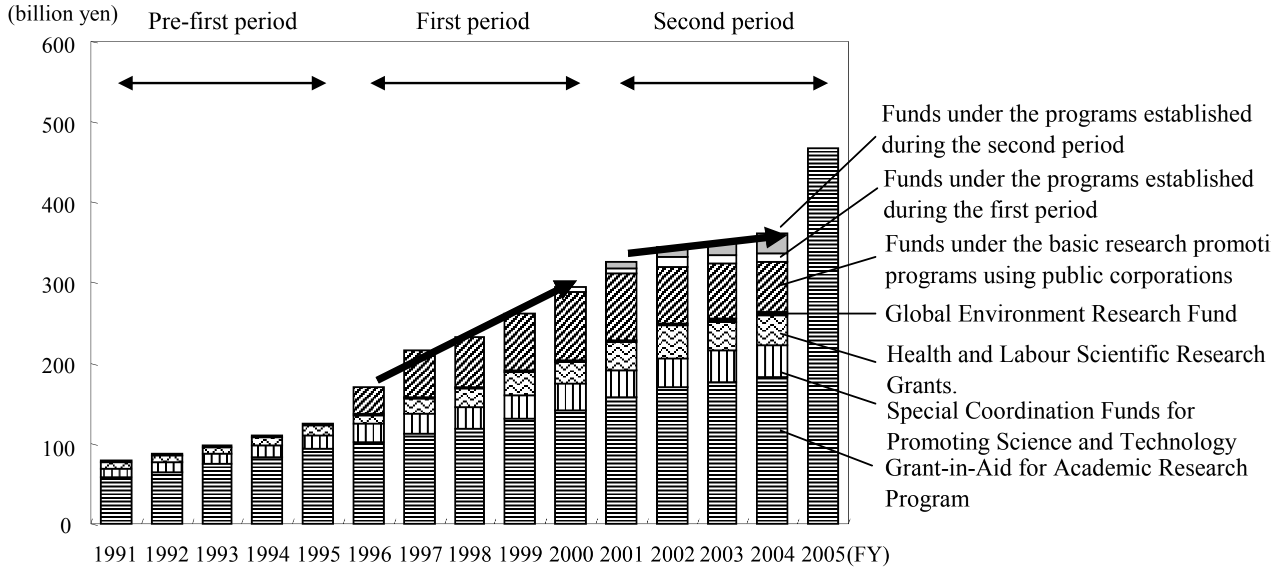


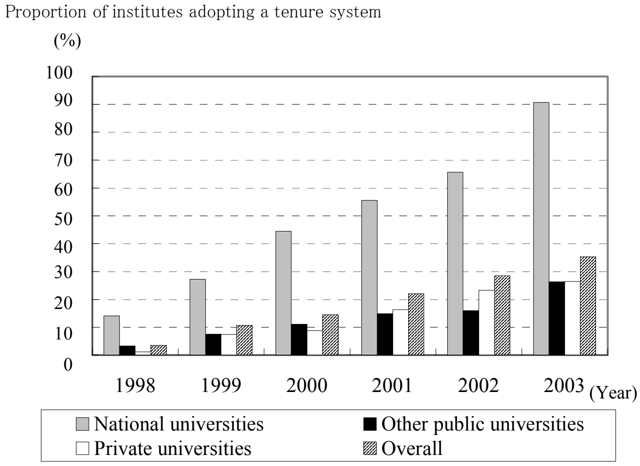
Figure 1-2-29 Budget for Competitive Funds

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Highlights -" (NISTEP Report No. 83, March 2005)

(Development and mobilization of human resources)

With regard to human resources, the "Program to Support 10,000 Postdoctorals" was set up in the First Basic Plan, and effort was made to improve the mobility of researchers and the self-reliance of young researchers throughout the First and Second Basic Plans. As a result, the number of persons subject to support under the budget, such as postdoctorals, reached 10,000 during the First Basic Plan period, and the number has stayed above 10,000 every year since 1999. However, there are also problems including the difficulty for these people to gain a desired post for lifetime employment immediately after the termination of the support period including such positions in private companies.

In the area of improving the mobility of human resources, the number of institutes adopting a tenure system for assistants to professors, who tend to be young, increased, mainly among national universities, and the proportion of assistants under a tenure system in all assistants working for universities grew to about 11% (Figure 1-2-30). On the other hand, movement of researchers between organizations is not active; in particular, movement of researchers from universities or public research institutes to private companies is rare. Thus, mobility of human resources is still insufficient (Figure 1-2-31).



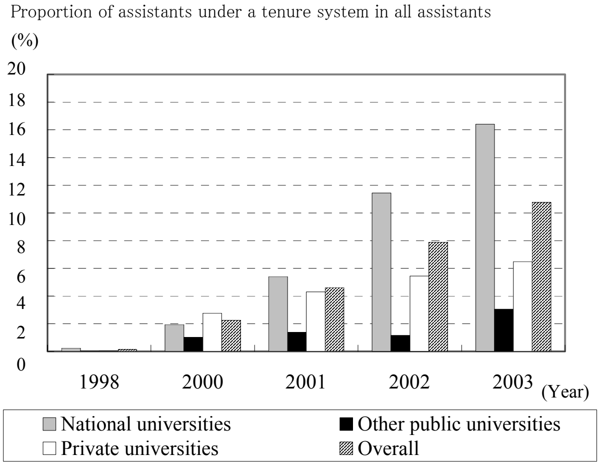


Figure 1-2-30 Introduction of a Tenure System at Universities

Notes: 1. Left graph shows the proportion of universities that adopt a tenure system in all universities in the respective years.
2. Right graph shows the proportion of assistants under a tenure system in all assistants in the respective years.
3. Graphs show the status of introduction of the system under the "Law on the Tenure System for University Instructors." Some private universities adopt a tenure system that is not based on this law.

Source: Surveyed by MEXT

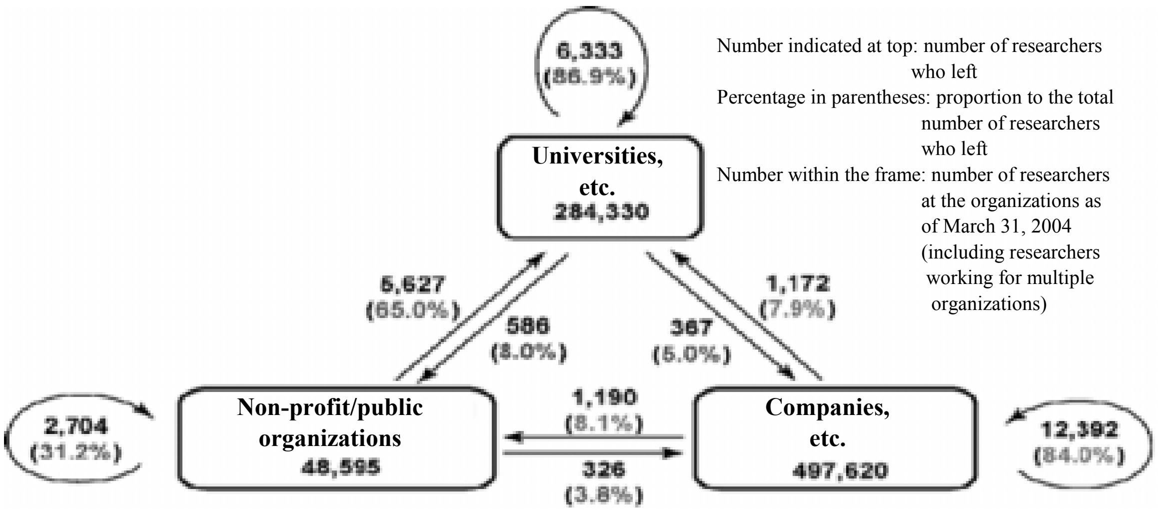


Figure 1-2-31 Mobility of Researchers Among Organizations

Note: 1. Number of researchers includes those in social sciences and humanities.
2. Chart only targets movements between organizations, and does not include movements within the same organization, such as transfer to another department of the same university.
3. Researchers include postdoctorals.
4. University researchers include students taking a doctor's course.
5. "Non-profit/public organizations" refers to national or other public research institutes, public corporations, and independent administrative institutions for the purpose of conducting experimental research or survey research.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Highlights -" (NISTEP Report No. 83, March 2005)

(Promotion of coordination between industry, academia and government)

In terms of coordination between industry, academia and government, joint research projects between national universities and private companies continued to increase as a result of various measures to improve the environment, such as development of related systems and facilities as well as deregulation. The number of such joint research projects reached a record high of 8,023 in fiscal 2003 (an 18.3% increase over the previous year), and 9,255 with those of public and private universities combined (Figure 1-2-32). Looking at the company size of the counterpart, joint research projects with small and medium-sized enterprises (SMEs), such as national universities, was 2,717, increasing by 387 projects (a 16.6% increase) over the previous year, and accounting for 33.9% of the total. This is considered to be an outcome of progress in development of the conditions for such projects and the gathering of momentum for promotion of coordination between industry and academia among both universities and companies.

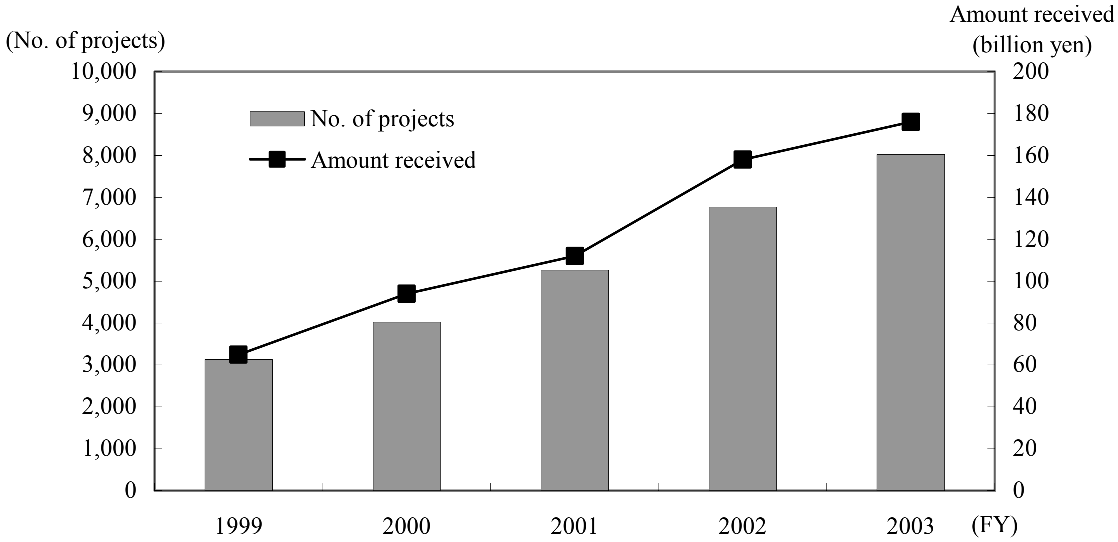


Figure 1-2-32 Joint Research Projects of National Universities, etc.

Source: MEXT, "Survey on Industry-Academia Collaboration Implemented in Universities, etc. (FY 2003)"

The number of university-launched ventures, which start up by using the "knowledge" of universities, etc. as the core of their business, is also increasing. According to a survey conducted by the University of Tsukuba from fiscal 2000 as part of the MEXT's "Model Program for Establishing a 21st Century Method for Coordination Between Industry and Academia," the number of university-launched ventures as of the end of August 2004 was 916. The number has been rapidly increasing from around 1998 when the Law Promoting Technology Transfer from Universities to Industry was enacted, and more than 100 such companies are established every year (Figure 1-2-33).

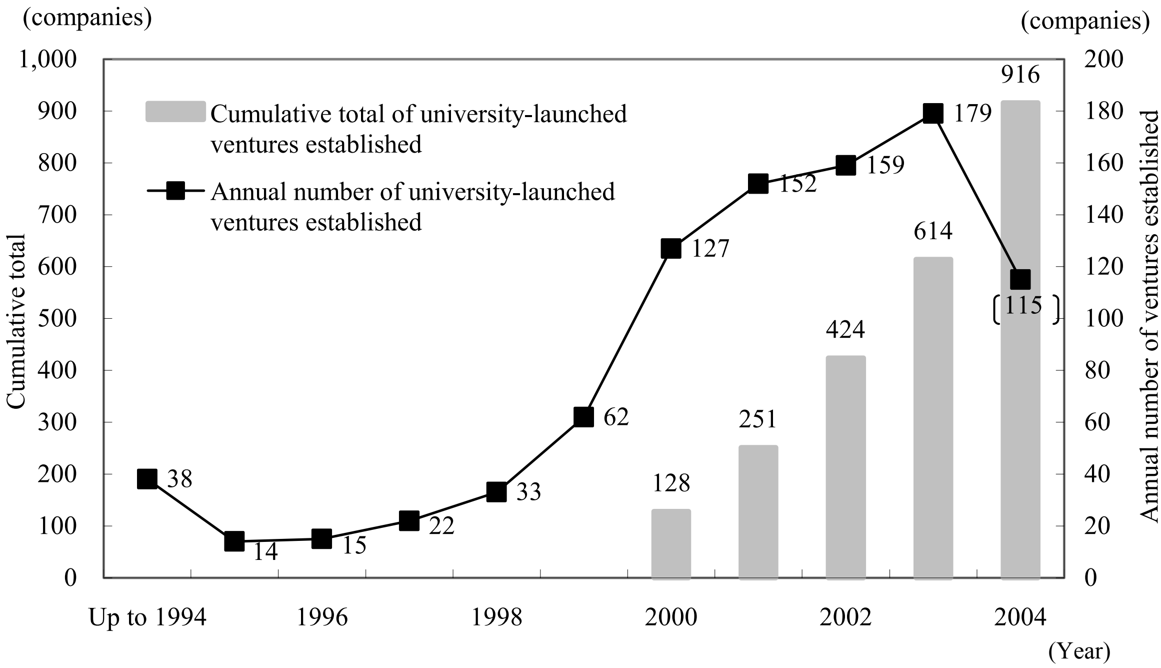


Figure 1-2-33 Number of University-Launched Ventures Established

Note: 1. "Cumulative total" indicates the number of ventures that were revealed by the survey conducted at the end of August every year, starting in 2000."Annual number of ventures established" indicates the number of ventures that were established during the period
from January to December of each year out of the 916 ventures that were revealed by the survey conducted at the end of August 2004.
2. Number of ventures established in 2004 is not the annual number, but the number as of the end of August.
Source: Surveyed by University of Tsukuba

(Promotion of science and technology in the region)

In order to promote science and technology in the region, MEXT has engaged in the "Intellectual Cluster Program" since fiscal 2002, and currently implements the program in 18 regions. In fiscal 2003, the number of patent applications filed from all regions reached about 160, while about 140 universities and about 230 companies participated in joint research projects. In addition, the Ministry of Economy, Trade and Industry (METI) has launched the "Industrial Cluster Program" since fiscal 2001, and currently implements 19 projects nationwide. Under this program, METI makes efforts to build close cooperative relationships with about 5,800 small and medium-sized local companies that are venturing into new businesses and researchers of more than 220 universities, enhance the quality and quantity of information distributed among industry, academia, and government, and support technology development that makes use of the characteristics of the region. Close coordination between these two kinds of clusters will become important in future regional development.

(Improvement of facilities)

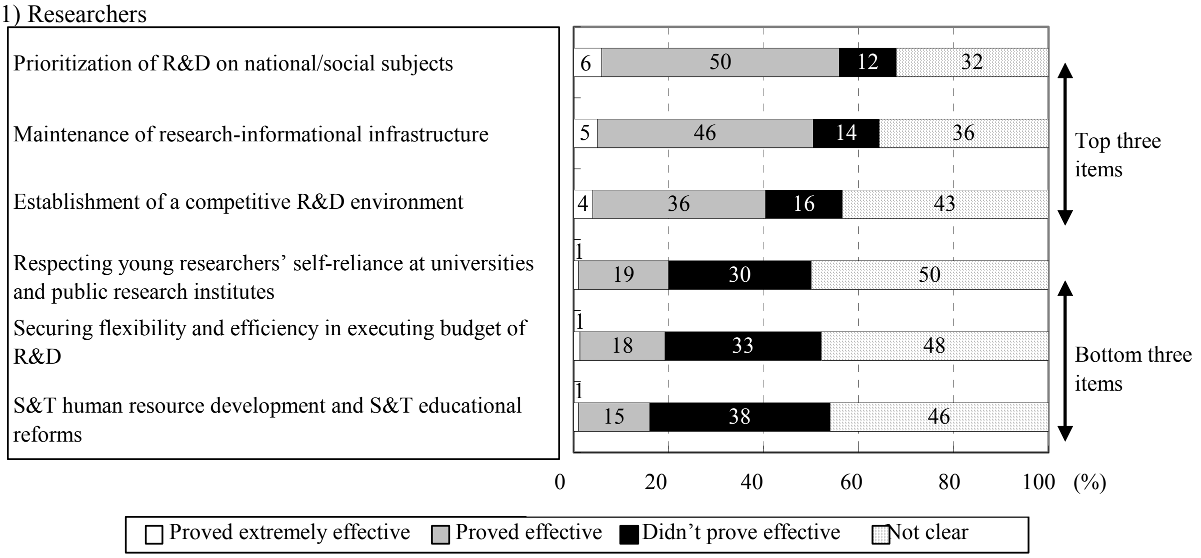
With regard to improvement of facilities, Japan had promoted a plan to improve facilities of approximately six million square meters during the Second Basic Plan period in the "Five-Year Plan for Urgent Development of the Facilities of National Universities, etc." Of this plan, improvement of facilities of graduate schools, centers of excellence (COE), and university hospitals, which was a priority target, is likely to be attained as planned with 3.73 million square meters being improved with the budget of up to fiscal 2004. However, the projects for upgrading aged facilities have only made about 50% progress at national universities. Meanwhile, the proportion of facilities that require repair or improvement at national research institutes, which once fell below the 20% recorded in fiscal 1995, increased again in fiscal 2003, so further improvement efforts are needed.

(Researchers' awareness of the Science and Technology Basic Plan)

When MEXT conducted a questionnaire survey on researchers about the abovementioned measures under the Second Basic Plan, the three items for which the most respondents answered "proved extremely effective" or "proved effective" were "prioritization of R&D on national/social subjects," "maintenance of research-informational infrastructure," and "establishment of a competitive R&D environment (an increase of competitive funds)." In contrast, the three items for which the least respondents gave such answers were "science and technology human resource development and science and technology educational reforms," "securing flexibility and efficiency in executing national budget," and "respecting young researchers' self-reliance at universities and public research institutes." The measures that should continue to be promoted were "maintenance of research-informational infrastructure," "prioritization of R&D on national/social subjects," and "an increase of government investment in R&D." These results suggest that researchers welcome the government's active investment in science and technology, and find problems in the government measures on human resources development. When the same questionnaire survey was conducted on private companies, "promoting R&D by private companies" and "reform of universities, etc. and promotion of R&D" ranked high along with "prioritization of R&D on national/social subjects," which suggests that private companies highly evaluate reform of universities. On the other hand, similar to the results for individual researchers, human resources development and flexibility in executing budget were mentioned among other items as measures that did not prove to be effective (Figure 1-2-34).

In a questionnaire survey conducted by NISTEP on the head authors of the top 10% scientific papers that were most cited by other papers (top researchers), the respondents answered that the research environment had been improved in many ways compared to before the First Basic Plan, but they had less "time for research." The most improved areas were "introduction of a tenure system for researchers at one's institute," "programs supporting coordination/technology transfers between industry, academia and government," and the "amount of competitive R&D funds provided by the government." The only worsened aspect was the "time for research," and less improved areas included the "amount of ordinary R&D funds" (Figure 1-2-35).

(1) Researchers



Note:Respondents were asked to evaluate 28 items extracted from the measures under the Second Science and Technology Basic Plan.
Source: MEXT, "Survey of the State of Japan's Research Activities (FY 2004)"

(2) Private companies

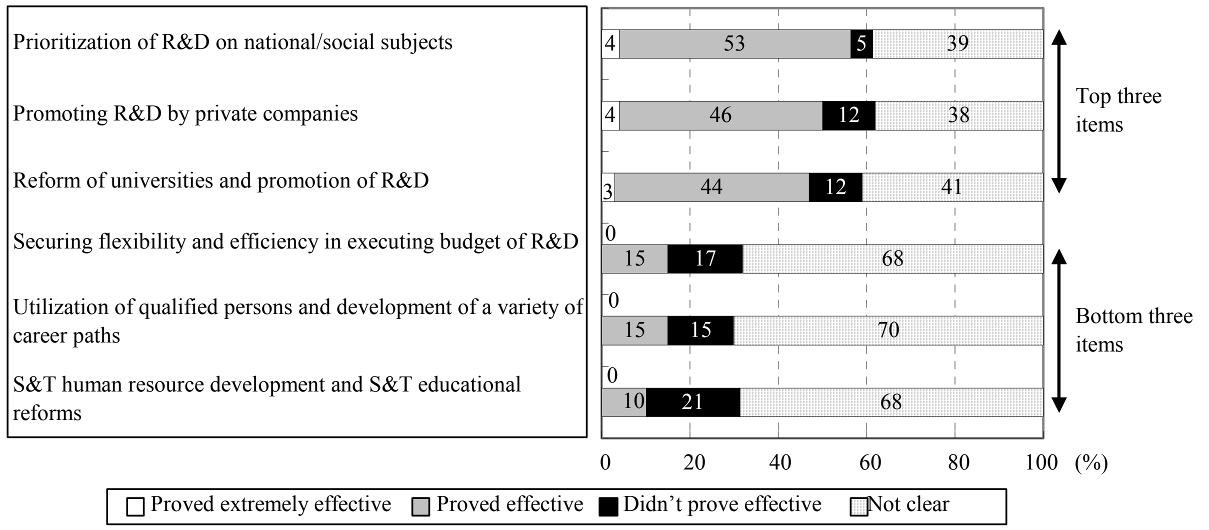


Figure 1-2-34 Measures under the Second Science and Technology Basic Plan That Proved Effective

Note:Respondents were asked to evaluate 28 items extracted from the measures under the Second Science and Technology Basic Plan.
Source: MEXT, "Survey of the State of Japan's Research Activities (FY 2004)"

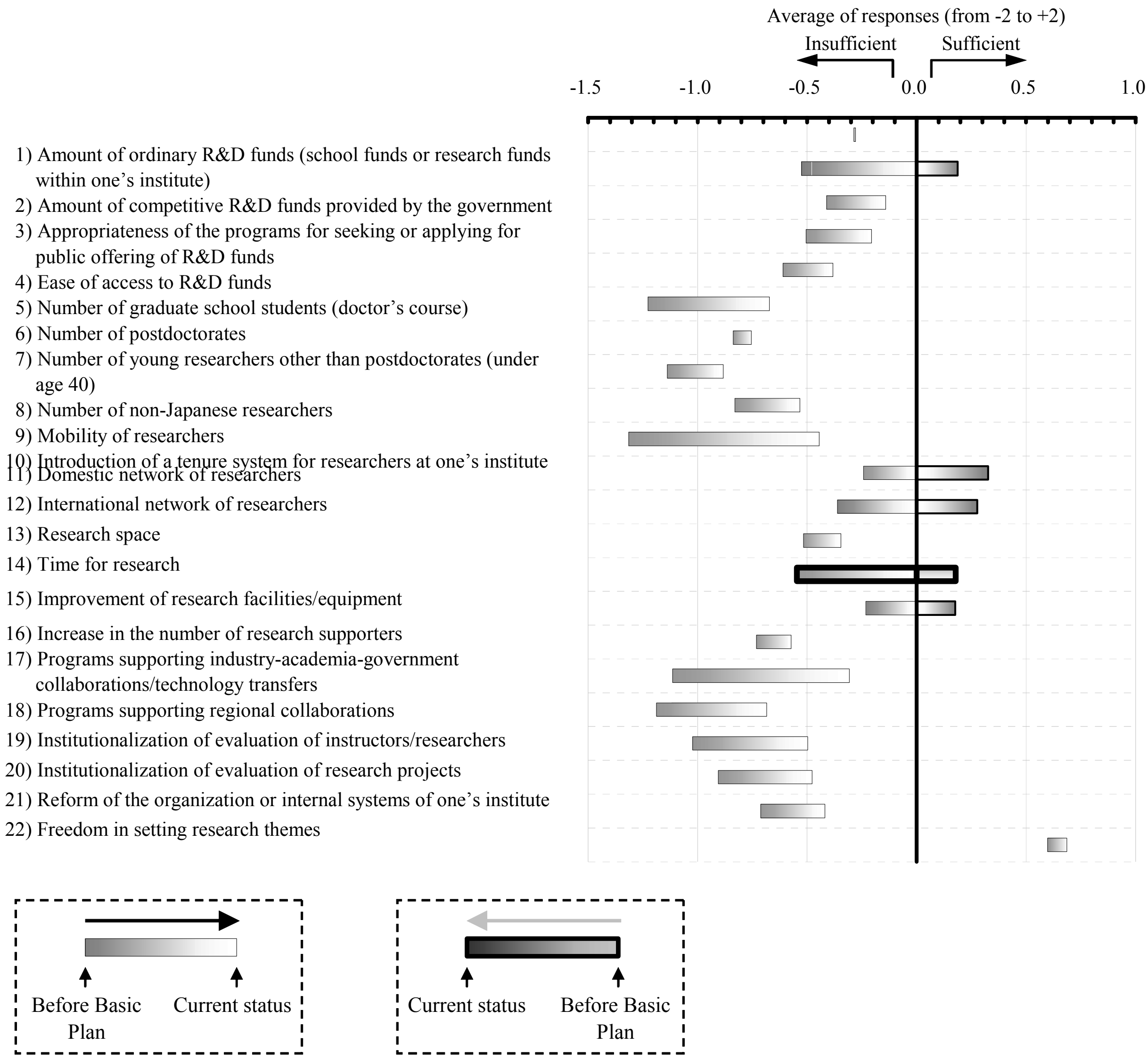


Figure 1-2-35 Changes in Research Environment Perceived by Top Researchers

Note: "Top researchers" refers to the 846 respondents of NISTEP's "Survey on the Effects of Science and Technology Policies and the R&D Level Perceived by Top Researchers (October - December 2004)," which targeted the authors of the top 10% scientific papers that were most cited by other papers based on the Science Index (2001).
Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan - Highlights -" (NISTEP Report No. 83, March 2005)

(Changes pertaining to incorporation)

When MEXT conducted a questionnaire survey on researchers about changes pertaining to the incorporation of national universities and public research institutes, both the researchers at national universities and those at public research institutes said "access to external funds such as competitive funds increased," "research for meeting industrial needs and that in priority fields came to be more emphasized," and "more active efforts are made to disseminate information such as research results" as the top three changes. On the other hand, the three items that were least mentioned as notable changes were "the time available for concentrating on research increased," "research results can be achieved in a shorter time," and "the authorities and responsibilities within the organization became clearer and correspondence with outside became easier" (Figure 1-2-36). When the same survey was conducted on private companies, the respondents made favorable evaluation of incorporation of universities and public research institutes, such as "universities and institutes came to participate in coordination between industry, academia and government as an organization," "research that meets the needs of the private sector is conducted more frequently," and "it became easier to conduct joint research and commissioned research."

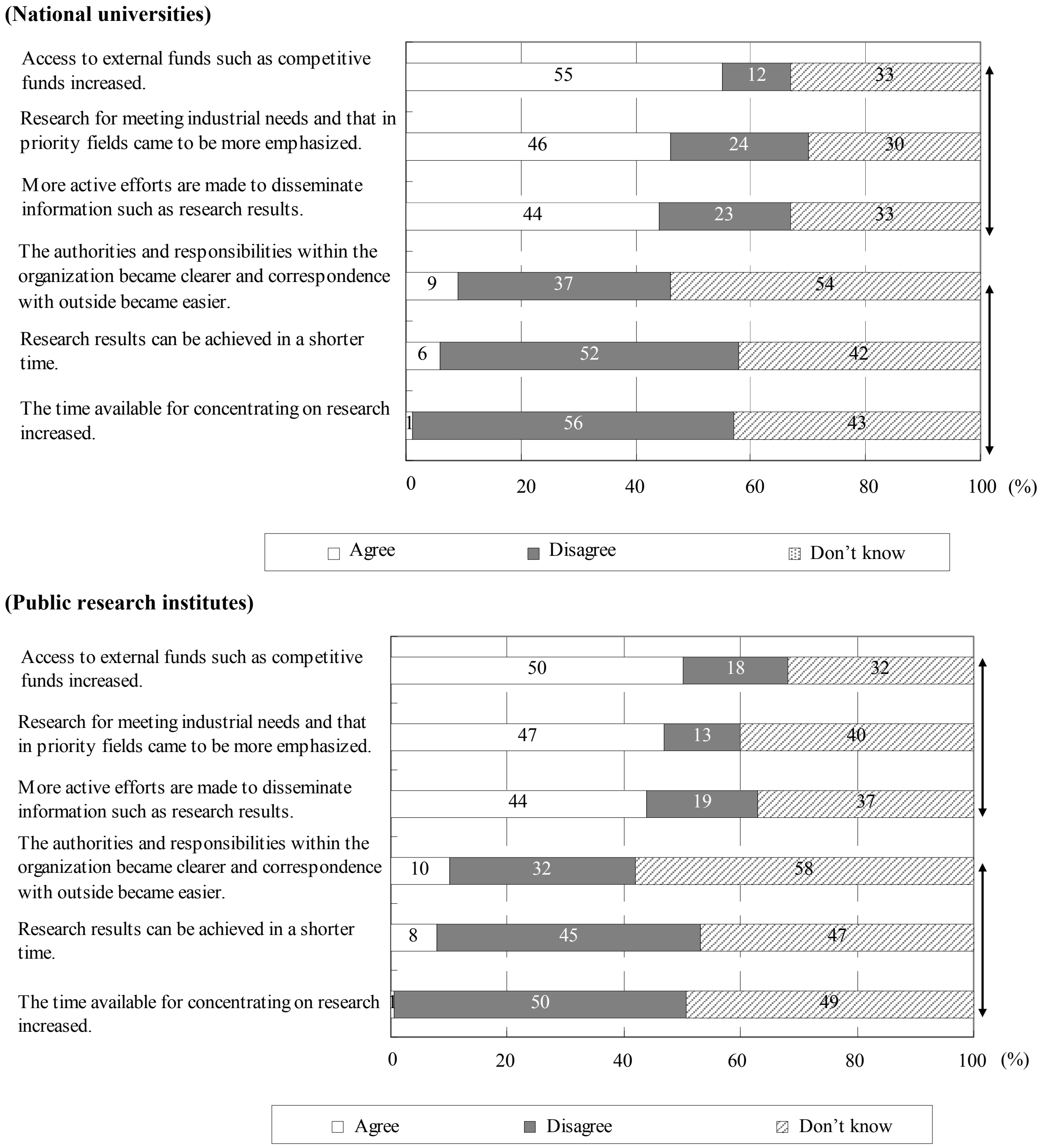


Figure 1-2-36 Changes Pertaining to Incorporation Perceived by Researchers

Source: MEXT, "Survey of the State of Japan's Research Activities"

(Achievements and challenges)

As mentioned above, various measures have been implemented based on the First and Second Science and Technology Basic Plans. In addition, there have been changes in the promoting frameworks such as the incorporation of national universities and public research institutes. As a result, considerable improvements have been made to the research environment, including more active implementation of coordination between industry, academia and government, progress in the fostering of a competitive population due to an increasein post-doctorals. As discussed in detail in the next section, the research standard is rising due to an increase in the number of influential scientific papers, and, as mentioned in 2.1, achievements and spillover effects of the measures are also appearing. At the same time, there are still challenges to be tackled. For example, Japan is still behind the United States and other countries in the area of full-fledged joint research and technology transfer among industry, academia, and government, there is still a need to improve the self-reliance of young researchers, and the efforts to secure diverse human resources including females and non-Japanese are not necessarily sufficient.

1.2.4 Level of Science and Technology in Japan

This section discusses Japan's international level of science and technology as well as its strong and weak points, while introducing the international situation surrounding science and technology and the trend of the relevant policies of other countries.

1.2.4.1 International Trend and Foreign Countries' Policies Concerning Science and Technology

(Worldwide trend toward a knowledge-based society)

In Japan, measures for promotion of science and technology have been further strengthened after the enactment of the Science and Technology Basic Law in 1995. However, due to the world's shift to being a knowledge-based society, other countries are also recognizing the importance of the role of science and technology and holding increasing expectations for contributions of science and technology.

Looking at the trend of research and development (R&D) expenditures in major countries,[5] the increase in the R&D expenditures temporarily slowed down in western countries and Japan in the first half of the 1990s, immediately after the end of the Cold War. However, in the second half of the 1990s, investment in R&D activities became active again with expenditures starting to increase rapidly first in Japan and the United States, and expenditures also turning to an increase a little later in Germany and the United King dom (Figure 1-2-37).

Furthermore, the growth in R&D expenditures and the number of researchers in China and South Korea has also been remarkable in recent years. In 2001, China became the world's third-ranking country following Japan in terms of R&D expenditures, surpassing Germany, while it also became the world's second-ranking country following the United States in terms of the number of researchers in 2000, overtaking Japan. R&D expenditures and the number of researchers in South Korea are still far from the levels in the United States and Japan, but are becoming closer to the level in the United Kingdom and France (Figure 1-2-37 and Figure 1-2-38).

In this manner, knowledge competition worldwide, including China, South Korea, and other Asian countries in addition to conventional western developed countries and Japan, is becoming more and more intense.

5 In this section, major countries refer to the United States, Germany, France, the United Kingdom, EU, China, South Korea, and Japan unless otherwise specified.

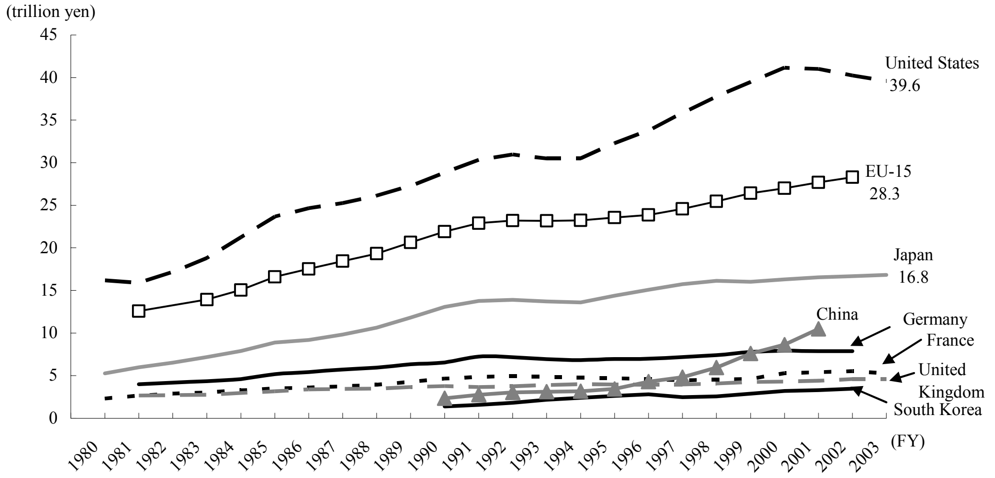


Figure 1-2-37 Total R&D Expenditures in Major Countries

Notes: 1. Values are converted in yen based on OECD's purchasing power parity rates.
2. Values for all countries include those of social sciences and humanities in order to make international comparison.
3. With regard to the values for Japan, the industries covered by the survey were expanded in fiscal 1996 and fiscal 2001.
4. Values for the United States from 2002 onward and values for France in fiscal 2003 are provisional ones.
5. Values for EU are OECD estimates.

Sources: Japan: Statistics Bureau, MIC, "Survey of Research and Development";
United States: National Science Foundation, "National Patterns of R&D Resources";
Germany: Federal Ministry of Education and Research, "Bundesbericht Forschung," "Faktenbericht Forschung";
France: "Project de Loi de Finance: Rapport Annexe sur l'Etat de la Recherche et du Development Technologique";
United Kingdom: Office for National Statistics, "Gross Domestic Expenditure on Research and Development"; however, values for 1983 and earlier are based on OECD, "Main Science and Technology Indicators"
EU-15, China, and South Korea: OECD, "Main Science and Technology Indicators"

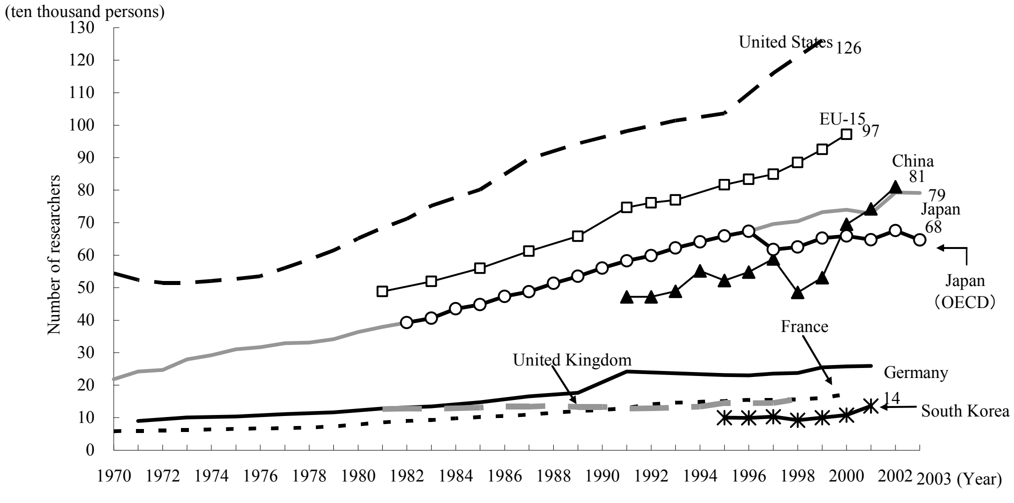


Figure 1-2-38 Number of Researchers in Major Countries

Note: Values for "Japan (OECD)" are those reported to the OECD. Full-time equivalent values (when a person working eight hours a day spends four hours in research activities, this person is counted as a 0.5 [four hours/eight hours] researcher) have been reported from 1997 onward.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP Report No. 88, March 2005)

(Positioning of science and technology policy)

Due to these circumstances, promotion of science and technology is being positioned as one of the government's important issues in all of the countries.

At the Meeting of the OECD Committee for Scientific and Technological Policy (CSTP) at Ministerial Level in January 2004, the ministers of the member countries highlighted the benefits that society can derive from advances in science and technology, and they reaffirmed that knowledge creation and diffusion are increasingly important drivers of innovation, sustainable economic growth, and social well-being.

The positioning of science and technology policy and efforts for individual key policy issues in the major countries are summarized in Table 1-2-39.

The table shows that scientific and technological progress is regarded as a driving force for economic growth and creation of employment in all countries. For example, in the Unite States, the awareness that investment in science and technology is the key to eternal development of the country's industry and economy and is important for national security has become widely established, as symbolized by the words "Science—The Endless Frontier" in the 1945 Bush Report, which has been the undertone of U.S. science and technology policies after World War II. In the EU, the Lisbon Strategy (2000), which is a comprehensive social and economic policy until 2010, has set targets including making the EU "the most dynamic and competitive knowledge-based economy" and measures to promote science and technology, such as creation of the European Research Area, are indicated as important measures for achieving these targets.

One of the factors underlying this situation is the worldwide awareness that the proportion of economic activities based on advanced scientific and technological knowledge is increasing in the economy of developed countries and that this tendency will become even stronger in the future; in other words, it will be the time for a knowledge-based economy in the not-so-distant future.

In reality, the amount of real value added in the high and medium-high-technology manufacturing industries is considerably increasing in developed countries including Japan, according to OECD statistics. This trend also applies to post and telecommunications industries and finance/insurance industries, which are referred to as knowledge-intensive "market" services (Figure 1-2-40).

The science and technology policies of the respective countries are not only intended for economic purposes, but are positioned as means for resolving wide-ranging social problems, such as improving the quality of people's lives, maintaining and promoting health, conserving the environment, as well as ensuring safety and security, which have particularly drawn attention in recent years.

For example, Germany implements the "FUTUR" program, which predicts the social changes and new social demands in the future and explores the science and technology required to deal with these predicted developments through dialogue among not only researchers, but also people from the industrial sector and various social and political segments. As its first step, visions including "lifelong health and vitality through prevention" and "living in a network world: individual and secure" were adopted in July 2002, and they have been put into practice as policies.

	Japan	United States	EU-25	United Kingdom
Positioning of science and technology; basic principles of science and technology policy	- Creation of wisdom - Vitality from wisdom - Sophisticated society by wisdom (Second Science and Technology Basic Plan)	- Promotion of people's health - Economic development - National security (Bush Report)	- Strengthening the scientific and technological base of industries - Strengthening - Promotion of necessary research activities for other various measures (Treaty of Nice) Creation of the European Research Area toward making the EU "the most dynamic and competitive knowledge-based economy" (Lisbon Strategy)	- Creation of wealth and improvement of productivity - Improvement of people's health, environment, and quality of living (Science Budget 2003-2004 to 2005-2006)
Basic law; basic plan	- Science and Technology Basic Law (1995) - Second Science and Technology Basic Plan (FY 2001-2005)	None	Sixth Framework Program (2002-2006)	Science and Innovation Investment Framework (2004-2014)
Quantitative targets concerning amount of R&D investment	Total government investment in R&D during the Basic Plan period: 24 trillion yen*1	- Doubling the budget for the National Institutes of Health (NIH) (FY 1998-FY 2003; already achieved) - Doubling the budget for the National Science Foundation (NSF) (FY 2002-FY 2007) - Doubling the budget for the National Nanotechnology Initiative (NNI) (FY 2005-FY 2009)	Increasing the R&D investment in entire EU to 3% of GDP (of which 2% will be private investment) by 2010	- Increasing the government research budget by an annual rate of 5.7% until FY 2007 (Office of Science and Technology and Department of Education and Employment) - Increasing the research budget for the whole country to 2.5% of the GDP by FY 2014 - Allocating about 650 million pounds to the priority fields from FY 2001 to FY 2005
Government-financed R&D expenditure proportion to GDP*2	3.4 trillion yen (0.68%) (FY2003)	10.2 trillion yen (0.81%) (FY2003)	6.7 trillion yen (0.67%) (FY2001)	1.2 trillion yen (0.59%) (FY2003)
Priority fields	Prioritization of R&D on national/social subjects (1) Life sciences (2) Information and telecommunications (3) Environmental sciences (4) Nanotechnology and materials science/technology (5) Energy (6) Manufacturing technology (7) Infrastructure (8) Frontier	(1) National security (2) Networks and information technology (3) Nanotechnology (4) Environment and energy (5) Life sciences	(1) Life sciences (2) Information society technology (3) Nanotechnlogy and nanoscience (4) Aviation and space (5) Food quality and safety (6) Sustainable development (7) Citizens and governance	(1) e-science (2) Life sciences such as genome (3) Basic technologies (nanotechnology, etc.) (4) Stem cell (5) Sustainable energy economy (6) Agricultural economy and land use (revitalization of rural areas; measures against animal diseases; food safety, etc.)
Distinctive policy or trend		Country with largest number of science and technology human resources in the world; dependence on inflow of human resources and a sense of crisis about the future	Prevention of brain drain and calling back human resources; improvement of mobility within the region (Marie Curie Action Program)	Reform of the dual funding system

	Germany	France	China	South Korea
Positioning of science and technology; basic principles of science and technology policy	Making Germany strong - economically, socially and ecologically (Aims and Tasks of the Federal Ministry of Education and Research)	- Competitive power; driving force for growth and employment - Resolution of social problems - One of the components of culture in a broad sense (Annexes to Evaluation des Voies et Moyens FY 2005)	Science and technology is the chief force of productivity (Deng Xiaoping's slogan)	Achievement of economic growth and a welfare society (Science and Technology Basic Plan)
Basic law; basic plan	None	Formulation of research basic plan and law currently under consideration	- Tenth Five-Year Plan - National Long- and Medium-Term Plan for Science and Technology Development (under formulation)	- Science and Technology Basic Law (2001) - The Long-term Vision for Science and Technology Development toward 2025 (1999) - Science and Technology Basic Plan (2002-2006)
Quantitative targets concerning amount of R&D investment	- Increasing R&D investment to 3% of GDP (of which 2% will be private investment) by 2010 - Increasing the budget for research institutes at an annual rate of 3% for a while	Increasing R&D investment to 3% of GDP (of which 2% will be private investment) by 2010	- Increasing R&D investment in the whole country to 1.5% of GDP by 2005	- Increasing R&D investment in the whole country to 80 billion dollars by 2025 - Increasing R&D investment in the whole country to 2.4 trillion won by 2025 - Making the growth in government R&D budget during the Science and Technology Basic Plan period exceed the growth rate of the overall budget
Government-financed R&D expenditure proportion to GDP*2	2.0 trillion yen (0.80%) (FY2002)	1.9 trillion yen (0.92%) (FY2003)	0.4 trillion yen (0.33%) (FY2000)	0.4 trillion yen (0.63%) (FY2003)
Priority fields	(1) Information and telecommunications (2) Biotechnology (3) Medical care and health (4) Environmentally-friendly technologies for sustainable development (5) Materials (6) Nanotechnology (7) Energy (8) Transportation and mobility (9) Aviation and space	- Life sciences - Communication and information science and technology - Human/social sciences - Energy - Transport and living environment - Space field - Global environmental science	- 863 Plan (high-tech) Biotechnology, space, information, laser, automation, energy, advanced materials, marine - 973 Plan (basic research) Genome, information science, nanoscience, environment, earth science	6T - IT (information technology) - BT (biotechnology) - NT (nanotechnology) - ST (spatial technology) - ET (environmental technology) - CT (cultural technology)
Distinctive policy or trend	- Cluster development policy through BioRegio, which developed the largest number of biotech ventures in Europe - FUTUR program, which provides society-oriented science and technology forecasts	Invitation of prominent researchers working overseas (Attractiveness of French science: "Excellent Teaching " program)	- Powerful policy to call back overseas human resources (Haigui [sea turtle] policy) - Establishment of national high-tech parks including Zhongguancun (Taimatsu plan)	Special education for gifted children at science schools for gifted children, etc.

Figure 1-2-39 Policy Trend in Major Countries

Notes: 1. Table assumes the proportion of government R&D investment to GDP during the Basic Plan period to be 1% and GDP nominal growth rate during the same period to be 3.5%.
2. Government-financed R&D expenditures and their proportion to GDP include those of local governments. Government-financed R&D expenditures were calculated in Japanese yen based on IMF rates.

Source: Produced by MEXT based on the National Institute of Science and Technology Policy, "Comparative Analysis on Science and Technology Policies and Their Achievements between Major Countries" (NISTEP REPORT, No. 91, March 2005), OECD, "Science, Technology and Industry Outlook 2004," and other materials.

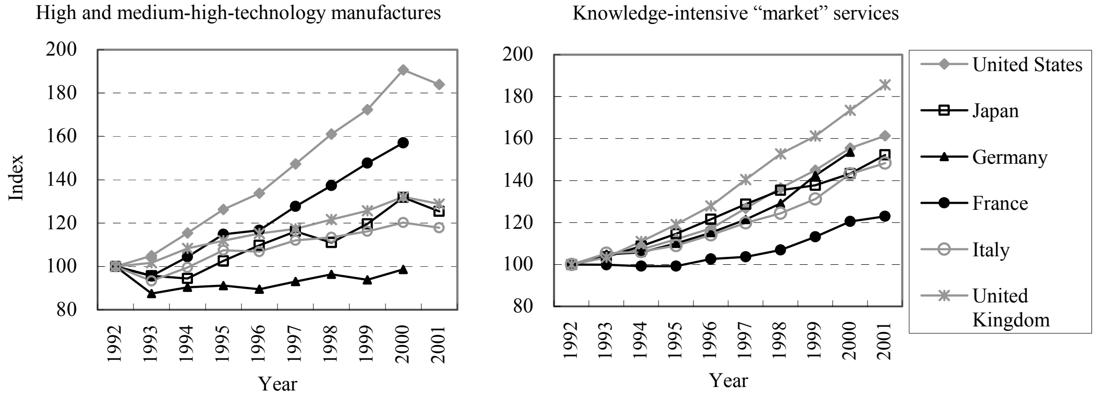


Figure 1-2-40 Real Value Added in High and Medium-High-Technology Manufactures and in Knowledge-Intensive "Market" Services (value in 1992 is indexed at 100)

Notes: 1. High-technology manufactures refer to the following five manufacturing industries in which the proportion of R&D cost in the manufacturing cost is high: aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, TV, and communications equipment; and medical, precision, and optical instruments.
2. Medium-high-technology manufactures refer to the following five manufacturing industries in which the proportion of R&D cost in the manufacturing cost is high next to such proportion in the high-technology industry: electrical machinery and apparatus; motor vehicles, trailers, and semi-trailers; chemicals excluding pharmaceuticals; railroad equipment and transport equipment; and machinery and equipment.
3. Knowledge-intensive "market" services refers to the following three service industries: post and telecommunications; finance and insurance; and business services (excluding real estate).

Source: OECD, "Science, Technology and Industry Scoreboard 2003"

(Expansion and intensification of R&D investment)

In light of the importance of science and technology, many developed countries including Japan make efforts to expand the R&D investment made by the whole nation (public and private combined) or made by the government, by setting quantitative targets.

The positioning and the compulsory nature of the targets are not necessarily the same in the respective countries. However, the EU has set a numerical target to raise the percentage of public and private investment in R&D within the region to GDP from the 1.9% in 2002 to 3% (of which about one-third is government investment) by 2010 as part of the Lisbon Strategy. In line with this, Germany, France, and the United Kingdom, which are EU members, have all set a quantitative investment target for the entire country or for the government, with an effort to expand the investment. Among major countries, the United States has no investment target for overall R&D, but has set a target for the federal government's R&D budget for specific fields and organizations, such as nanotechnology and the National Science Foundation.

At the same time, the countries make intensive investment in scientific and technological fields for which large effects can be expected for future economic growth, employment, and social benefits. Although the extent of intensification varies among countries, the priority fields of the respective countries have much in common, and not only Japan, but all the major countries categorize life sciences, information and telecommunications, and environment as priority fields. In addition, nanotechnology, energy, and space development are also specified as priority fields in most of the countries.

Some countries also make efforts to take strategic and long-term measures to build cutting-edge research facilities that engage in development of specific science and technology fields that are important for the country, apart from setting such priority fields. For example, in 2003, the U.S. Department of Energy selected large science and technology-related facilities that should be established or improved with priority over the next 20 years. In the United Kingdom also, the Office of Science and Technology formulated a strategic roadmap for development of large research facilities that cannot be established by a single organization in 2001 (revised in 2003).

(Developing and securing scientific and technological human resources)

It is predicted that the demand for scientific and technological human resources that engage in creation, diffusion, and use of knowledge will increase in line with the further shift to being a knowledge-based society. Meanwhile, a large number of scientific and technological human resources in the baby-boomer generation are expected to retire in Japan and major western countries. In consideration of these factors, the developing and securing of scientific and technological human resources has become a key, common, urgent issue for countries.

Therefore, with respect to development of domestic human resources, all countries are promoting activities for enhancing people's understanding of science and technology, reviewing science education curriculums, and improving the training programs for instructors in response to the declining interests of children and young people in science and technology. In addition, the countries are providing financial aid to young researchers including doctoral students and postdoctorals and encouraging the activities of female researchers. Also, from the viewpoint of using overseas human resources, countries make efforts to actively support the researchers of their own country who are working overseas and good overseas researchers by accepting them in their country.

(Promoting coordination between industry, academia and government)

Since promotion of economic use of scientific and technological achievements is being increasingly emphasized, it has become an important task to establish a system of intellectual cycle that links private companies, universities, and public research institutes. All the countries take measures to promote coordination between industry, academia and government. Although the details vary depending on the situation of the respective countries, they implement measures to have research achievements, which are mainly made by universities, commercialized by venture companies, etc., as well as to establish incubators and form networks or clusters to promote such commercialization.

Notable examples include the "BioRegio" in Germany, which succeeded in forming the sole bio-clusters in Europe by adopting a "contest for development of clusters" where regions compete for government funds, and China's "Torch Plan" for building high-tech parks in 53 locations nationwide including Zhongguancun in Beijing, which is referred to as the Silicon Valley of China.

[Column 17]

Intensifying International Competition for Procurement of Human Resources

In the race to gather the best human resources from around the world, the United States has recently been the clear winner. Eminent scientists from all over the world have been gathered in the United States. As of 2001, for example, at least 33% of doctorates in natural science, as well as at least 56% of doctorates in engineering presented in the United States are held by non-American citizens. Additionally, at least 28% of science/engineering doctors hired by a college or university in the United States are born outside the country. A total of 38% of doctors in science or engineering engaged in their fields except college/university instructors in the United States are born outside the country, too.

To compete with the United States, other countries have also taken various policies to promote acceptance of human resources from foreign countries.

The European Union, for attaining the goal of achieving R&D investment equivalent to 3% of GDP, is in its present state lacking 700,000 researchers, according to a trial calculation. To address this lack, the EU has been working on calling back its researchers from other countries such as the United States, while improving the mobility of human resources inside the EU. As part of the Marie Curie Action under the Sixth Framework Programme, for example, the subsidy system is enforced for eminent academics outside the EU to invite or call them back to EU member nations. The grant is given to researchers in and/or from a foreign country such as the United States, when they work on in a facility inside the EU. Furthermore, there is a grant system for researchers who are from an EU nation and working in another EU nation.

China has the next-most researchers in the world after the United States (the number of researchers in China was approximately 810,000 in 2002). The Chinese government set a target of increasing the number of scientists and engineers to 900,000 by 2005. To solve the difficult problem whereby many Chinese students studying abroad do not return to China, the government is carrying out callback policies for talented Chinese scientists working overseas. Based on the "100 People Incentive Project," for example, the Chinese government gives priority to talented young Chinese scientists working outside the country when it comes to giving grants. The researchers who return to China, who are called "turtle scientists," have been playing a major role in R&D in China.

Corresponding to the intensifying competition for procurement of human resources all over the world, the U.S. government has a sense of crisis about gathering talented people in the future. Current U.S. human resources issues include immoderate dependence on talented people from other countries, as well as the forecast that citizens born in the United States and who graduate from science and technology departments will decrease. In the National Science Board, discussions have been made to examine the measures that the federal government should take for the training and procurement of talented people in the field of science and technology.

1.2.4.2 Level of Science and Technology in Japan

(Research expenditures and number of researchers)

Japan's research expenditures have been on an increasing trend throughout the First and Second Basic Plan periods, ranking second in the world after the United States, and the percentage of research expenditures to gross domestic product (GDP) is the highest among the major countries. The government-financed R&D expenditures in major western countries had been declining for a long time since the 1980s, but began to rise again from around 2000. Meanwhile, those of Japan had been increasing since 1990, but have stayed on the same level for the past several years (Figure 1-2-41).

The growth in the number of researchers slowed down slightly in the Second Basic Plan period, but Japan ranks third among the major countries following the United States and China, and ranks highest among the major countries in terms of the number of researchers per 10,000 citizens.

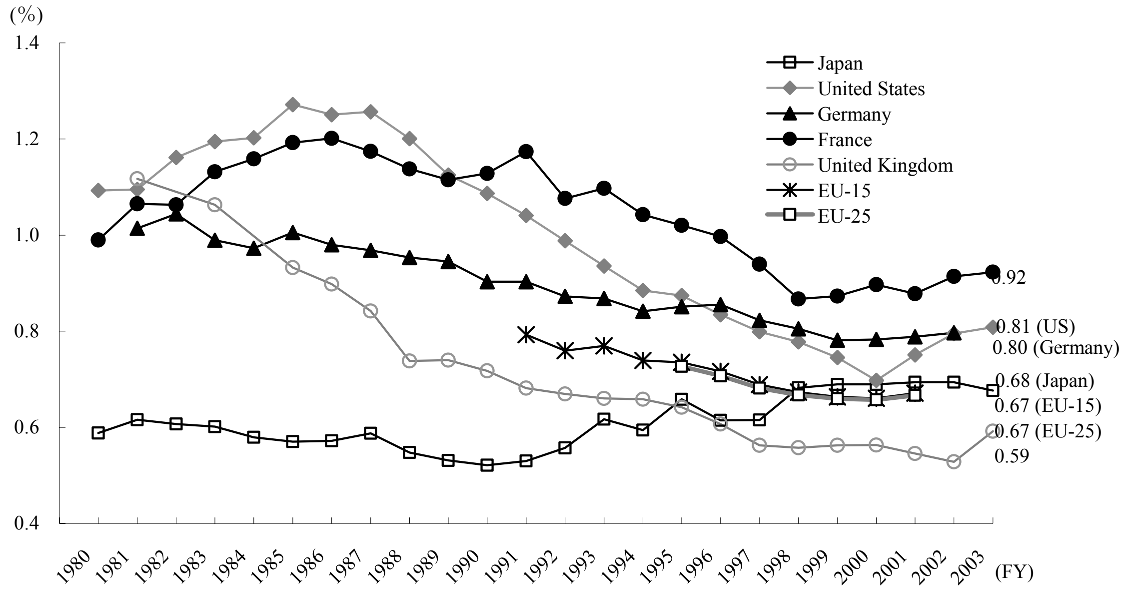


Figure 1-2-41 Trends in the Proportion of Government-Financed R&D Expenditures to GDP in Major Countries

Notes: 1. Values for all countries include those of social sciences and humanities in order to make international comparison.
2. With regard to the values for Japan, the industries covered by the survey were expanded in fiscal 1996 and fiscal 2001.
3. Values for the United States Fiscal 2003 data for Finance is provisional from 2002 onward are provisional ones.
4. Fiscal 2003 values for France are provisional ones.

Sources: Japan: Statistics Bureau, Ministry of Internal Affairs and Communication, "Survey of Research and Development"
United States: National Science Foundation, "National Patterns of R&D Resources"
Germany: Federal Ministry of Education and Research, "Bundesbericht Forschung," "Faktenbericht Forschung"
France:"Project de Loi de Finance: Rapport annexe sur l'Etat de la Recherche et du Developpment Technologique"
United Kingdom: Office for National Statistics, "Gross Domestic Expenditure on Research and Development"; however, values for 1983 and earlier are based on OECD, "Main Science and Technology Indicators"
EU: Eurostat Website databases; OECD, "Main Science and Technology Indicators"

(Scientific papers)

During the First and Second Basic Plan periods, the number of Japanese scientific papers and the frequency of their citation have steadily increased their shares (Figure 1-2-42). Although there are still large gaps with the United States and EU-15, the gap with the United States has narrowed. After the beginning of the First Basic Plan period, larger growth was observed for the share in the frequency of citation than for the share in the number of scientific papers. In particular, Japan greatly increased its share in the "top 1%" of the most frequently cited scientific papers (Figure 1-2-43), indicating an improvement in the quality of scientific papers.

Looking at the number of scientific papers by sector, the university sector accounts for the largest proportion in all countries, but the situation in Japan is characteristic in that the proportion of the industrial sector is relatively high. From 1991 to 2001, the number of scientific papers by the university sector and government research institutes increased significantly in Japan, while that by the industrial sector remained at the same level (Figure 1-2-44)

In China and South Korea, the number of scientific papers has been rapidly increasing. Although there are still gaps with Japan in terms of the absolute number of scientific papers, China ranks sixth and South Korea ranks highest in the world in terms of the increase rate.

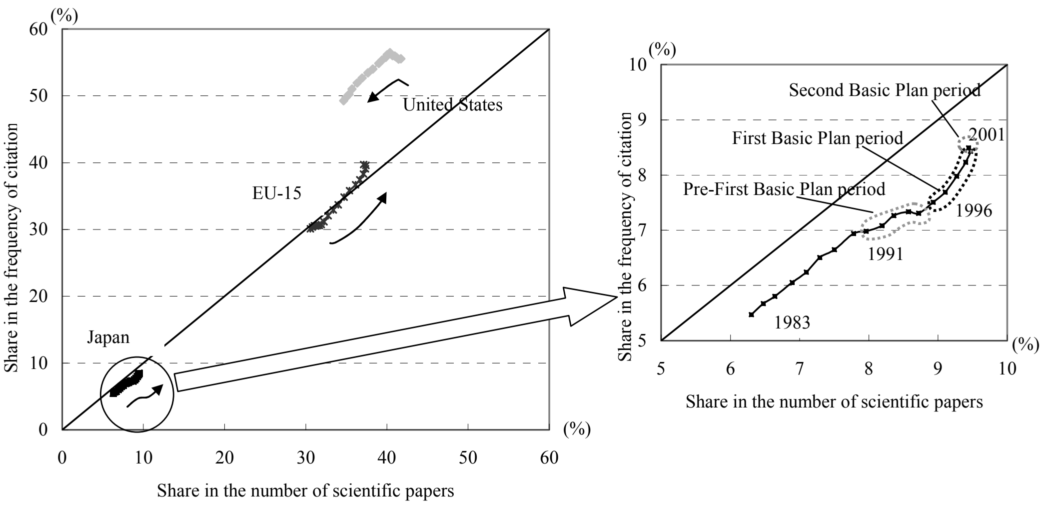


Figure 1-2-42 Shares of Japan, the United States, and EU-15 in the Number of Scientific Papers and the Frequency of Citation

Note: Value for each year is calculated based on five-year duplicated data (number of scientific papers: aggregate sum of the number of scientific papers published during five years; frequency of citation: aggregate sum of the number of times the scientific papers published during five years have been cited in another scientific paper during the same five years). The figure indicates the middle year of such five years; e.g., "1983" for a value based on five-year duplicated data for 1981-1985.

Source: National Institute of Science and Technology Policy, "Study for Evaluating the Achievements of the Science and Technology Basic Plans in Japan" (NISTEP REPORT, No. 83, March 2005)

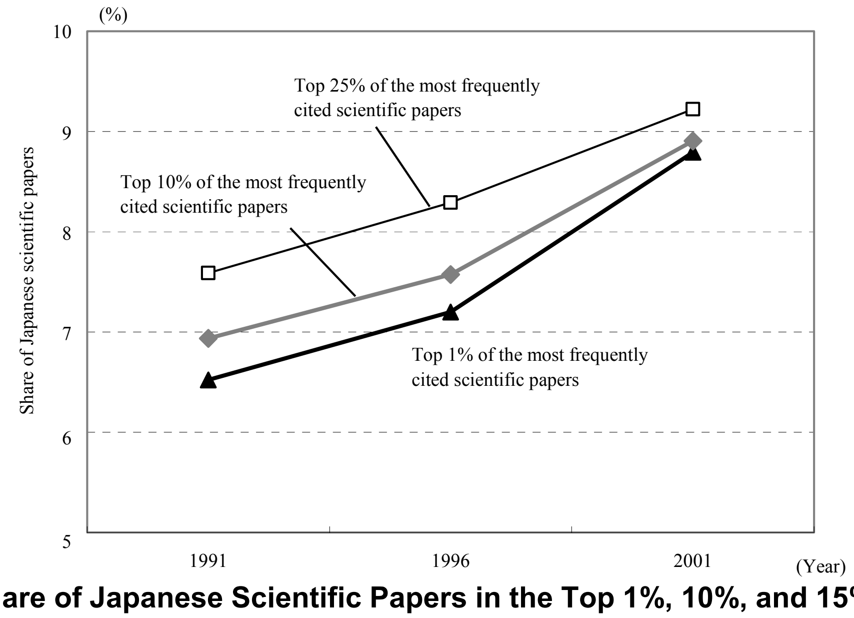


Figure 1-2-43 Share of Japanese Scientific Papers in the Top 1%, 10%, and 15% of the Most Frequently Cited Scientific Papers

Notes: 1. Frequency of citation is a value that has standardized the number of times a scientific paper was cited according to the field and the year of publication.

2. Share of Japanese scientific papers is the proportion of scientific papers in which at least one Japanese organization has participated.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

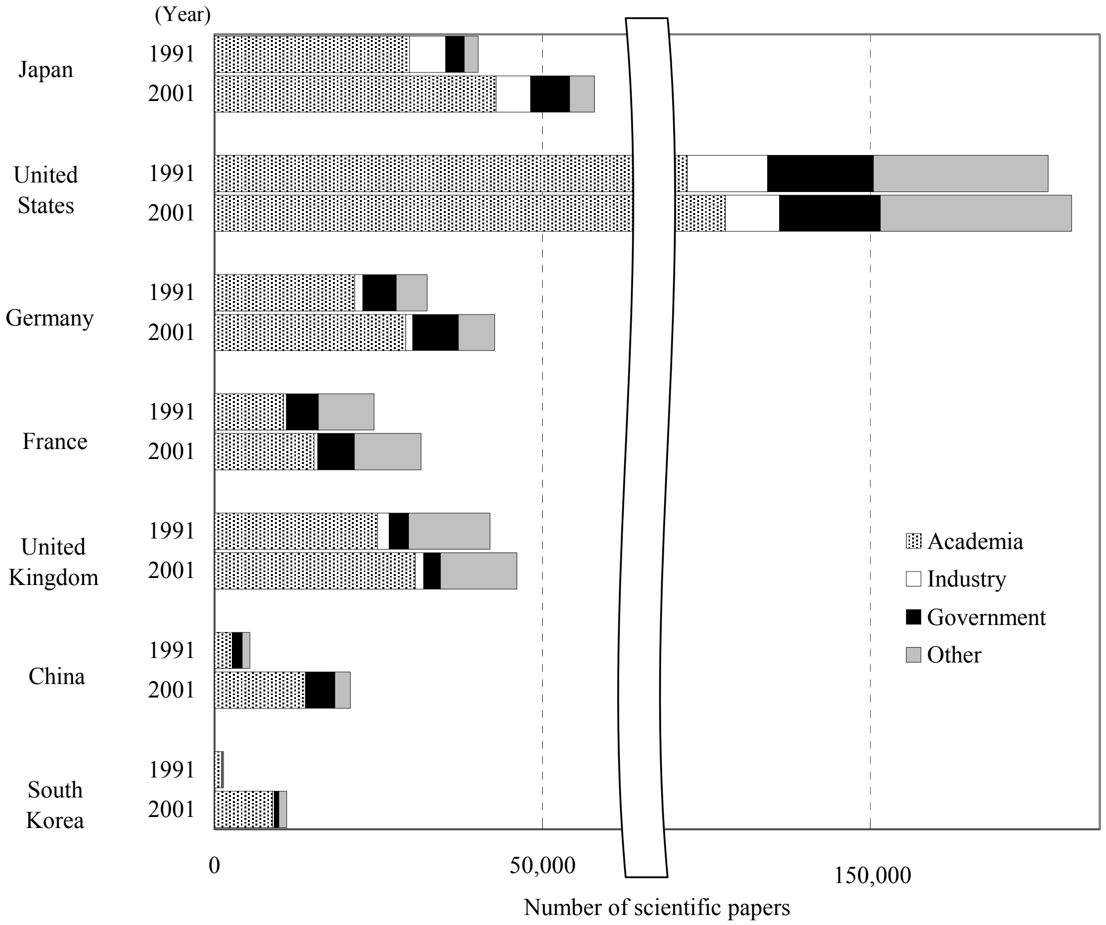


Figure 1-2-44 Number of Scientific Papers in Major Countries by Sector

Note: A co-authored paper (co-authored between different countries or co-authored between sectors) was counted by a fractional number.
Source: Produced by MEXT based on NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

(Productivity of scientific papers)

In this manner, the number of scientific papers has been steadily increasing in Japan in line with the increase in the resource input for research, such as R&D expenditures and the number of researchers. One way to examine research efficiency would be to verify the ratio of resource input to one type of output—the number of scientific papers—or in other words, the productivity of scientific papers. Considering that the productivity of scientific papers differs considerably by sector and that the systems and the statistical methods differ by country, the NISTEP compared the productivity of scientific papers at universities, which can be defined in a relatively similar manner in Japan and the United States, as follows.

Firstly, in calculating the productivity of scientific papers per R&D expenditures, there was a difference between Japanese and U.S. universities regarding the definition of research expenditures, such as treatment of the personnel cost for instructors. Thus, the productivity was estimated after adjusting the R&D expenditures in Japan in two ways to make them approach the values under the U.S. definition (Japan [U.S.-based estimation (1)] and Japan [U.S.-based estimation (2)] in Figure 1-2-45). While Japan's productivity directly obtained from the statistical values (Japan [statistical values] in Figure 1-2-45) was considerably lower than that of the United States, the values based on these estimates stayed at a certain level when the U.S. values were declining in recent years, and they were close to the U.S. values.

As for the productivity of scientific papers per researcher, the definition of researchers at universities differed between Japan and the United States, so a trial calculation was made by using the number of faculty members at universities of natural science as data that can be compared under the same conditions as much as possible. As a result, the productivity of scientific papers per faculty member at universities of natural science in Japan has continued to increase in recent years, and the gap with the United States has been narrowing to an extent that such productivity is slightly lower in Japan than in the United States (Figure 1-2-46).

In this way, there are analysis results indicating that the productivity in terms of the number of scientific papers in Japan may reach the same level as that of the United States, at least in estimate.

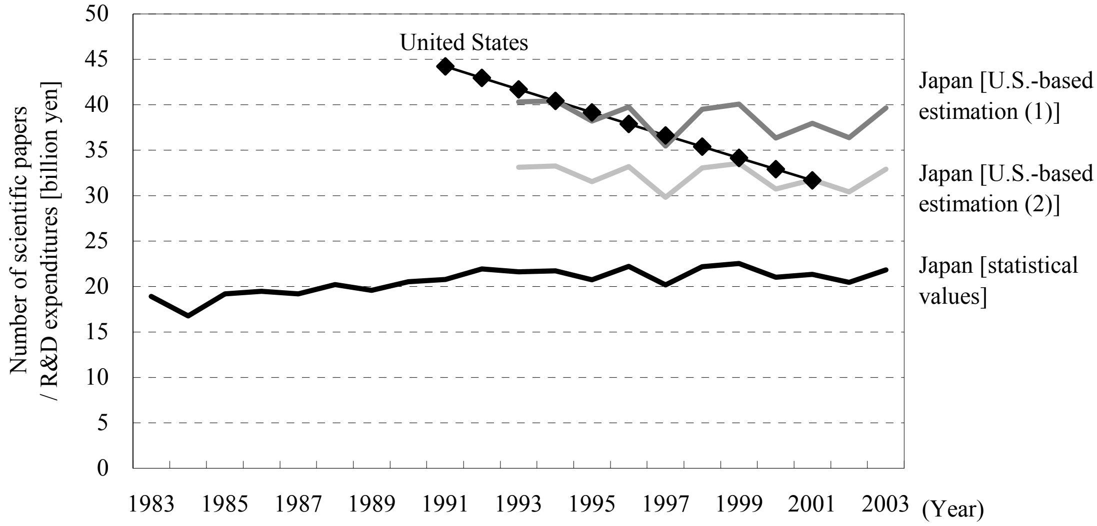


Figure 1-2-45 Japan-U.S. Comparison of the Number of Scientific Papers per R&D Expenditures of Universities (Natural Science)

Notes: 1. R&D expenditures of Japanese universities are turned into real values by using the R&D expenditure deflator (for natural science; universities) and those for U.S. universities by using the GDP deflator.
2. Period from the spending of R&D expenditures until publication of a scientific paper is deemed to be two years for both Japan and the United States (e.g., the value for “2001” on the graph was calculated based on the R&D expenditures in 1999 and the number of scientific papers in 2001).
3. In Japan [U.S.-based estimation (1)], the personnel expenditures for researchers at universities who only engage in research were first estimated, and the R&D expenditures were calculated by excluding the personnel expenditures for the other personnel (fixed personnel expenditures), in order to make the values closer to the definition of R&D expenditures in the United States. In Japan [U.S.-based estimation (2)], considering the possibility that the expenses for U.S. R&D projects may include personnel expenditures for instructors for a span of about three months, a quarter of the fixed personnel expenditures was added to the R&D expenditures of Japan [U.S.-based estimation (1)].

Source: NISTEP, “Study for Evaluating the Achievements of the S&T Basic Plans in Japan” (NISTEP REPORT No. 83, March 2005)

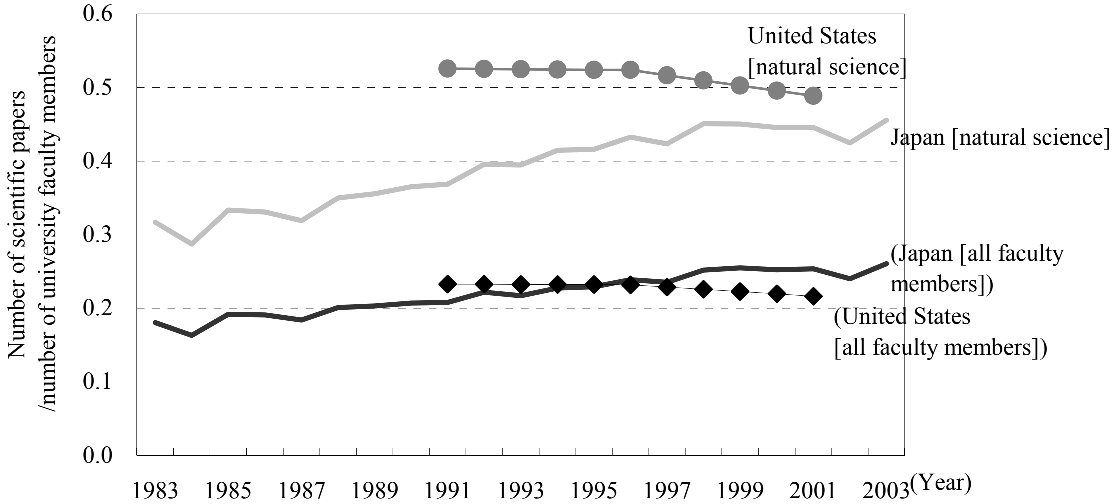


Figure 1-2-46 Japan-U.S. Comparison of the Number of Scientific Papers per University Faculty Member

Notes: 1. Number of university faculty members is based on head-count both in Japan and the United States.
2. Period from the spending of R&D expenditures until publication of a scientific paper is deemed to be two years for both Japan and the United States (e.g., the value for "2001" on the graph was calculated based on the R&D expenditures in 1999 and the number of scientific papers in 2001).
3. Since data on the proportion of university faculty members in natural science to all university faculty members for each year could not be obtained, the values for "United States [natural science]" were obtained by applying the proportion in 1992 to the other years as well.

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

(Patents)

Figure 1-2-47 shows the shares of countries in terms of the number of patent applications filed in the world. Since a patent application filed with multiple countries is counted in an overlapped manner, the graph is likely to indicate how much the patenting of technologies is being promoted in addition to the number of inventions. Although the number of patent applications has increased for Japan, its share has declined from slightly less than 30% in 1991 to a little over 10% in 2001. On the other hand, the United States and countries other than the major western countries such as China and South Korea are greatly increasing their shares (Figure 1-2-48).

Meanwhile, Figure 1-2-49 shows the relative citation impact of U.S. patents owned by patentees of the respective countries. According to this, the relative citation impact of U.S. patents owned by Japanese patentees has increased in recent years, so the quality gap with U.S. patents is narrowing.

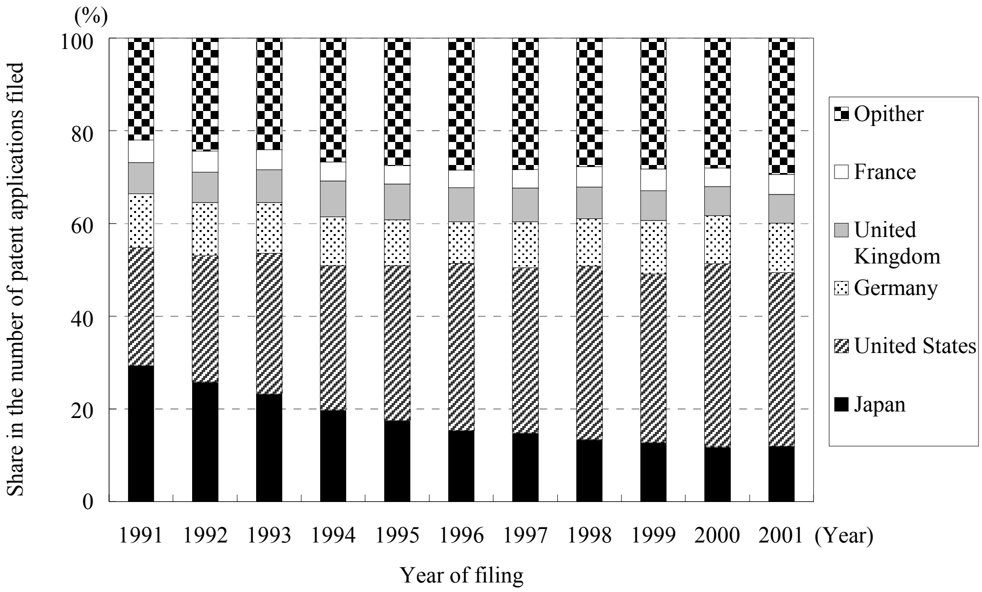


Figure 1-2-47 Shares of Major Countries in the Number of Patent Applications Filed in the World

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

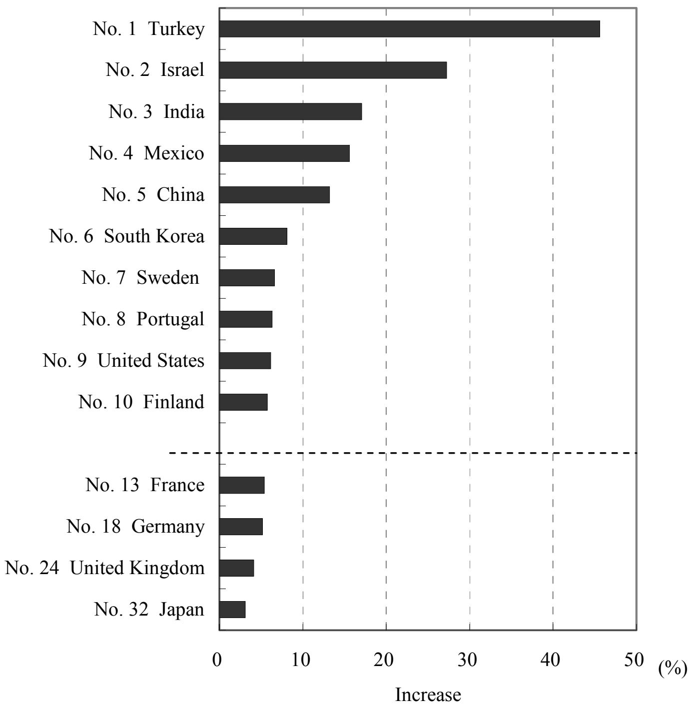


Figure 1-2-48 Increase in the Number of Patent Applications Filed in the World by Applicants of the Respective Countries (ranking of the rate of increase from 1994 to 2001)

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

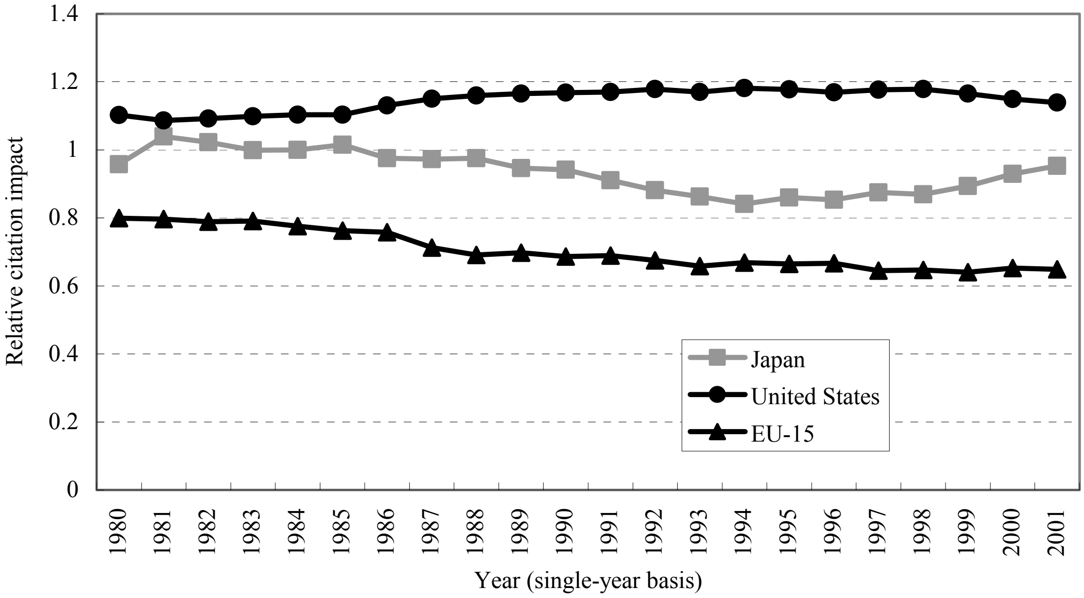


Figure 1-2-49 Relative Citation Impact of U.S. Patents Owned by Japanese, U.S.,and EU-15 Patentees

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

(Technology transfer from universities)

Technology transfer from Japanese universities to industry has made progress to a certain extent in terms of patenting and licensing, but it has yet to produce revenues such as royalties. Compared with the United States and the United Kingdom where institutional infrastructures were established 20 years earlier, real achievements have yet to be made based on organizational partnerships in Japan, where use of intellectual property had mainly relied on individual initiatives (Figure 1-2-50).

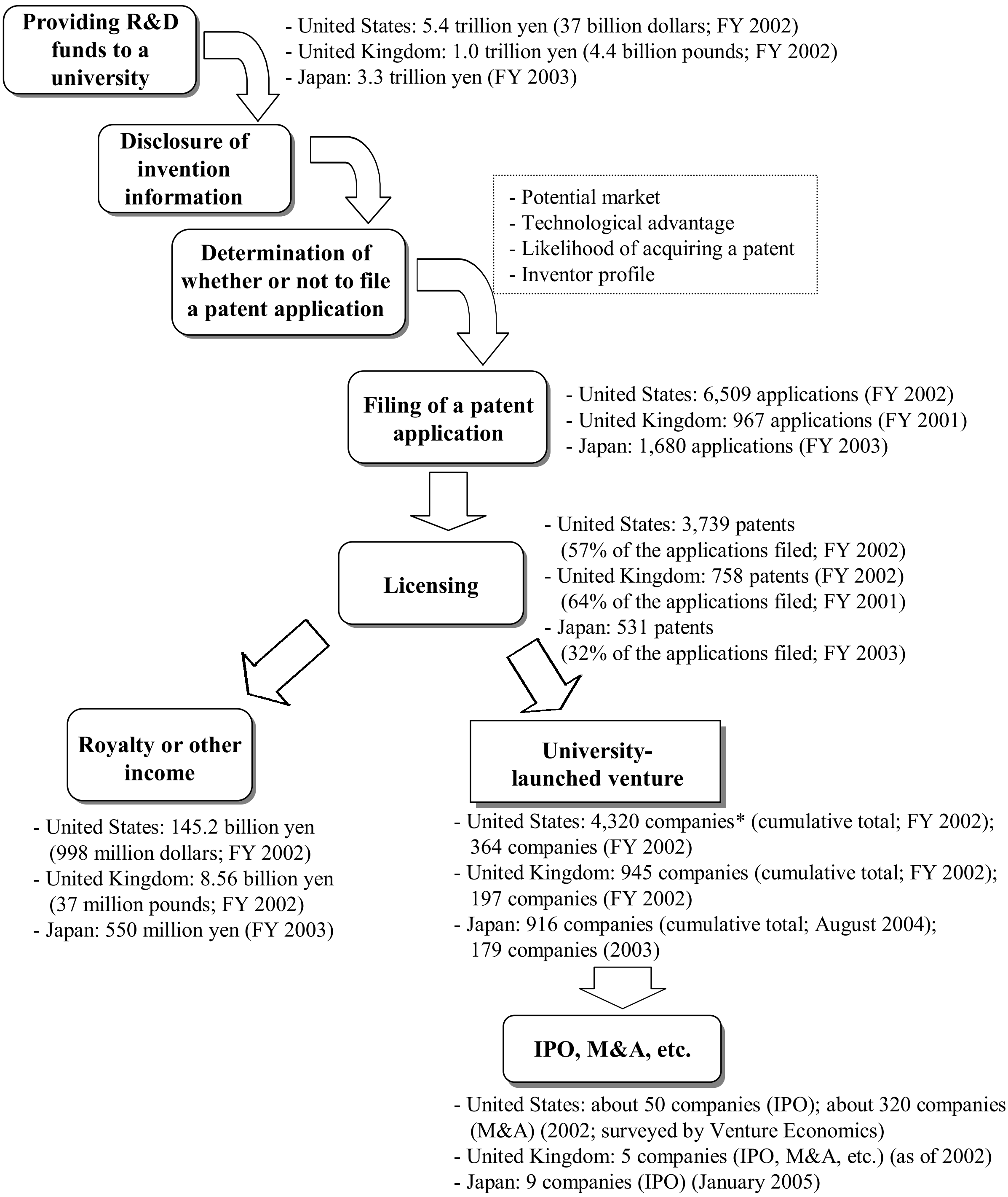


Figure 1-2-50 International Comparison of Coordination Between Industry and Academia

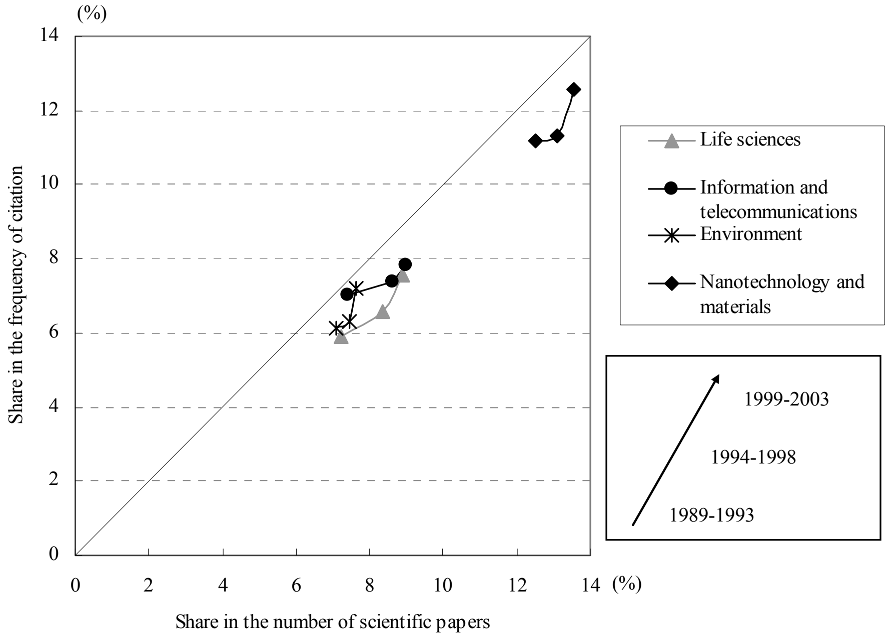
Note: "IPO, M&A, etc." indicates the number of university-launched ventures that were made subject to public offering of stock, merger, acquisition, business alliance, or the like.
Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 83, March 2005)

(Priority fields)

Figure 1-2-51 shows Japan's shares in the num ber of scientific papers and the frequency of their citation in the four priority fields under the Second Basic Plan (life sciences, information and telecommunications, environment, nanotechnology/materials) and four other fields (energy, manufacturing technology, social infrastructure, and frontier).

The graphs indicate that both the shares in the number of scientific papers and the frequency of their citation are steadily increasing in all fields. Japan is relatively strong in the fields of nanotechnology/materials, manufacturing technology, and energy, while it is relatively weak in the fields of frontier and social infrastructure compared to the other fields. The fields in which the share in the frequency of citation increased more than the share in the number of scientific papers, or in other words, the fields in which quality increased remarkably from the 1994-1998 period to the 1999-2003 period were nanotechnology/materials, manufacturing technology, energy, environment, and social infrastructure.

According to patent-related indices aggregated by NISTEP, the share of Japanese applicants in the number of U.S. patents registered in recent years has been relatively high for nanotechnology/materials and manufacturing technology, and low in social infrastructure and life sciences, though the trend of increase varies by field. Meanwhile, the relative citation impact was high for environment, social infrastructure, frontier, and energy compared to the other fields, and low for information and telecommunications, and life sciences.



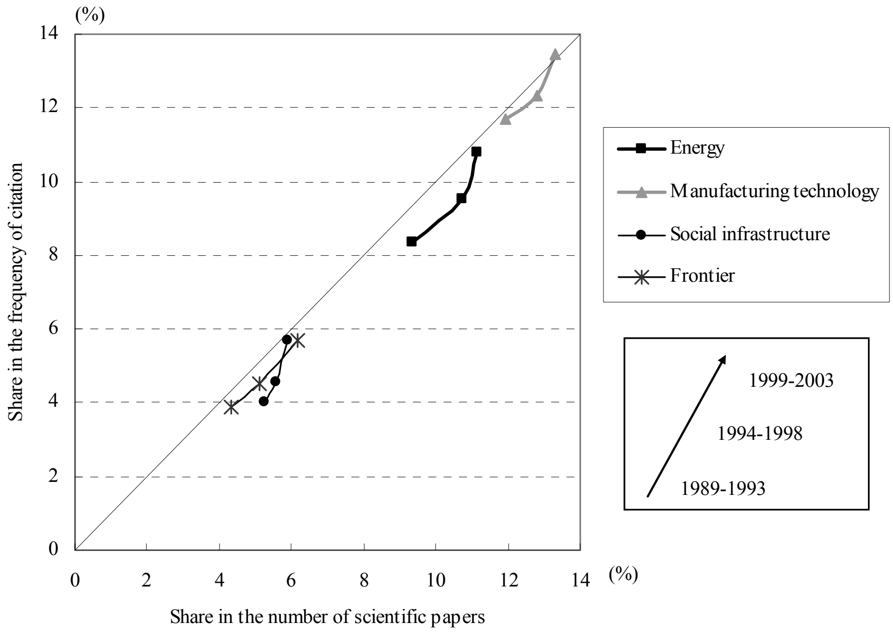


Figure 1-2-51 Japan's Shares in the Number of Scientific Papers and Frequencyof Their Citation by Field (1989-2003)

Source: NISTEP, "Study for Evaluating the Achievements of the S&T Basic Plans in Japan" (NISTEP REPORT No. 88, March 2005)

(Opinion survey)

According to the opinion survey conducted by MEXT targeting researchers in industry, academia, and government, researchers considered the research level in Japan to be generally behind compared to that in the United States and Europe, but was ahead of that in China, South Korea, and other Asian countries. They thought that the gap with the front-runner, the United States, had been narrowing, but the gap with Europe had widened, and Asia was closing in from behind. This trend coincides with other trends, such as the changes in the share in the number of scientific papers.

Furthermore, researchers considered that Japan had a relatively higher advantage in applied/development research rather than basic research (Figure 1-2-52).

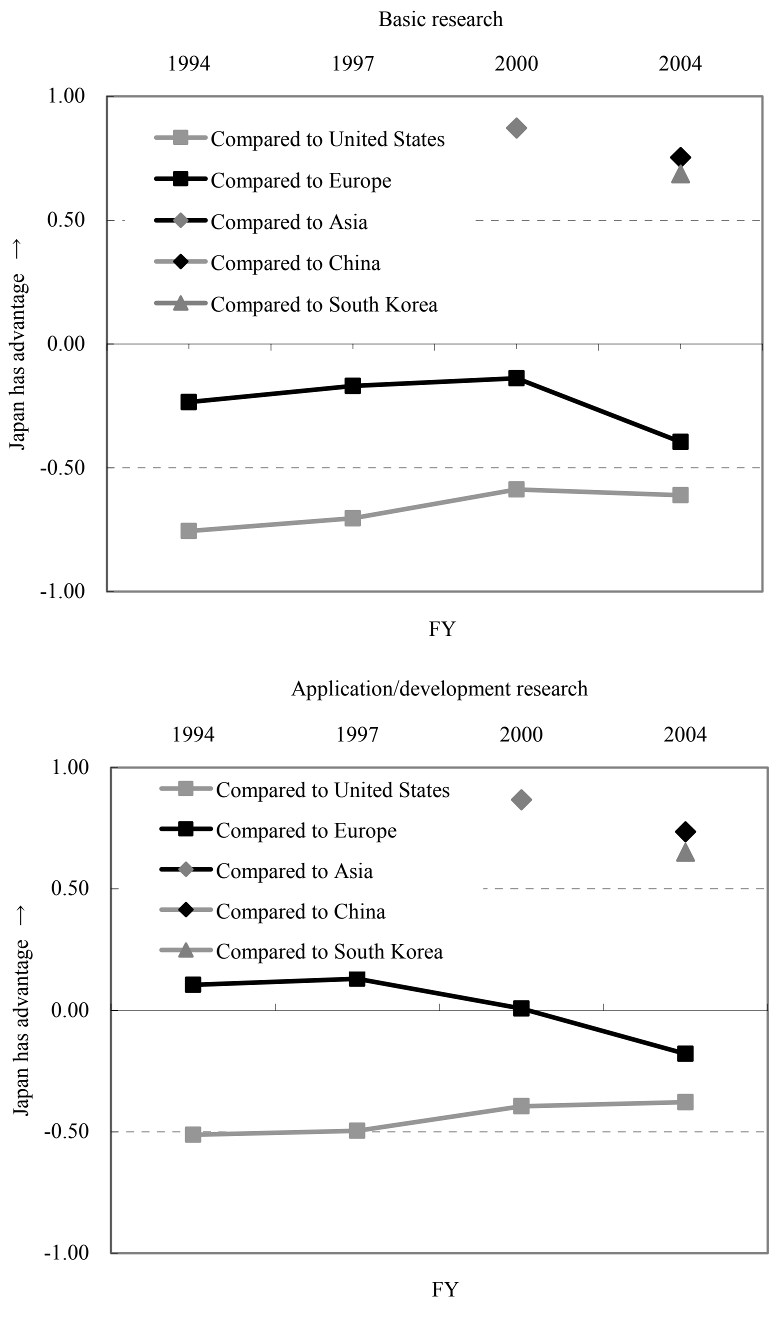


Figure 1-2-52 Research Level of Japan Compared to Other Countries

Note: Values were derived by counting the respondent's answer as +1 if he/she thought that Japan has advantage over the country/region, 0 if he/she thought that Japan is at the same level as the country/region, and –1 if he/she thought that the country/region has advantage over Japan, then totaling these scores and dividing it by the number of respondents.

Source: MEXT, "Survey of the State of Japan's Research Activities (FY 2004)"

1.2.4.3 Japan's Characteristics, Strengths, and Weaknesses

(Japan's strengths and weaknesses viewed from its history of accepting modern science and technology)

The history of modern science and technology in Japan started in full-scale in around the Meiji Restoration by accepting science and technology from the West. The efficient introduction of science and technology led by the Meiji government was one of the major reasons that Japan could achieve modernization ahead of other non-western countries. This success is said to have owed to the availability of social infrastructure for introducing science and technology. For example, people's average educational level was high, such as a high literacy rate, and the manufacturing technology in traditional crafts was highly advanced already in the Edo period. Science and technology was also actively imported from the United States and other countries in the process of making economic recovery after being defeated in World War II. Then, the imported science and technology, in combination with Japan's excellent quality control system and diligent workforce, contributed to developing such industries as iron and steel, home electrical appliances, and automobiles, and lead Japan to high economic growth.

In this manner, Japan's attitude toward science and technology had basically placed emphasis for a long time on practical use—efficiently importing science and technology from other countries and applying them in the economy—in order to catch up with western developed countries. In this process, a characteristic of Japanese culture—relativizing the subject—had been suitable for such import of science and technology, as indicated by Japan's history of absorbing and assimilating the ideas and cultures of other countries by processing and improving them to make them more adaptable to Japanese people. This characteristic can still be seen today in that there is a relatively small number of bachelors of science and a relatively large number of bachelors of engineering in Japan and that a large number of patent applications are filed in Japan. Furthermore, the national character and social characteristics that are expressed as Japan's strong points with such keywords as people's strong sense of belonging to an organization, good teamwork, a high level of discipline, field-oriented ideas, and meticulousness, seemed to have had advantageous effects mainly at the manufacturing sites of private companies.

Then again, emphasis on practical use is not always suitable for creating science, which aims at exploring the absolute truth. It has been pointed out that Japan tends to overlook the basics of science and technology and is strongly oriented toward making efficient use of the achievements. This tendency makes people attach more importance to uniformity and being safe and sure than to creativity, prefer loyalty to the organization over active human resource mobility, increasingly feel a sense of sectionalism, and more inclined to look inward and disregard the international dissemination ability. Because of this, Japan's characteristics, which had been regarded as strengths, have come to be indicated as weaknesses through the dramatic changes in the times.

(Challenges for being a front-runner)

The mobility of researchers in Japan, which has been indicated as being low since the First Basic Plan period, is still at a low level in the world. In an interview survey conducted by NISTEP on overseas top-class scientists and researchers, the respondents mentioned that long-term acceptance of scientists from other countries and overseas dispatch of young researchers should be further promoted for making research by Japanese people more globalized. In the same survey, there was an opinion on Japan's ability to disseminate information to the world that the presence of publications in Japanese language is good in providing a dynamic research environment in Japan, but it delays the presentation overseas, making it difficult for Japanese research to be evaluated as being innovative. According to the survey conducted by MEXT in fiscal 2004 targeting Japan's researchers in industry, academia, and government, about 60% of researchers mentioned they submit their scientific papers at first to journals in Japanese language. This percentage has hardly changed from that in the survey in fiscal 1998 (Figure 1-2-53). Moreover, due to excess focus on safeness and assuredness, the amount of venture capital investment for supporting practical application and commercialization of products using new ideas or technologies is low in Japan compared to other developed countries.

In order for Japan to advance science and technology in the intensified worldwide competition today as a front-runner, it needs to promote creative basic research and establish a system for efficiently using the achievements in society and the economy. To this end, it will be important to further use such potential as the characteristics of Japan's manufacturing known as *suriawase* (tight coordination) and *konare no waza* (mature techniques), which had been Japan's strengths, and Japanese children's academic abilities, which rank high in the world, while tackling various challenges in Japan's scientific and technological system, which are regarded as Japan's weaknesses.

As discussed above, the research level of Japan has certainly risen in general. In addition, Japan is rapidly expanding its share in terms of the number of scientific papers in some fields including physics, material science, and immunology. Also, according to the interview survey conducted by the NISTEP on overseas top-class scientists and researchers, Japan is highly acclaimed for its outstanding projects, such as the Earth Simulator and the Super-Kamiokande, and its contributions in international joint research projects including those on decoding the human genome. Thus, Japan is significantly increasing its presence in some fields. It may be regarded as the sprouting of the results of measures that have been taken since the enactment of the Science and Technology Basic Law, so such efforts should be further promoted in the future.

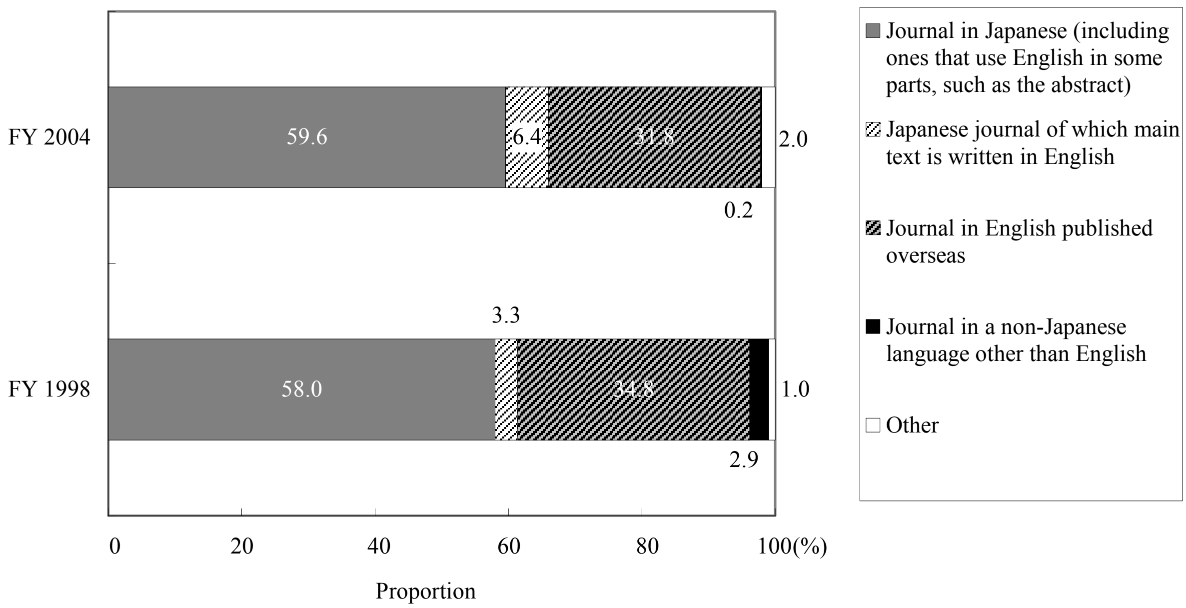


Figure 1-2-53 Journal to which Japanese Researchers Submit Their Scientific Papers at First

Source: MEXT, "Survey of the State of Japan's Research Activities" (FY 2004, FY 1998)

[Column 18]

Japanese Traditional Arts Utilized for High Technologies

Prior to Japan's modernization since the Meiji era, traditional crafts and technologies have been developed in Japan, founded on its distinctive culture and climate. Such traditional arts and technologies have been continuously passed down through the generations until now, and some of them considerably influence current high technologies, as shown in the following examples:

<Traditional Japanese Paper and High Performance Paper>

"High performance paper" is made of synthetics, minerals, or metal fiber instead of vegetable fiber. Depending on the material of the fiber, the types of high performance vary, and include incombustibility, friction resistance, electric conductance and non-conductance. High performance paper is used for various products, including a friction material for vehicles, electronics parts and batteries.

The fibers of high performance paper should be evenly woven based on manufacturing techniques similar to those for traditional Japanese paper. That is why, in many of the manufacturing districts of high performance paper, traditional Japanese paper is also produced.

<Traditional Japanese Ceramics and Electronics Parts>

Japan has many ceramics production areas such as Kiyomizu and Arita. Traditional ceramic techniques are now utilized for technologies to produce condensers, which are indispensable to electronics devices. It is not surprising that Japan boasts such a high global market share in electronics and ceramics manufacturing.

<Gold Foil and Electric Circuits>

Gold foil is an essential material for traditional Japanese crafts. Japan has manufacturing and processing techniques of which it can be proud in the world for gold foil as thin as several ten-thousandths of a millimeter. The techniques are applied to manufacturing and processing of ultra-thin copper foil used for electric circuit substrates. The traditional technologies fundamentally support high technology industries, in which the lightness and thinness of the products are valued.

<*Tatara* Iron Making and Special Steel>

Tatara (foot bellows) iron making is a traditional art in Japan, using *masa* iron sand and charcoal unlike the less purer ingredients such as iron ore and coke that are used in modern iron making. Steel made based on the *tatara* method has been used for Japanese swords since old times. Utilizing the traditional method, the refinery techniques for mass-production of purer steel were established. The manufactured steel is combined with nickel and chrome to produce special steel with resistance to burning and abrasion. The special steel is used for products with rigorous mechanical, physical, or chemical requirements, such as tools and knives with high strength and abrasion resistance, electronics parts, ultra-heat-resistant alloys for aviation parts such as jet engines, and parts of nuclear facilities.

In addition to the examples above, many other traditional arts and technologies inherited in Japan have been applied to advanced technologies. For example, the braiding techniques for kimono sash cords and sword tassels have been applied to the development of compound materials with high strength, elasticity, and heat-resistance, by substituting carbon or glass fiber with vegetable fiber. Furthermore, the pattern printing in the *Yuzen* process of dyeing is considerably relevant to the technology of symbol printing on the buttons of mobile phones.

References: Kyodo News Editorial Office Ed., "*Washi* Paper and Mobile Phones";
NHK, "Japan Impact" Project, Ed., "Japan Impact: Traditional Techniques for Our Bright Future";
Institute for Future Technology (INTECH), "The Encounter between Japanese Culture and Science: Tradition for New Creation"