# WHITE PAPER
# ON
# SCIENCE AND TECHNOLOGY

# 2006

## Challenges for Building a Future Society

- the Role of Science and Technology in an Aging Society with Fewer Children -

Edited by
Ministry of Education, Culture, Sports,
Science and Technology
Japanese Government

This White Paper on Science and Technology 2006 is translated from the Japanese language original published by Ministry of Education, Culture, Sports, Science and Technology, Japanese Government.

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# Foreword

Japan, being short of natural resources, was quickly rebuilt after the devastation from World War II, and has attained today's prosperity by grace of the important role of science and technology. Today, science and technology penetrates into every aspect of society and it is no exaggeration to say that our daily lives could not be accomplished without science and technology. Keeping this in mind, what role should science and technology play in the society to come?

In the 21st century, being called the "Century of Knowledge," as our nation will have to cope with the existing global environmental problems and the progressively aging society along with a decrease in the number of children, and as our nation will continue to achieve sustainable development in the midst of intensifying international competition, the role of science and technology will likely become even more important.

In March 2006, the Third Science and Technology Basic Plan, which keeps the basic tenet of "science and technology to be supported by the public and to benefit society," was adopted by the Cabinet Council Meeting. Under the Basic Plan, the total amount of government investment in research and development is targeted to be about 25 trillion yen over a five year period starting from fiscal year 2006. However, under the critical financial conditions of Japan, it is crucial for the Government to obtain the support and understanding of all citizens in order to steadily advance science and technology policy and promote science and technology.

This White Paper on Science and Technology, therefore, presents the current situation and roles to which science and technology should correspond from the perspective of the problems that confront our society, i.e., the declining population and an aging society along with fewer children, and for establishing a vital and abundant society responding to the expectations of all people. In addition, the White Paper aims to be an often-used visual reference to be kept at hand.

I hope that this document will help the Japanese people to deepen understanding on science and technology policy as well as to feel more familiar with science and technology.

June 2006

Minister of Education, Culture, Sports, Science and Technology
Kenji Kosaka

## Preface

Pursuant to Article 8 of the Science and Technology Basic Law (Law No. 130 of 1995), this document reports the measures that have been conducted in order to promote science and technology.

In Part I and II of this document, various movements of science and technology activities will be described, and in Part III, the actual measures that have been conducted regarding the promotion of science and technology will be explained.

In Part I, entitled “Challenges for building a future society: the role of science and technology in an aging society with fewer children,” we analyzed, from a science and technology perspective, what is required for Japan in the situation of facing a decline in population and an aging society with fewer children earlier than other countries, and what is to be established for achieving a lively and affluent society in order to respond to various issues that arise from changes in the population composition, and indicated the expected role to be played by science and technology.

# Part 1
# Challenges for Building a Future Society
## - the Role of Science and Technology in an Aging Society with Fewer Children -

# Introduction

Japan is experiencing a rapid progression toward an aging society with fewer children. Accompanying this, it is estimated that the total population in 2005 has been lower than that of the previous year. Excluding a decline due to World War II, the population of Japan has grown steadily since the Meiji era, but has now started to decline. It is predicted that the aging society and a declining in population will continue over the long term in the future. This is likely to have a variety of effects on the society and economy of Japan, and our society is about to face a turning point.

The effects of an aging population with fewer children have been pointed out from a variety of perspectives. In particular, as a countermeasure to the declining birth rate, one of the factors causing the aging population, various measures have been taken to reverse the trend of fewer children. In the future, even stronger action is required to change the circumstances in society that make it difficult to give births and to bring up children, and to avoid overly rapid changes in the population structure.

On the other hand, even if the birth rate could be increased in the near future, it would take time for the effects to be seen, so the country could not entirely avoid the aging of the population and a decrease in population. For this reason, it is necessary to continue to deal with the issues of a society with a declining population, fewer children and a growing elderly population, such as by maintaining the vitality of society and achieving an abundant life for the people.

Turning eyes to the world, although the total world population is expected to increase, it is predicted that many countries may possibly experience population declines, primarily industrialized nations and Asian countries. Japan is in the position of being among the first in the world to deal with the issues of a decrease in population and an aging society with fewer children.

Along the population issues, it is necessary to adopt the perspective of sustainable development for the society, including both environmental and economic concerns, and addressing the problems that are shared with the rest of the world, with respect to the environmental problems, food supply problems, energy problems and resource problems. There is a need to reconsider the societal emphasis on mass production, mass consumption and mass use of resources, and to pursue a new vision of wealth and abundance.

Regarding such large problems, how could science and technology contribute?

Science and technology have been contributing greatly to mankind through new knowledge, such as the discovery of scientific principles, and the fruits of a wide variety of technology development. Extension of the life expectancy, which is one of the factors of the aging society, is also one result in which science and technology contributed to fulfilling a wish of human beings.

However, it is also true that the development of science and technology expands the activities of man to bring about new problems on a global scale, such as environmental problems.

The development of science and technology in recent years has made impacts on all levels of society, and it is no longer possible to separate science and technology from the daily lives of people. The relationships between S&T and society has continued to become closer and stronger, therefore, S&T should be supported by society and people, and at the same time, S&T is required to provide benefits to society and people.

Regarding the problems of an aging society with fewer children that are now facing our nation, there are naturally limits to what could be accomplished by science and technology alone. Nevertheless, science and technology should certainly serve as an important part of the solution to these problems.

The first section of the annual report on the promotion of science and technology presents the trends in science and technology activities focusing on a specific theme. The relationship between S&T and society was broadly addressed in 2003. In this report, as Japan now faces a major turning point with prospects of shifting the decreasing population, the focus is on presenting and analyzing the role of science and technology from the view point of an aging society with fewer children.

## 1.1 Current Status of an Aging Society with Fewer Children and Challenges for Science and Technology

### 1.1.1 Current Status and Predictions for an Aging Society with Fewer Children


### Summary

The population in Japan switched to a declining trend in 2005, two years earlier than projected, due to the effects of an aging society with fewer children. It is predicted that this declining trend will continue for the long term in the future.

For the world as a whole, the population will continue to grow in the future, but many developed nations and various countries in Asia are also expected to make the transition to declining populations in the near future. Japan will face the issues of declining population and the aging of society and decrease in the number of children before these other countries.


**●Start of a society with a declining population**

According to the 2005 population statistics and annual projections released in December 2005 it was projected that there would be 1,067,000 births and 1,077,000 deaths in Japan that year, a difference of 10,000 people due to “natural attrition”.

Furthermore, according to the Population Census (preliminary report), the projected population on October 1, 2005 was 127.76 million, a decrease of 20,000 from the projected population of 127.78 million for October 1, 2004.

In 2005 the total population of Japan dropped below the level of the previous year for the first time since World War II. This start of a population decline is two years sooner than the 2007 date predicted in the National Institute of Population and Social Security Research January 2002 projections (intermediate forecast) (Figure 1-1-1).

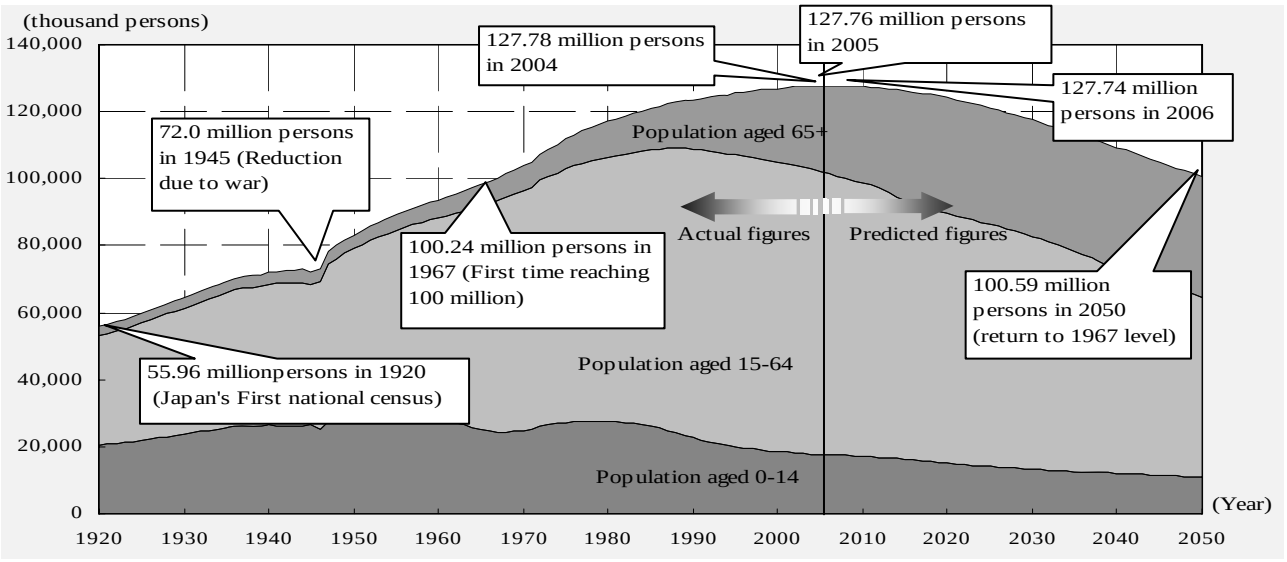



**Figure 1-1-1 Changes in the population structure in Japan**

Note: Between 1941 and 1943 the breakdown of the population into the three age groups was supplemented from the values for 1940 and 1944. The data from 1946 through 1971 does not include Okinawa. In the total numbers for the Population Census the people for whom age was not known were distributed proportionally among the age groups.

Source: Through 2005, numbers are taken from the Ministry of Internal Affairs and Communications, Statistics Bureau “Population Census,” “October 1 Population Estimates.” For 2006 and after, values are based on the National Institute of Population and Social Security Research, “Population Projections for Japan (January 2002 Projections)” and the Cabinet Office “White Paper on Birthrate-Declining Society 2004” (December 2004)

### ●Progress of aging society and decrease in the number of children

A direct cause of population decline is a decrease in the number of births and an increased number of deaths according to aging.

Looking at the number of births, there has been a decreasing trend since Japan's second baby boom in 1974. The total fertility rate[1] reached an all-time low of 1.29 in 2004, and the decrease in the number of children is progressing more noticeably than in Europe and the USA.

The proportion of elderly people indicated by the percentage of the population aged 65 years or over, rose rapidly after 1970 with the increase in life expectancy and decrease in number of children. This proportion surpassed 14%, the level regarded to constitute an "elderly society," in 1994. In October 2004 the rate reached 19.5%, with Japan's proportion of elderly people surpassing that of other developed nations.

The aging of society in Japan is characterized by its high proportion of elderly people and the extremely rapid aging rate compared to other countries. Based on comparison of Japan's expected future proportion of elderly people with that of other countries, based on estimates by the United Nations, it is projected that the aging of society in Japan will continue at a rapid pace that exceeds that of other countries (Figure 1-1-2).

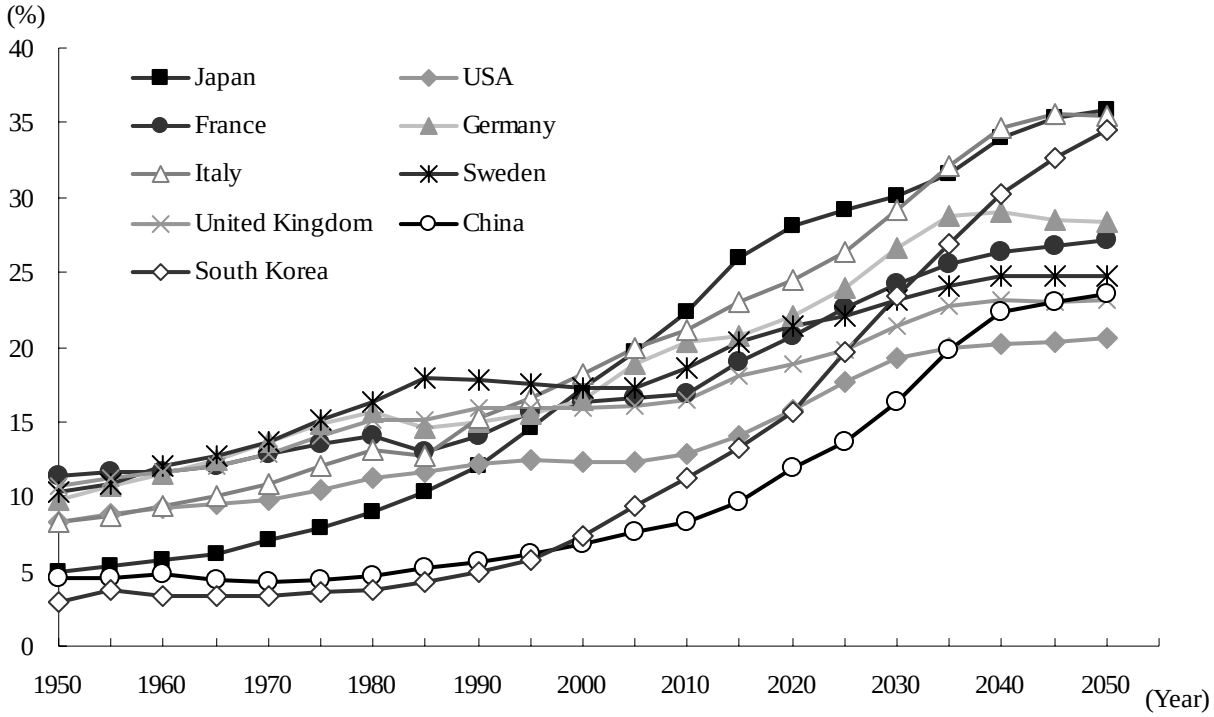



**Figure 1-1-2 Percentage of population aged 65 and older in various countries**

Source: United Nations, World Population Prospects: The 2004 Revision

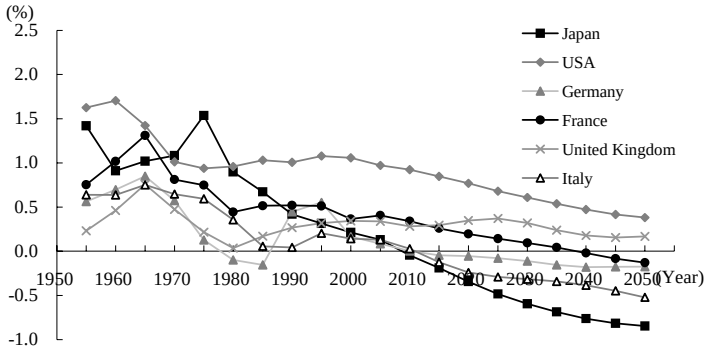
[1] The sum of the age-specific fertility rates for females between the ages of 15 and 49 for that year. It is equivalent to the number of children that one woman would bear over her lifetime if she were to experience the current age-specific fertility rates.

### ●Population Projections for Japan and the World

According to the projections of the National Institute of Population and Social Security Research (January 2002 median projection), the population of Japan is expected to continue to decline and become about 100.59 million in 2050. At that time, the percentage of the population aged 65 or older is projected to be 35.7%, while the percentage of the population aged 14 and younger will be 10.8%, so there will be 3 times as many elderly people as children, creating an elderly society with extremely few children. (Figure 1-1-1)

According to the United Nations projections in 2004 the total world population is expected to continue to increase, although the rate of increase will decline. In major developed nations it is predicted that the populations will begin to decrease, in the 2010s for Italy and Germany, and in the 2040s for France. Furthermore, in Asia it is projected that South Korea will experience a population decline that is even quicker than that in Japan, while China in the 2030s and Thailand in the 2040s are expected to start facing population declines. Japan is facing this situation earlier than these other countries and is now confronting the problems of a declining population and an aging society with fewer children (Figure 1-1-3).

#### (1) Main developed nations




#### (2) Asia

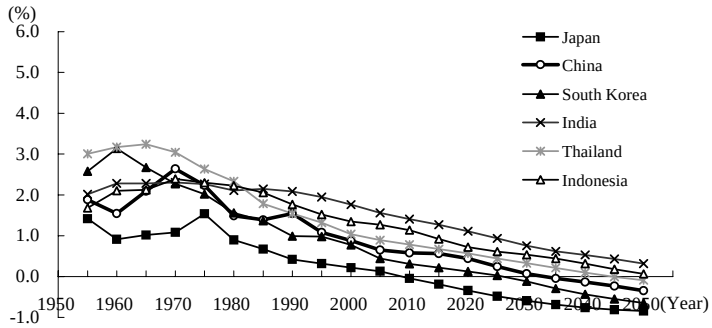



**Figure 1-1-3 Projected annual average population expansion for main developed nations and Asia**

Note: For countries other than Japan, the numbers here may differ from the country's own projections
Source: United Nations, World Population Prospects: The 2004 Revision
For Japan, numbers through 2005 are from the Statistics Bureau "Population Census," "October 1 Population Estimates," for 2010 and later, based on the National Institute of Population and Social Security Research, "Population Projections for Japan (January 2002 Projections)".

## 1.1.2 Issues to be Addressed by Japan and the Role of Science and Technology

### Summary

The rapid progression of an aging society with fewer children will have a large and far-reaching impact on Japan's society, including concerns about insufficient personnel to support a science and technology-based nation.

Measures to change the trend in fewer children and to mitigate the rapid changes in the population structure are certainly required, but there is also a need to develop new social systems to deal with the unavoidable decline in population and aging society with fewer children.

It is anticipated that science and technology will contribute to resolving the issues of building a spiritually wealthy society, vitalizing the economy and creating an environment whereby individuals can participate in society regardless of age or sex while achieving a healthy balance in their daily lives, as the demographic structure changes.

Furthermore, as the connection between S&T and society deepens, there is a need to foster the interest, empathy and confidence of the public in science and technology, establish comprehensive human resources development policies to improve quality of and secure the personnel working in science and technology, and develop an environment that allows a wide variety of people to actively participate.

### 1.1.2.1 Effects of the Progression of Aging Society with Fewer Children

#### ●Impact on Society

As shown in section 1, over the long term the population of the country is projected to decline, along with the rapid advancement of an aging society with fewer children. This kind of structural population change is expected to have large and wide-ranging effects on society.

First, the percentage of the elderly population is increasing. In 2004 there were 3.4 people in the number of working-age population (15–64 years) for every elderly person. This is projected to drop to 1.5 by 2050, raising concerns about the increasing burden of social security from pensions as well as health care and nursing care. In addition, the working population (persons aged 15 years or over who intend to work) has been declining since 1998, with decreases projected to continue in the future. Furthermore, it is projected that in 2007 the baby boomer generation (consisting of people born between 1947 and 1949) will start to retire from the labor market as they approach the age of 60. This is the generate on that has supported the country's economic growth and had a profound impact on all facets of society. Looking at the society of the country in terms of the population structure, it is predicted that there will be a complete change from the structure of the past (Figure 1-1-4).

With regard to the stock of social capital, including roads, airports and sea ports, there is a view that the per capita social capital stock will increase as the population decreases, and that this will create a surplus. However, since much of the social capital stock formed during the period of high economic growth will require updating and renewal in the next dozen or so years, there is expected to be a large increase in maintenance and new investment costs.

Turning our attention to local communities, although in the past the progressive aging of society was mainly apparent in rural areas, it is projected that the aging of society will soon be apparent in urban areas as well. The maintenance of the vitality of local communities in rural areas in which the aging of the population has progressed is already an issue. It is likely that there will be changes in urban functions and the connection between the elderly and local areas as elderly people in cities and the surrounding suburbs retire and return to their home towns.

#### ●Impact on Science and technology

There is fear that changes in the composition of the population could have a large impact on the ability to secure the personnel that support a science and technology-based nation. As the population ages, the percentage of middle-aged and elderly people working in specialized/technical jobs is increasing, a trend that is expected to continue in the future. In addition, the Year 2007 Problem as above is expected to have a large impact on shortage of engineers and skilled workers, particularly in the fields of science and technology, and on the passing on of techniques and skills.

Even though it is crucial to ensure that the

younger generation with vitality and creativity enter the fields of science and technology in order to strengthen and maintain the science and technology abilities of Japan, if there continues to be a decline in the interest of the younger generation in science and technology as the decrease in the number of children progresses, there is concerns about the predicted both the quality and the quantity of science and technology personnel will be inadequate.

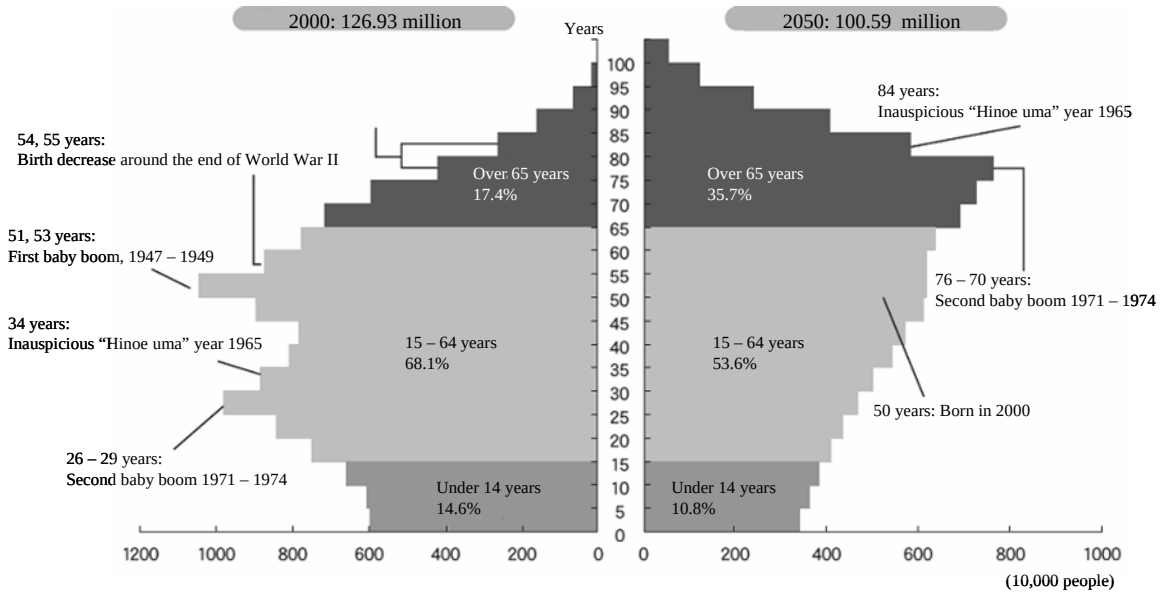



**Figure 1-1-4 Changes in Japan's population structure by age**

Source: For 2000, Ministry of Internal Affairs and Communications' "Population Census." For 2050, the National Institute of Population and Social Security Research's "Population Projections for Japan (January 2002 Projections)".

## 1.1.2.2 Dealing with Aging Society with Fewer Children and the Role of Science and Technology

### ●Measures to change the trend in fewer children

A major factor of the population decline and aging society with fewer children that are predicted to have a wide range of effects on Japanese society, is the decline in the birth rate that has continued over a long period.

The decline in the birth rate is the product of individual personal choice, and there are certainly those who view low birth rates and fewer children as phenomena that are common to developed nations and difficult to avoid. However, it has been suggested that the rapid decrease in the number of children in Japan has been accelerated by more people raising children alone and decreases in assistance with child care locally and from the extended family as urbanization progresses and more people live in nuclear families; increases in the costs of raising children; a working environment that makes it difficult to maintain both family life and a job; changes in attitudes about marriage and families; and socio-economic conditions making it difficult for young people to establish themselves, including the high youth unemployment rate.[2]

A continuation of such societal conditions in which it is difficult to bear and raise children will cause drastic changes to the demographic structure, making countermeasures even more difficult. This threatens to shake the very foundations for the sustainability of Japanese society.

[2] See General Policies of Measures for an Aging Society with Fewer Children (adopted by the Cabinet on June 4, 2004)

The government established "National Youth Development Policy" in June 2004, aiming to make a transformation to a society in which children can be raised healthily and in which it is possible to bear and raise children joyfully, in order to "reverse the trend of fewer children." In December that same year a "Support Plan for Children and Childrearing" was established as a concrete plan of action incorporating the measures described in the general policies. Focused measures are now underway, and it is important for the entire society to make continued efforts in the future.

### ●Building new social systems

Even if the trend in fewer children is changed and the birth rate begins to increase, some time will be required before there is a big enough effect to increase the population, so Japan cannot avoid a decline in population in the short term. Even based on the National Institute of Population and Social Security Research's optimistic projection which assumes that the total fertility rate will return to 1.63, it is projected that the population will begin to decline after reaching a peak in 2009, dropping by about 20 million people by 2050.[3]

Japan must maintain the vitality of society, achieve a society that offers an abundant life and provide a stable future in the midst of a decrease in the labor force accompanying the declining population and aging society with fewer children, as well as the decrease in the population of children and young people.

As the global population continues to grow, the global-scale issues, such as environmental problems, food supply problems, resource and energy problems, require a shift from our mass-production, mass- consumption, mass-waste civilization of the 20th century.

How will science and technology be involved in solving these problems?

As a nation with few natural resources and little land, wealth has been achieved through a high level of education and the high level technical abilities of the human resources. In the future, as international competition becomes even more intense, it is necessary to continue to maintain international competitiveness and provide high value-added products and services to the world, while corresponding to the changes in the population composition, maintaining and improving the quality of life of citizens and achieving an abundance that includes spiritual and mental aspects. There is also a demand to actively contribute to global scale problems such as the environmental problems, and it is believed that the role of science and technology will continue to grow.

The foundation that supports the progress of science and technology more than anything else is the ability of the people who are engaged in science and technology. As globalization progresses, every nation is increasing measures to secure science and technology personnel, revealing a kind of global competition for human resources. In Japan, it has been estimated that there could be a shortage of more than 1 million researchers and engineers by 2030, depending on changes in the economic growth and industrial structure. As population decline and the aging society with fewer children progresses, the measures to ensure the quality and quantity of science and technology personnel must be promoted even more strongly. Furthermore, as we enter the age of a knowledge-oriented society, and science and technology impacts every facet of daily life, it is necessary to foster the understanding, interest, empathy and confidence of the public towards science and technology.

In a situation of a decreasing population and an aging society with fewer children, development of "Human Resources" and achievement of a "Science and Technology-based Nation" have become even more important and significant as the path that must be followed by Japan.

[3] For the high projection in the 2002 projections of the National Institute of Population and Social Security Research, based on the rate of never-married people in the 10 prefectures with the highest percentage of unmarried people, it is assumed that the total fertility rate will immediately rebound from the 2000 value of 1.36 and reach a level of 1.63 in 2049

As international competition intensifies, a decline in the population that is the source of the nation's vitality is a major issue. Nevertheless, there is no time to defer addressing the previously-mentioned global problems. In addition, developed nations and various countries in Asia are also expected to be facing declining populations in the near future.

In such an era, by approaching the handling of a declining population and an aging society with fewer children as a challenging opportunity to build the future society and being the first in the world to resolve the issues, if Japan can realize new social systems to deal with population decreases and aging society with fewer children and show the world an abundant, sustainable society, this becomes an opportunity to present a model to other countries that will face the same issues in the future.

In addition, an abundant and stable society is connected to the realization of a society in which people have hopes for the future and the desire to raise children, so this is likely to contribute to reversing the trend of fewer children as well. A change in society involves a variety of elements, such as the various social systems and attitudes of people, and science and technology is only one such element, but nevertheless an important one. In the following section, the challenges to be faced in achieving a wealthy and stable society amidst the population decline and advent of an aging society with fewer children are divided into three areas: dealing with changes in the population structure, revitalizing the economy, and building a society that provides spiritual well-being. Discussions are made on the role that science and technology should play in tackling these respective challenges and on the issue of fostering peoples' understanding of and interest in science and technology as well as on the development and securing of the human resources which would constitute the basic foundation for dealing with all of the above challenges.

### ●Science and technology to deal with changes in the population composition

In a society with a declining the working population, it is necessary to achieve a society in which it is easy for women and the elderly to work, to increase the rate of participation of these groups in the labor force, which has conventionally been low, and to increase the abilities of each individual, in order to ensure the necessary quantity and quality of the work force.

Science and technology are expected to play a major role in realizing a society in which the elderly can be healthy and active. In other words, science and technology are expected to make major contributions to increasing peoples' "healthy lifespan," that is, to enable health to be maintained throughout peoples' lives through the prevention, diagnosis and development of treatments based on a new understanding of various diseases.

Progress in technology, such as the development of robotic technology to assist the elderly with physical functions, is also needed to reduce the burden of nursing care and assist in the independence of the elderly.

Furthermore, it is important to make it easier to combine work and raising children, and to fully utilize the talents of each individual, so it is necessary to further diversify work practices. Besides the traditional pattern of employment, part-time work, telecommuting and an entrepreneurial culture should be promoted. There is a need to realize a society that allows the choice of a variety of work styles to match each individual's personal circumstances and family activities, including women and the elderly. By achieving this, it will be possible for more people to participate in society with enthusiasm while maintaining a balance between work and family life. It is anticipated that this will be a society in which everyone works and supports each other, regardless of sex or age. To achieve such a society, effort is likely to be made in areas such as the development of an environment in which it is easy to work using IT (information technology) and robot technology, as well as improved efficiency for housework using a variety of home electric and electronic products. In addition, in the midst of a drastically-changing society, in order to maintain and improve the required job skills, it is anticipated that learning assistance using IT will play a significant role in securing the opportunities to study and develop job skills throughout one's life.

It is not appropriate to simply bring in foreign labor to deal with an insufficient number of workers. Furthermore, the practice of bringing in unskilled foreign labor requires careful consideration of all the issues, including the effect on the domestic labor market and the social costs. Nevertheless, to vitalize our nation's economy and society and to

advance internationalization, it is important to actively recruit foreign labor in specialized and technology fields. Specifically, for the science and technology field, in the midst of amidst intensifying international competition for human resources there is a need to develop the research environments and recruiting systems that make it possible to attract a large number of talented personnel to come and be active in the research community in Japan, without regard to nationality.

On the other hand, in a society with fewer children, raising each child to be healthy and able to participate independently in society becomes an issue of even greater importance. This is also related to the development of the conditions which facility ate the bearing and rearing of the next generation, by strengthening the economic foundation and encouraging the younger generation to become in- dependent in society. Research in pediatric care is being promoted with the goal to improve the health of children, and the results of brain science research are expected to contribute to resolving questions related to learning and achievement in children.

With regard to social capital, technology development aims to adopt universal designs for the purpose of encouraging the participation of the elderly in society and making devices easy to use even when bringing up children, as well as reducing the maintenance and management burden.

Science and technology also expected to provide answers to the needs of society and resolve social problems, including tackling global environmental issues and building a safe and secure society. Science and technology is expected to make significant contributions to issues that threaten the security of society, such as the spread of contagious diseases across national boundaries like avian influenza, terrorism, and large-scale natural disasters. Furthermore, if there are failures to deal with global-scale environmental problems, there is a danger that this will lead to enormous problems that threaten the continued stability of human society.

It cannot be denied that the global problems we are now facing are associated with the development of science and technology and the rapid expansion of human activity that has followed. Nevertheless, science and technology will be crucial for solving these problems in the future. In addition to improvements in observation and data analysis technology to properly understand the issues, it is essential to continue with a variety of technology development activities to resolve the problems.

### ●Science and technology to vitalize the economy

As population decline and the aging of society with fewer children progresses there is a need to continue to increase productivity in order to mainta in economic vitality and achieve stable economic growth.

In addition, the economy is becoming more globalized and many countries in Asia are developing rapidly, so international competition is expected to become even more intense in the future. Under these circumstances, it is crucial for there to be internationally-competitive businesses to drive Japan's economy. Therefore, there is a need for measures to deal with the operational aspects of business, such as developing new markets to adapt to changes in the population structure, providing high-value-added goods and services, and preparing the capital that is appropriate for a society with a declining population, as well as improvements in productivity and development of new products through technology development. Science and technology will play a central role in improving productiveity and strengthening competitiveness, and it is necessary to further promote science and technology. It is important to strive to achieve sustainable economic development through the development of social systems that closely link the results of science and technology with innovation (the creation of new social and economic value by combining scientific and technical discoveries with insight and intuition).

### ●Science and technology to contribute to the building of a spiritually wealthy society

During the long life of the people due to the increase in the average lifespan, it has become possible for each individual to enjoy wealthy life actively participating not only in work, but also in hobbies, learning and local activities (Figure 1-1-5).

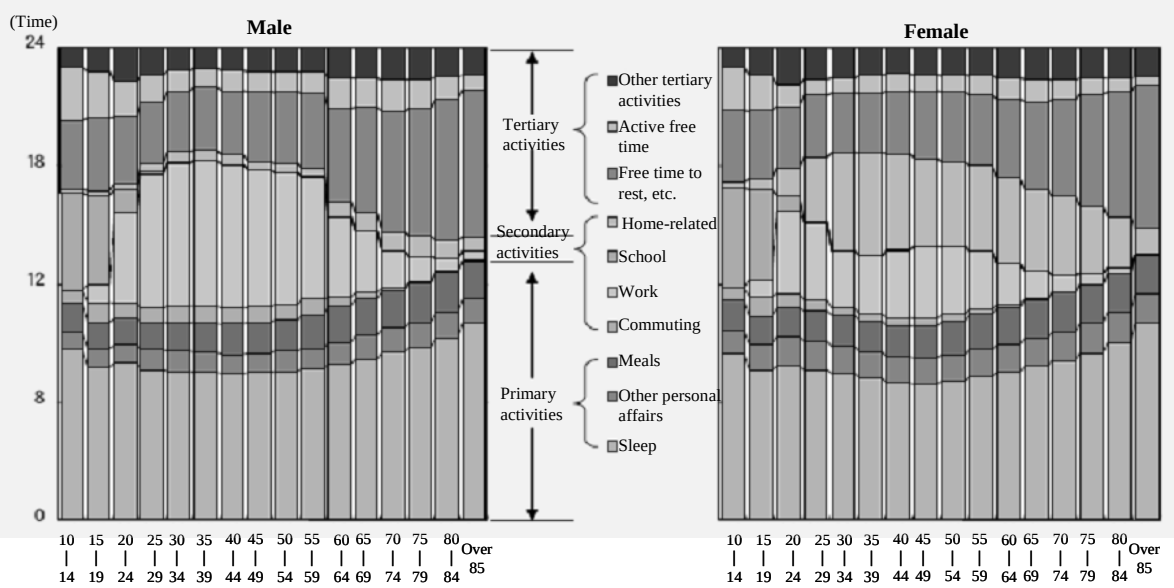



**Figure 1-1-5 Daily activity times per week by age group**

Notes: 1. The “Free time to rest, etc.” is the total time spent for “television, radio, newspapers, magazines” and “rest/relaxation.”
2. The “active free time” is the total time spent for “study/research,” “hobbies/pastimes,” “sports” and “volunteer activities/ social participation activities.”
Source: Ministry of Internal Affairs and Communication “2001 Survey on Time Use and Leisure Activities”

There is likely to be further progress in the trend of greater focus on spiritual wealth rather than material wealth, and greater interest in cultural activities, sports and lifelong learning. While these fields are related to the mental feelings and attitudes of each individual, spiritual wealth is often not compliant with the pursuit of convenience and efficiency, so there is a need for science and technology to contribute to not only material wealth, but also to achieving spiritual wealth. For example, in the field of media arts there has been development in a wide variety of art expression activities using new methods of expression resulting from the advancement in computer technology. In addition, science and technology can be used for the preservation, restoration and utilization of the cultural heritage items that are the shared assets of humanity, making it possible for more people to have direct contact with cultural assets, and to obtain information on cultural assets and traditional arts from far away, using digital archives, etc.

Furthermore, basic research conducted based on free imagination satisfies intellectual curiosity and leads to new knowledge for humanity. The development of science and technology is making progress in fields unknown to mankind in the past, such as space, deep oceans and the earth’s core, and contributing to new understanding in fields such as anthropology and history. There are also many examples of the results of basic research becoming the basis for a wide range of applications many years later, and contributing to new industries and improving daily life.

### ●Science and technology for people and the supporting personnel

The connections between S&T and society are becoming closer, and the influence of science and technology now extends into every corner of human activity. However, in recent years the interest of the public in science and technology, particularly among the young, has been tending to drop. In order for science and technology to contribute to resolving the social issues as expected by people, and also de- al with the problem of the aging society with fewer children in the future through the creation of new intellectual and cultural value, it is necessary for people to have an interest in and under-

standing of science and technology. Therefore, for the promotion of science and technology there is a need to pro- mote the empathy and confidence of citizens from the viewpoint of science and technology for society, and science and technology partnering with the people.

Furthermore, it is important that each individual citizen has the basic knowledge and skills regarding science and technology (science and technology literacy) in order to sufficiently appreciate the results of science and technology, have an interest in the function of science and technology in society, and be able to make related independent judgments.

To achieve this it is necessary to make efforts to foster a broad understanding of and interest in science and technology among citizens, from children to adults, by taking measures to allow researchers to learn the needs of the people through dialogue between researchers and the public, as seen in the science café sessions held nationwide, and expanding peoples' opportunities to touch, experience and learn about science and technology through measures like increasing and improving museums and exhibitions.

It is extremely regrettable that cases of misconduct by researchers/engineers have damaged the reputation of science and technology development activities in society. With regard to this problem research institutes and national agencies have started taking measures based on the self-regulation of researchers and scientists, and such efforts are also being sought from universities and scientific organizations.

The foundation of science and technology development, more than anything, is the people. As society continues to age and the number of children declines, there is a need to prepare an environment that allows a wide variety of people to actively participate in society, while securing and improving the quality of the personnel working in science and technology. For this reason, it is necessary to proceed with measures to increase interest in science and technology among children from the elementary and lower secondary stages of education, and to provide means to expand the individuality and abilities of talented children. In addition, there must be comprehensive measures to develop the required human resources, including an increase and improvement of the universities and graduate schools responsible for sending science and technology graduates into society, and continuing to develop the human resources to meet the needs of society. In addition, it is also necessary to ensure a supply of talented personnel even amidst the intense international competition for workers, by develop- ping an environment that allows a wide variety of people to actively participate, including the young, women and the elderly, and by building a research environment that is attractive to talented researchers from abroad, as well as the acceptance systems, including support for daily life.

With the widespread support of the public for science and technology, research activity by a variety of talented researchers, and the endeavors of a variety of science and technology-related person- el returning the research results to society, new knowledge will be created, and science and technology will develop and contribute to resolving various problems facing the nation. There is a need for even greater efforts toward building a science and technology-creating nation and the human resources that are the basis for this.

In Chapter 2 there is a section with detailed explanations for each of the items above regarding the role of science and technology for the development of a new society.

[Column 1]

## The Time When Everything Is Thought to Be "Science"

In a society with a decreasing and aging population, what significance do scientific attitudes have for living life better and what effect can they have on society? Dr Kenichiro Mogi of Sony Computer Science Laboratories, Inc., who is known for his study on human awareness and explains philosophical subjects in his various books and media in a way that's easy to understand, talked to us about "science in life."

### Science is in every phase of life

What I felt in England (Note 1) was that there was something like a "scientific spirit" in that country, which is essential to better living in every facet of life. English people hate to be considered as being assertive without any support by facts. They have a thoroughgoing spirit of the idea that "facts are telling." I think that scientific attitude in a broad sense has made England and America big powers in the world.

In Japan, we tend to consider science in a narrow sense, but I think that in the current era science relates to everything, not just as an idea but whether or not there is empirical data in every aspect of daily life, such as the relationships in a family or how to bring up children. Nowadays, anything and everything in the world are considered to be science. The representative science magazines "Nature" and "Science" are proactive in publishing such topics, and it is considered to be admirable to think of something as an object of science that was not thought to be an object of science in the past. For example, the first thesis of small world network theory (Note 2) that is now a focus of interest, analyzed co-star relations in Hollywood movies as an example, and was published in "Nature."

### Grabbing chances in the economy quickly by adopting a flexible attitude about "science"

Currently, neuroeconomics is experiencing a big boom in the U.S. In this sense, America moves quickly but Japan does not. Neuroeconomics is the science of studying, from brain mechanisms, how a man judges and acts when an uncertain situation exists. For example, there are Internet auction systems where a person puts something he/she doesn't need up for auction on the Internet to call for bids. It is a rapidly growing market and one major company is said to already have a market size equivalent to one-tenth of that of all convenience stores. How a brain copes with uncertainty is connected with the system design for this bidding. Furthermore, brain science is related with finance engineering, stock markets, foreign exchange markets, and company strategies for investments and mergers. When considering the recent rapid growth of Internet search businesses, I think Japan may become a more interesting country if we can produce more human resources in neuromarketing, a field of neuroeconomics, to make new companies. This may be needed in the global competition era.

As you can imagine from the term "political science," the territory of "science" in the English language is wider than "science" in Japanese. Science, in English, makes a paradigm of systematic thinking for a certain target of research by keeping logical consistency and collecting proof. I think it will be a big challenge to make such a broad science concept take root in Japan.

### Breakthroughs in science may be realized by explaining science in ways that the general public can understand

To explain science for the general public to understand is "enlightenment" in Japan, and is considered to be an activity of lower rank than real science. However, I have recently considered that this is not true. Like Darwin in the past and Dawkins of today (Note 3), the books that first class scientists wrote for the general public brought about scientific breakthroughs in the world at the same time. This is true especially for brain science. Brain science is a big science now. In a variety of brain science fields, individual researchers perform research on the respective functions and structures, but the brain cannot be understood by viewing just a part. To explain the brain to the general public in a way that is easy to understand, various kinds of knowledge must be put together. When performing research on consciousness or on what human intellect is, putting various kinds of knowledge together leads to breakthroughs. In other words, explaining science from an integrated viewpoint and bringing about new interdisciplinary breakthroughs by combining different areas are the same thing. Doing a new thing is an "Egg of Columbus" (an extremely simple solution to a difficult problem, that is hard to find, but once known, looks trivial and even obvious) and it's not difficult once you hit on an idea. Rather, the later you come, the more difficult it becomes. A person who is given the Nobel Prize is the first person who did something, and it cannot be done without comprehensive thinking to create an interdisciplinary bridge. I think there is a problem of specialization caused by withdrawing into one's own academic field.

Note 1: Studied in Cambridge University from 1995 to 1997.

Note 2: The "small world" phenomenon is an "It's a small world!" kind of idea. It is the hypothesis that everyone in the world can be reached by following a chain of social acquaintances. The small world network is a model to explain this phenomenon by network theory, and "Nature" published the first thesis in 1998. If you track down the movie co-stars of Kevin Bacon, an actor, you can reach all the movie actors and actresses in Hollywood within six steps.

Note 3: Richard Dawkins (1941-): British ethologist, known for the selfish gene theory which holds that natural selection acts through differential survival of competing genes.

## 1.2 Science and Technology to Create a New Society

### 1.2.1 Science and Technology to Respond to Demographic Change


### Summary

As a nation facing an aging society with fewer children it is necessary to bear and raise healthy children, maintain health throughout life and stretch the potential abilities of each individual to the fullest. To achieve this there is a need to clarify the mechanisms of biological phenomena and various diseases, and to develop the means to prevent, diagnose and treat diseases. In addition more effective welfare tools should be developed to assist the elderly in being independent and participating in society, as well as to reduce the burden on care-givers, and working styles providing a better balance with private life should be achieved by making it possible to simultaneously work and raise children as well as allowing active elderly people to contribute to society through further promotion of telecommuting and lifelong learning utilizing IT (information technology). Such efforts will be effective not only for distributing the burden imposed by an aging society with fewer children, but also for changing the trend of fewer children by altering the balance between family and the workplace.

Furthermore, the social infrastructure in an aging society with fewer children should encourage participation in society by those raising children and the elderly, and must also be of high-quality and able to be used effectively for many years so as to be appropriate for the mature economy. Therefore, it is necessary to develop materials that are highly durable and easily recycled, efficient and strong construction methods, and maintenance and management methods to ensure safety over the long term.

On one hand, the expansion in human activity that has accompanied the progress of science and technology has placed a burden on the global environment, and increased the fragility in terms of safety. The public desires a safe and secure society, and this is particularly important for the weaker members of society, such as children and the elderly. From a long-term perspective, harmony between the environment and human activity, and assured resources, like energy, are crucial for a safe and secure daily life. Therefore, it is necessary to be aware of the potential risks in advance, and to establish the appropriate preventive and response measures, and to promptly implement effective measures if a situation occurs. In addition to developing the technology for making measurements and predictions at a variety of levels, detection, damage prevention and mitigation, and for emergency response, there must also be progress on the development of energy conservation technology and alternate energy sources to support sustainable development. Furthermore, there is a social demand for the development of systems to grasp the production history information of products, and to support reliable information sharing and the establishment of communication.

To meet the demands of society it is necessary to continue with a wide range of research and development, from basic research to applications, while keeping in mind these demands; and then to proceed with social change through innovation based on the results.


#### 1.2.1.1 Science and Technology for Lifelong Health

According to surveys by the Ministry of Health Labour and Welfare, in 2005 there were more than 25,000 people aged 100 years or more. In the first national census conducted in 1920, there were only 113 people aged 100 or more, so there has been a more than 200 times increase in the last 85 years. The average lifespan of 42.1 years for males and 43.2 years for females in 1921 – 1925 has been nearly doubled to 78.6 years for males and 85.6 years for females in 2004, reaching the top level in the world.

This enormous increase in the average lifespan is largely due to the contributions from improved medical standards, nutrition and sanitation that have sprung from advances in science and technology. (Figure 1-2-1) In general, today's children can grow up without fear of infectious diseases like tuberculosis or other ailments that threatened the lives of children and youths in the past. The elderly too are able to maintain better health in comparison to people of the same age in the past.

However, for Japan, now facing an aging society with fewer children, in order to maintain and im-

prove the vitality of society and the quality of the daily lives of individuals in the future, there are three big issues regarding the health of the citizens.

The first is to make it possible for people who desire children to bear them safely and in good health. The second is to assist in raising healthy children. The third is to make it possible for the elderly to continue to enjoy good health throughout a long life, and to maintain vigor.

The role of science and technology in addressing these issues is summarized below.

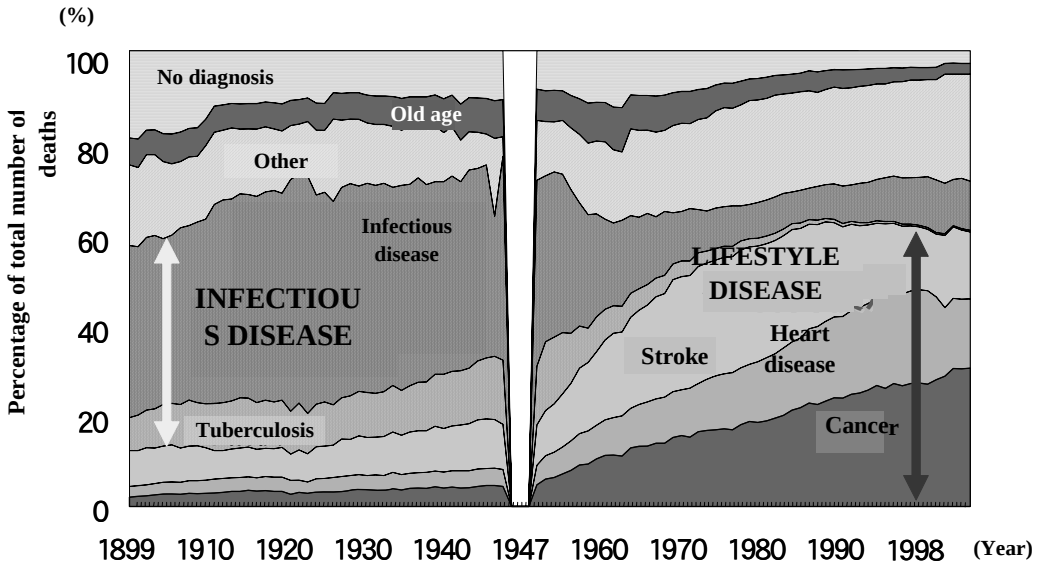



**Figure 1-2-1 Epidemiological trends regarding cause of death in Japan.**

Source: Created by the Ministry of Education, Culture, Sports, Science and Technology based on the Ministry of Health, Labour and Welfare "2004 White Paper on Health, Labour and Welfare" with some revisions.

## (1) Building a society favorable to bearing and raising children

According to the "2002 Japanese National Fertility Survey" reported by National Institute of Population and Social Security Research, married couples felt that the ideal number of children was an average of 2.56, but the actual number of children planned was an average of 2.13. For couples who plan to have fewer children than they feel would be ideal, when the wives were asked the reason, many indicated the burdensome costs of raising and educating children. Among the couples surveyed, 12.7% had no children, and about half of the couples without children were concerned about infertility. Furthermore, more than half of those who were concerned about infertility responded that they had undergone tests and/or treatment for infertility.

In a 2004 White Paper on Birthrate-Declining Society, the changes in the birth rates were analyzed, and it was confirmed that there has been an increase in the number of people who have never married, who marry later, and bear children later, and that the trend of fewer children was produced by couples married since about 1990. It is pointed out that some of the factors are delays in the preparation of the environment to support working while raising children, more people pursuing higher education, changes in the sense of values regarding marriage and child birth, increases in the feeling of burden from raising children, and an increase in economic uncertainty. This indicates that the major influences on the birth trends are the timing of marriage and the decision whether to have children. There are

limits to what can be accomplished with science and technology in this regard, but IT could probably make some contribution, such as through telecommuting, and remote learning during maternity and child care leave or before re-entry to the work force, helping society to prepare the environment to support people desiring to simultaneous work and rear children. This is discussed separately later.

According to research by the Ministry of Health, Labour and Welfare, in FY2002 it was estimated that about 467,000 people had gone through fertility treatment for infertility. The *in vitro* insemination and embryo transplant technology that is part of the available fertility treatments were first performed in the United Kingdom in 1978; and in Japan in 1983 the first baby resulting from *in vitro* insemination was born. Since then, the technology has spread rapidly, with the Japan Society of Obstetrics and Gynecology (JSOG) reporting in 2003 that about 68,000 people underwent *in vitro* fertilization and embryo transfer at 648 facilities registered with the JSOG, resulting in the births of about 17,000 children. Fertility treatments assist couples afflicted by infertility, but the technology is left up to the individual medical facilities. In addition to improving technology, such as increasing the implantation rate, there are other issues to be resolved, including provision of information clarifying the limitations and scientific basis of *in vitro* insemination and its therapeutic application, safely providing new infertility treatments, not only from the medical aspects, but also including psychological support, as well as dealing with the life ethics and health problems for women resulting from a multiple pregnancy.

## (2) Raising healthy children

### ●Improving medical technology to help raise healthy children

The perinatal[4], newborn infant and infant mortality rates in Japan are among the best in the world. With regard to deaths of pregnant women as well, the level is on par with other developed nations, though not as high as in some countries in Europe (Table 1-2-2).

Pediatrics covers the health, growth and development of infants, small children and youths. This is a field of medicine that was born more than a century ago in response to an increasing awareness that the health problems of children are different from those of adults, and that there are varied reactions by children to stress and illness, depending on their age. At the start of the 20th century (1904) the neonatal and infant mortality rates in this country were 73.9 and 151.9, respectively (per 1,000 live births). One hundred years later (2004), these rates are 1.5 and 2.8, respectively, a drastic improvement. (Figure 1-2-3) These improvements are the result of progress in the prevention and treatment of disease, as well as other areas of science and technology. Consequently, pediatric care can focus attention even on diseases that have relatively few patients. There is ongoing development of treatments and research to elucidate the mechanisms of intractable diseases like pediatric cancers, metabolic disorders like endocrinological disease, asthma, and allergic reactions like atopic dermatitis. In addition, in order to support health throughout a long life in an aging society with fewer children, follow-up study, such as surveys of the later rate of incidence of cancer for childhood cancer patients, will be important, so there is starting to be research on building a database of chronic pediatric disease patients. By building mechanisms to appropriately manage and utilize the information based on the consent of the participants, and recording as much information as possible in the databases, this is expected to contribute to the future development of pediatric medicine.

[4] Perinatal mortality indicates the total of fetal deaths after 22 weeks of pregnancy and early stage newborn infant deaths (deaths within one week of birth) from the Ministry of Health, Labour and Welfare "Vital Statistics." Internationally, the comparison is for fetal deaths in and after the 28th week of pregnancy and early stage newborn infant deaths.

**Table 1-2-2 International comparison of perinatal, infant and maternal mortality rates.**

| | Fetal deaths in and after the 28th week of pregnancy + early stage newborn infant deaths (per 1000 births) | Infant mortality rate (per 1000 births) | Maternal mortality rate (per 100,000 births) |
|---|---|---|---|
| Japan | 3.7 (2002) | 3.0 (2002) | 7.1 (2000) |
| USA | 5.6 (2001) | 6.8 (2001) | 10.0 (2000) |
| United Kingdom | 8.2 (2000) | 5.2 (2002) | 6.0 (2002) |
| Italy | 6.7 (1997) | 4.7 (2001) | 2.1 (2001) |
| Sweden | 5.4 (2002) | 3.3 (2002) | 3.3 (2001) |
| Germany | 5.9 (2001) | 4.3 (2001) | 3.7 (2001) |
| France | 6.6 (1999) | 4.5 (2001) | 6.5 (2000) |

Source: Based on the United Nations “Demographic Yearbook” 2001 and 2002

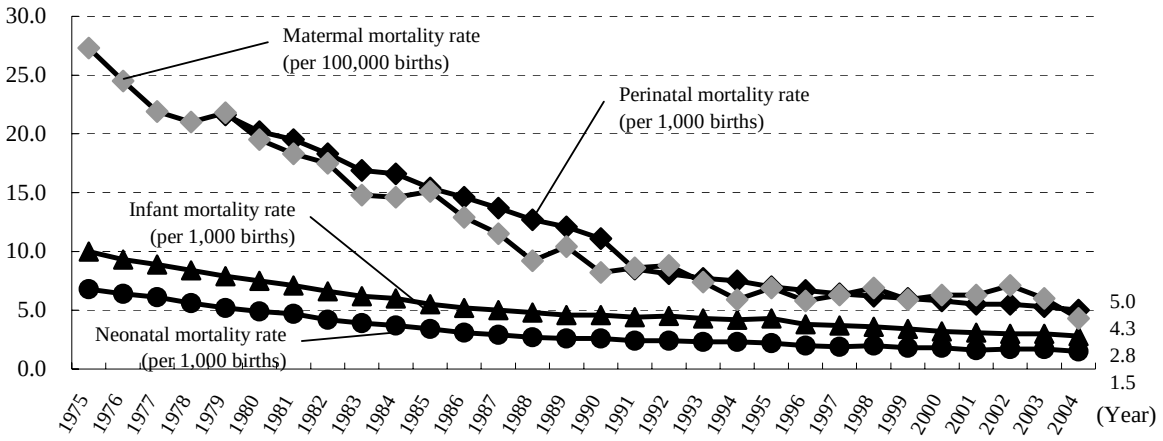



**Figure 1-2-3 Trends in indicators of mother-child health**

Notes: 1. The births for the maternal mortality rate are the number of foetal death (after 12 or more weeks of pregnancy) added to the number of live births.
2. The births for the perinatal mortality rate are the number of foetal death after 22 or more weeks of pregnancy added to the number of live births.

Source: Created by the Ministry of Education, Culture, Sports, Science and Technology using the Vital Statistics of the Ministry of Health, Labour and Welfare

### ●Incorporation of Brain Science Research

In a resource-poor nation like ours the most important issue is making the fullest possible use of the talents of each individual. As we face an aging society with fewer children learning and education throughout a lifetime becomes even more important. In particular, the period of infancy and early childhood is an extremely important time in which the foundation of the neural circuit that forms the base of thoughts and feelings is developed. While the various artificial devices that have arisen from the development of science and technology, such as television and the internet are drastically changing the living environments and behavior patterns of people, there is a growing concern about the effect of these changes on the development of children.

On the other hand, due to the recent advances in brain science, it has become possible to seek biological processes in the mechanisms of human learning and education. Progress in brain function imaging technology, such as functional magnetic resonance imaging (fMRI) has enabled empirical study of the function of the human brain. There is also progress on the identification of genes that contribute to intellectual activities in humans along with advances in molecular biology using model organisms, such as mice. These advancement of studies lead to the rise of research to elucidate genetic and environmental impact on human intellectual ability. From the biological point of view, “learning” is a process of the brain reacting to stimuli from the environment, and building or modifying it’s own neural network for managing and processing information; while “education” can be called a process of controlling/supplementing the necessary stimuli to build/modify the neural network.

The human brain has evolved by adapting to a changing, uncertain environment. The brain is the source of desires and emotions (feelings), which interact with memory and learning in various ways. The above-mentioned learning can occur in a sudden flash of understanding. If research based on scientific, empirical evidence progresses with regard to the important working of the brain in establishing human social activity, including the development of creativity and insight, empathy and understanding of the emotions and context of the speech of other people, and the ability to express one’s own thoughts and feelings with appropriate behavior, it should be possible to obtain important knowledge on raising people with sound bodies and minds. (Figure 1-2-4)

From this perspective, in 2000, Japan was the first in the world to establish an interdisciplinary field that combined brain science and education and subsequently initiated research in this area. The subject goes beyond the boundary between natural science and humanities/social science, integrating many different fields, including brain science, developmental psychology, ethology, linguistics and pedagogy. Research is proceeding using advanced brain function measurements and various information technologies. Through the collaborative efforts of scientists and teachers and other people directly involved in education, the accumulated on-site knowledge and know-how is being systematized based on the empirical evidence. To give one example, abnormalities in bodily rhythms, such as autnomic nerve/hormone secretion/body temperature regulation/sleep-waking functions, are one of the major factors in poor school attendance. It is gradually becoming clear from brain function imaging and physiological and molecular biology methods that if the situation continues, there is damage to higher-order functions, such as recognition abilities and judgment abilities. Based on this understanding, treatment methods are being developed, such as high-intensity light treatments, and progress is being made to clarify the lifestyle conditions that contribute to poor school attendance, and applications in actual society are being tried. In addition, basic research is being undertaken with the goal of clarifying the principles and mechanisms of brain development, with the focus on the growth and development of the human mind. For the first time in the world the mechanisms of the critical period (period in which functional changes of the brain can easily occur through experience and learning) have been clarified on a molecular level, and results are being obtained, such as success in achieving pharmaceutical manipulation. It is expected that connections with the acquisition of language and sociability will be clarified in the future. Japan has also sponsored a network conference attended by educators and brain science researchers from throughout the world, focusing on “Brain Development and Lifelong Learning” as part of an OECD (Organization for Economic Cooperation and Development) project. The goal is to contribute

to a dialog between brain science researchers and educators to identify issues in education and provide some brain science solutions, or provide new avenues of development for brain science. There is a demand for means to connect brain science and education, including the fostering of personnel with a deep understanding of both brain science and education.

Neuroethics have played an extremely important role in the advancement of the above-mentioned research and efforts to return the results to society. In addition to study on how to confirm the consent of the people participating in the research (informed consent), it is important to verify the knowledge obtained from a variety of perspectives, and to clarify what is clear and what is not known, and announce this to society. In the future, new problems may arise, such as how to handle the technology if it does become possible to externally read the thoughts of people, or if drugs are developed to improve performance, who would have permission to use them. For this, it is necessary to hold discussions with a wide range of interested people, and to proceed in ways that improve the quality and happiness of society and the daily lives of individuals.

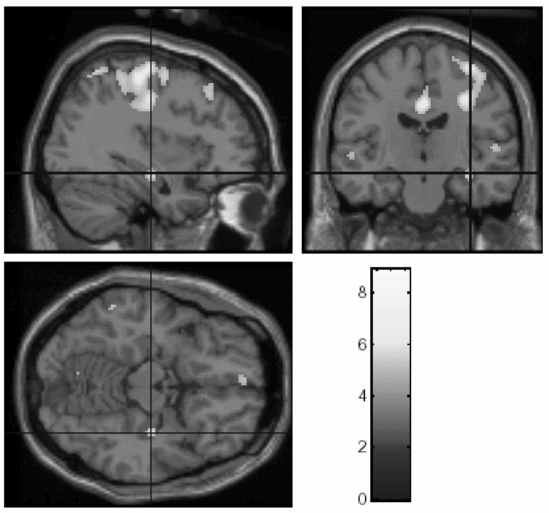



**Figure 1-2-4 Activity in the hippocampus during intellectual learning**

Photo courtesy of the National Institute of Advanced Industrial Science and Technology

## (3) Healthy aging for the elderly

According to the “Population Estimates” by the Ministry of Internal Affairs and Communications Statistics Bureau, as of October 1, 2004 the percentage of the total population aged 65 years or more was 19.5%, and the percentage of those ages 75 years or more was 8.7%. The 2002 projections by the National Institute of Population and Social Security Research indicate that by 2030 these percentages will be 29.6% and 17.8%, respectively. In an aging society with fewer children, it is very important for the elderly to keep fit and to support themselves for the purpose of increasing the quality of life of the citizens and decreasing the burden on society (Figure 1-2-5). From this perspective it is necessary to continue with research and development on the prevention, diagnosis and treatment of diseases including cancer and other lifestyle-related diseases, fractures and dementia that require full-time nursing care. Below is a description of the trends in research and development related to major illnesses.

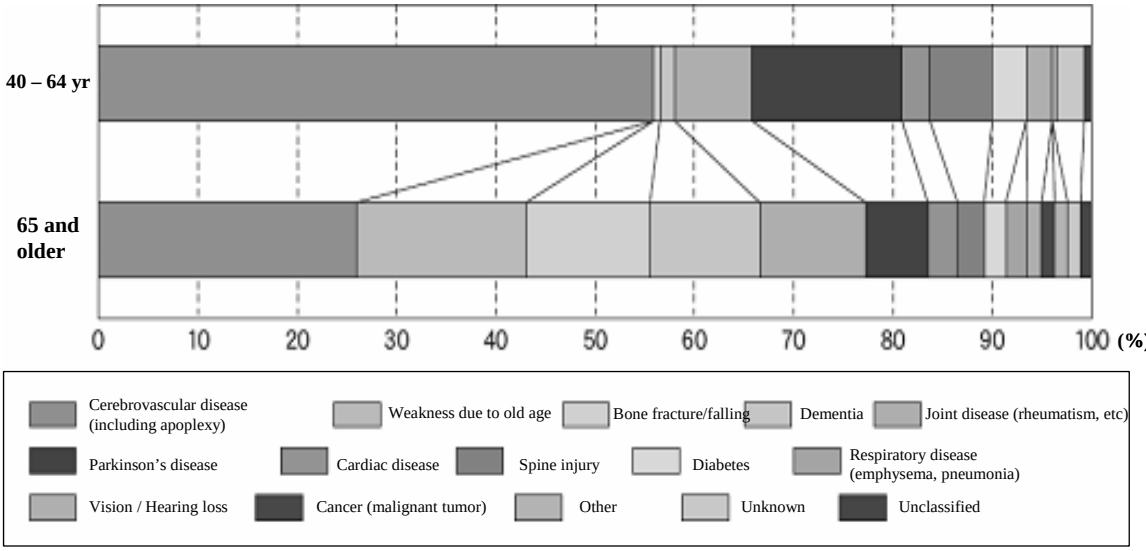



**Figure 1-2-5 Reasons nursing care is required**

Source: Ministry of Health, Labour and Welfare "2004 White Paper on Health, Labour and Welfare"

## ●Cancer

Since 1981 cancer has been the number 1 cause of death in Japan. As the aging of society progresses, the number of patients increases. In recent years more than 300,000 people die of cancer annually, accounting for more than 30% of all deaths. Controlling cancer is a common problem for all mankind, and various countries, including the USA, are placing a focus on cancer research. Researchers in Japan have long played an important role in cancer research, starting with the first successful carcinogenesis experiment in the world in the 1910s. The government has also provided focused support, including continuing research since fiscal year 1984 based on the "Comprehensive 10-year Strategy for Cancer Control" and the "New 10-year plan to overcome cancer."

Since the beginning of the 1980s genes related to the growth of human cancers have been discovered. These are widely present in nature, and it is known that originally they have important roles in normal cell growth and differentiation. It is also becoming clear that a single cancer cell is formed after a combination of successive mutations in various cancer genes and cancer-suppressing genes, and that it means there are abnormalities in the DNA replication function. This understanding is being applied to cancer prevention, diagnosis and treatment methods, and is producing significant results. For example, the location of a virus that causes a type of leukemia common in the Kyushu region and suppression of the main infection paths, resulted in a drastic decrease in infections.

Research on the diagnosis and treatment of cancer is proceeding rapidly, such as the development of cancer diagnosis at the molecular level, molecule targeted therapies[5], and immunotherapy[6]. Japan is also at the forefront in the development of medical equipment, such as the development of helical CT[7], which is effective for early detection, and particle ray treatment facilities to enable the treatment of formerly difficult-to-treat cancers.

[5] Molecule targeted therapy: Conventional anti-cancer drugs have been poor at differentiating between cancer cells and normal cells, creating many adverse drug reactions. Molecule-targeted therapy is a new kind of treatment that makes use of cancer research results to target the unique characteristics of the cancer cells at the molecular level with drugs. It is becoming an effective treatment method for leukemia, breast cancer and lung cancer.
[6] Immunotherapy: A method of treating cancer by targeting the various "tumor antigens" characteristic of cancer and directing the immune functions using a variety of cells and molecules involved in immunity to have the immune system attack the tumor, or suppress the tumor cells ability to avoid the attack from the immune system.
[7] Helical CT: A CT system is equipment to scan an object (patient's body, etc.) with x-rays, process the data with computers and create detailed cross-sectional images of structures inside the object. Helical CT is a form of CT in which the x-rays are emitted in spiral and images are obtained while the support table is moving. This makes it possible to obtain higher-resolution images in less time than with ordinary CT, and is effective for early detection of lung cancers, which can be difficult to find.

In addition, cancer epidemiology and the development of a foundation of cancer information have made it clear that changes in the cancer incidence rates have accompanied changes in customs of daily activities, such as westernized dietary patterns, revealing the importance of environmental factors in cancer prevention.

Much has been clarified by research so far, but details of the mechanisms that cause cancer to occur are still not clear, including how normally-functioning cells become cancerous, grow, invade surrounding cells, metastasize, and avoid attacks from the immune system. There are still cancers that are difficult to treat, like pancreatic cancer, and it is necessary to further improve cancer prevention, diagnosis and treatment methods.

In order to further improve the effectiveness of cancer countermeasures and increase the benefits to all citizens, "The Third Term Comprehensive 10-year Strategy for Cancer Control" was established as a strategy starting in FY 2004. Under this strategy, aiming at reducing the mortality rate due to cancer and maintaining the quality of life (QOL) of patients with cancer, in addition to technology development of molecular imaging research, there is also research being done to improve cancer prevention, early diagnosis and treatment methods, including promotion of translational research (Figure 1-2-6) applied to active prevention, diagnosis and treatment using the results of basic research obtained from research labs, as well as promotion of personalized medical care that is adapted to the characteristics of each individual (Figure 1-2-7).

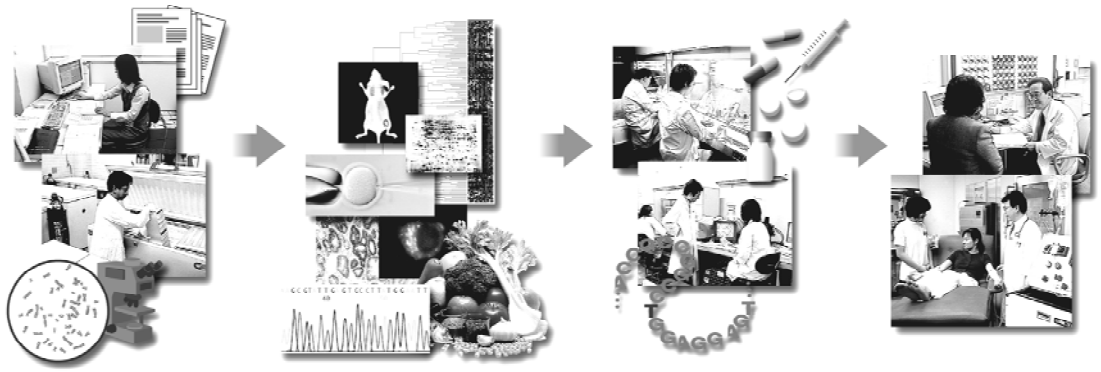



**Figure 1-2-6 Translational research**

Source: Ministry of Health, Labour and Welfare/Ministry of Education, Culture, Sports, Science and Technology

### ●Cardiovascular diseases

Heart disease and stroke (apoplexy) are cardiovascular diseases that, along with cancer, make up the three main lifestyle diseases.

According to the fiscal year 2004 vital statistics compiled by the Ministry of Health, Labour and Welfare, heart disease and stroke account for about 16% and 13%, respectively, of the deaths of Japanese people. The typical form of heart disease is a cardiac infarction, or heat attack. The vessels carrying blood to the heart muscle become blocked and a portion of the cardiac muscle tissue dies, resulting in a loss of heart function. A stroke (apoplexy) occurs when blood vessels in the brain become blocked or break. In many cases of stroke, even if the patient's life is saved, there is permanent damage that interferes with daily activities.

Arteriosclerosis is often associated with cardiovascular diseases. It was once thought that arteriosclerosis occurred as fatty deposits gradually accumulated on the inner walls of blood vessels. Recent research, however, indicates that the fatty deposits accumulate within the walls of the blood vessels, rupture and create lumps in the blood (thrombi) which cause spasms, such as heart attacks. It has become clear that inflammation during this process plays an important role. This knowledge is already being utilized for surgical tools. As research progresses in the future, it is expected that new diagnostic and treatment methods will be developed.

There is also research to comprehensively find the genetic factors associated with heart attacks. If the relevant genes can be identified, drugs can be developed to suppress their function, or an individual person's genes could be examined and advice on behavior and diet could be made, or medications administered to prevent the onset or recurrence of the disease.

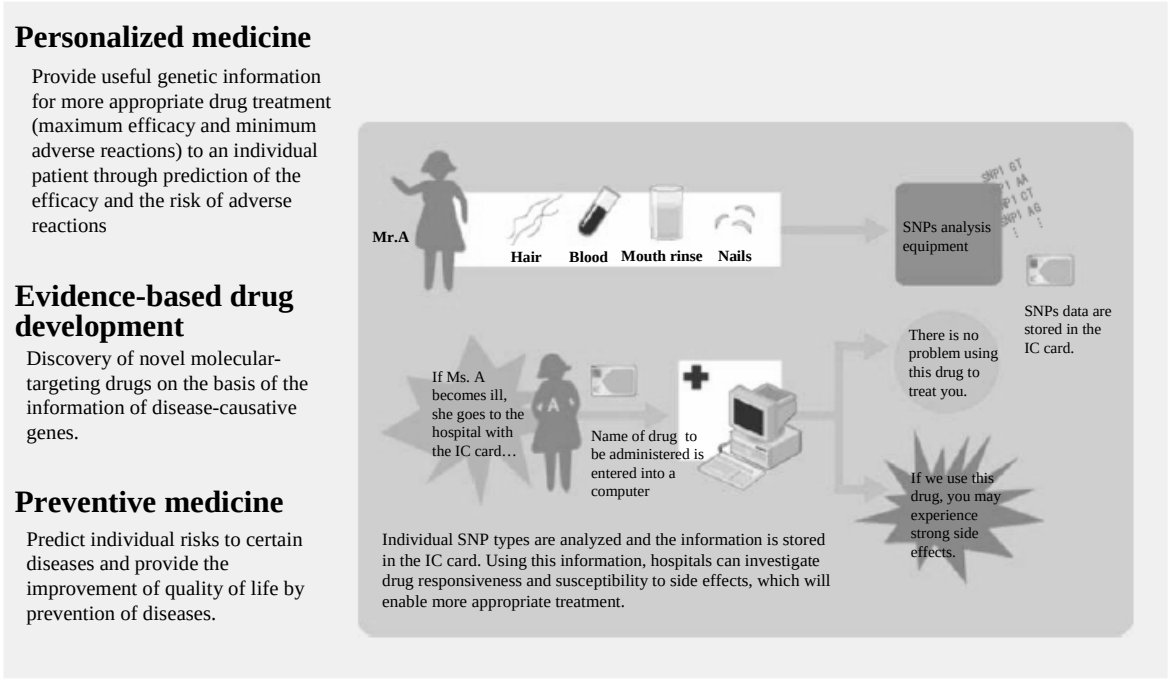



**Figure 1-2-7 Hospitals of the future**

Source: RIKEN

### ●Diabetes

In Japan there are about 7 million people afflicted by diabetes, and that number is estimated to be twice as large if potential diabetes patients are included. There are several types of diabetes, including varieties that appear during childhood, but more than 95% of the cases are Type 2 diabetes, which appears in middle age or later. Diabetes is associated with complications such as numbness or gangrene of the hands and feet, diabetic nephropathy, and loss of vision, and an increased susceptibility to arteriosclerosis and autonomic nerve malfunction. The impact of diabetes on society is quite large, not only due to the deaths directly attributed to diabetes, but also including all the complications that occur and the costs of medical treatment while fighting the illness.

In diabetes glucose, which is the source of energy for cells inside the body, is not taken up by the cells, so high concentrations of glucose remain in the blood, having a damaging effect on the blood vessels throughout the body, which causes the various symptoms described above. The concentrations of glucose in the blood are regulated by insulin secreted from the pancreas. Diabetes is thought to occur because of reduced secretions of insulin from the pancreas and/or resistance to the action of insulin in peripheral tissues such as skeletal muscles, adipose tissues and the liver. Obesity is a factor that increases the risk of diabetes. Dietary measures and exercise are necessary for the treatment of diabetes. At the same time, medications have been developed and used to stimulate the secretion of insulin and improve the insulin's effectiveness. In patients for whom it is not possible to obtain a sufficiently high insulin secretion, insulin manufactured using gene recombination technology is administered. This is cheaper and has fewer side effects than the insulin derived from cows and pigs.

### ●Bone and Joint disease

Many people are bothered by bone and joint diseases. In Japan out of the top 10 diseases that are generally treated on an out-patient basis, three are bone and joint diseases (2001 Ministry of Health, Labour and Welfare, "Comprehensive Survey of Living Conditions of the People on Health and Welfare"). The diseases are expected to increase as society continues to age. Damage to locomotive organs due to bone and joint disease has an especially large impact on the quality of daily life; it also imposes a large economic burden on society, as evidenced by the estimated 26 trillion yen (1995) spent on countermeasures in the USA. Bone and Joint diseases are a worldwide problem, and the World Health Organization (WHO) has engaged in countermeasures by positioning the 10-year period starting in 2000 as "Bone Joint Decade."

Bones and joints repeatedly break and form in response to external factors throughout life. In recent years research has made it clear that bone and joint diseases are multi-factorial hereditary diseases that result from genetic factors (multiple susceptibility genes) and environmental factors (exercise, diet, load from body weight, etc.). There are more than 10 million osteoporosis patients in Japan. There are anti-osteoporosis drugs that work on the metabolic processes, but they do not fully satisfy the needs of most patients. Through animal experiments a substance that attacks cells that destroy bone has been discovered in Japan. There will be efforts to develop marketable medications with minimal side effects in the future.

For other bone and joint diseases, currently there are basically no effective treatment methods. There is currently work underway to clarify the genetic factors, such as for osteoarthritis that affect approximately 7 million people in Japan, the herniated disks that are the major cause of lumbago and sciatica, in order to achieve a breakthrough. Application to develop effective treatments through functional analysis for the genes that are identified is expected.

### ●Alzheimer's disease

Alzheimer's disease is a representative disease that causes dementia. It is a disease in which the neurons of the brain slowly die over a long period of time and about one out of 5 people over the age of 85 is affected. There is concern about an increase in the number of patients as the aging of society progresses. In the past, the mechanisms of onset of the disease were not well understood and the treatment was to administer drugs to promote the transmission of information between neurons, rather than trying to prevent the death of neurons. In recent years there have been rapid advances in research on the mechanisms, including the production and breakdown of substances called tau proteins and $\beta$−amyloid, which is thought to contribute to

neuron damage (Figure 1-2-8). Based on the research results, efforts are being made to develop prototype vaccines and drugs to suppress these substances.

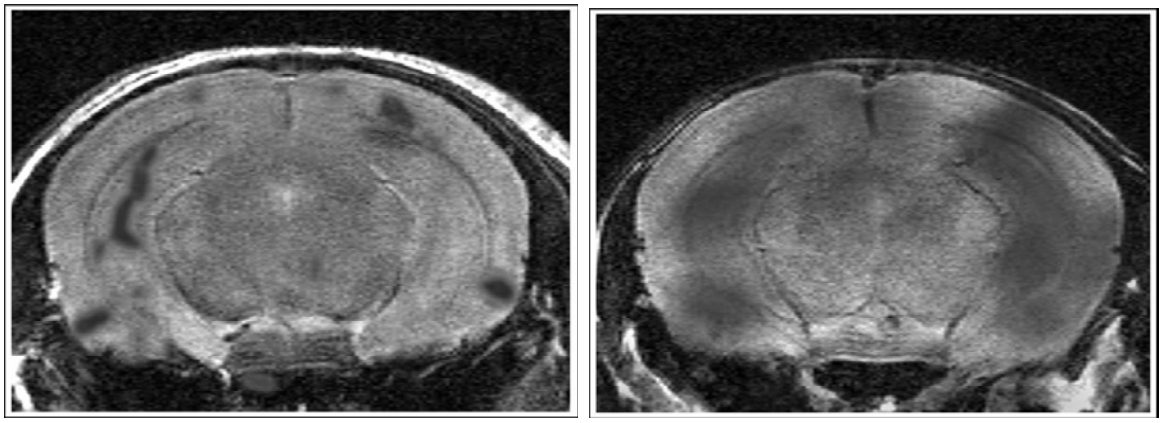


**Figure 1-2-8 Bioimaging of a mouse with Alzheimer's disease**

This is the first successful imaging of $\beta$-amyloid using MRI (red portion in the photo) on a living animal. The photo on the left was taken at a younger stage. In comparison, it is clear that the $\beta$-amyloid accumulation has advanced in the photo on the right.
Photo courtesy of RIKEN

[Column 2]

## Completion of the Haplotype Map of the Human Genome

About 99.9% of the base sequence of the human genome is the same, even among non-relatives. The difference of individuals is in the remaining 0.1%, and a part of it is thought to be connected with the difference of individuals relating to the risks of diseases or sensitivity to medicines. Analysis made by connecting the location of the variety of human genes or their patterns and the development of diseases or reactivity to medicines may lead to the clarification of pathogenesis and development of new treatments. For this purpose, a genome map that shows the variety of genes is necessary.

SNPs (Single Nucleotide Polymorphisms) are an index to show variety in the genome. SNPs are the difference of four (A, T, G, and C) types of bases, i.e. some people have A and others have G at a certain location. In an entire human being, there are SNPs in several hundreds of base pairs, and about 10 million SNPs in total are considered to exist throughout the whole genome.

To find medically important polymorphisms from about 10 million SNPs, it is not necessarily required to check all SNPs. Because the genes or SNPs linking close on a chromosome are passed from parents to children, it is effective to check individual differences by using a combination called Haplotype (Reference). The Haplotype Map was made by an international joint group of 14 centers in 5 countries, Japan, the U.S., U.K., Canada, and China. From Japan, the RIKEN SNP Research Center participated and was assigned the analysis of 7 chromosomes which are equivalent to 24.7% of the genome.

This project was completed in October 2005. Using a sample of 269 people from Africa, Asia including Japan, and Europe, SNPs of about 1.1 million locations were analyzed and a high-density Haplotype Map with at least one SNP located in each of 5,000 base pairs was made.

As a result of this project, it became clear that, with Japanese and Chinese people that a race composing a group is comparatively uniform, checking SNPs at 250,000 locations covers 98.5% of the entire genome of 10 million locations. Cancers and adult diseases are caused by a combination of several genetic factors and environmental factors. By the completion of this Haplotype Map, it is expected that genetic research related to such frequent diseases and effects and side effects of medicines will become more efficient, and that the discovery of genetic factors may lead to innovative diagnosis and the development of cures.

(Reference)

**Fig. A Types of theoretical Haplotypes**

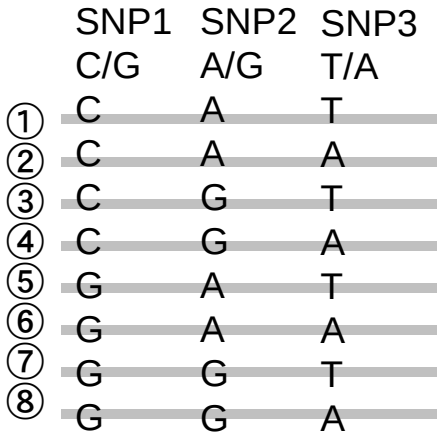
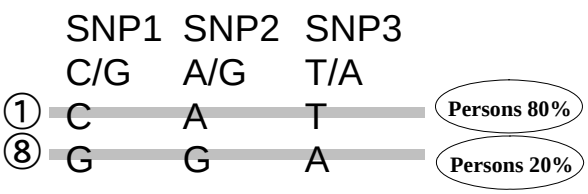



**Fig. B Example of Haplotype observed in actual groups**




As shown in Fig. A, when SNPs (Single Nucleotide Polymorphisms) exist at three locations, there are theoretically eight kinds of combinations on one chromosome. However, if the physical distances among three polymorphisms are comparatively close, it is often the case that only some kinds of Haplotypes are seen, as shown in Fig. B. The situation is different depending on the location on the chromosome, and it is necessary to understand the entire genome area.

## (4) Contributions to health from fundamental research of biological systems and nanotechnology

### ●Application of immunology to medical care

The immune system is a mechanism to monitor and defend the body. The immune system recognizes not only pathogens, such as bacteria and viruses that invade the body, but also foreign bodies, like cancers, that originate inside the body, and uses a variety of cells and molecules to destroy and eliminate them to maintain the body in a fixed condition. For the proper working of the immune system it is necessary to accurately select the target of the attack and perform the appropriate adjustment. The human immune system is a complex and ingenious mechanism comprising a diversity of cells and groups of molecules.

However, the performance of the immune system declines with increasing age after adolescence, increasing susceptibility to immune disorders and infectious diseases. As the aging of society progresses, there is a concern that there will be an increase in rheumatoid arthritis and auto-immune disorders[8]Japan has been a world leader in immunology, starting with Shibasaburou Kitasato, generating major results, such as clarification of the information transmission system of the immune system, but the immune system is an extremely complex network, and there is still much that remains unknown.

Treatment drugs for auto-immune diseases are being developed, but the immune system is a complex mechanism, and a broad suppression of immunity causes other problems, including increased susceptibility to cancer and infectious disease. Obtaining a more detailed understanding of the mechanisms of the immune system should make it possible to develop treatment methods that are better targeted and have fewer side effects.

### ●Cutting-edge technology - Regenerative medicine

Developmental biology is the study of the processes of aging and regeneration to restore lost tissue, focusing on the process (development) of the repeated cellular division and differentiation from a fertilized egg to form an individual, multi-celled organism. Modern medicine, including advancements in regenerative medicine, is opening the possibilities for the treatment of lifestyle diseases and difficult ailments, like spinal cord injury and cardiac infarction, through the use of cell and tissue transplants.

In addition, development is also promoted on such technologies as strong, readily-accepted artificial bones and ligaments that gradually release substances to promote tissue regeneration through the application of nanotechnology, artificial organs including artificial livers and pancreases that are a fusion of cells and nano-biomaterials, and nano drug delivery systems to deliver medications or genetic material to targeted areas in the body in order to treat difficult diseases or to provide genetic treatment.

### ●Fundamental research

In October 2004, the International Human Genome Sequencing Consortium, composed of research centers in six countries including Japan, announced results of verification and analysis of the precise sequencing of the human genome, including the approximately 22,000 genes that regulate the structure of the proteins that make up the human body. This number is significantly lower than expected. This has led to the extremely interesting new discovery that the RNA that can be read as the pattern for DNA has a wide variety of functions besides the previously-known role as the blueprint for creating proteins.

[8] Auto-immune disorders: The original role of the immune system is to recognize and eliminate foreign substances, such as bacteria, viruses and tumors. This is a general term for the diseases in which the immune system over-reacts and attacks normal cells and tissues of its own body.

Progress continues on genome research, including study of the background behind the differences in abilities, such as between humans and chimpanzees and between exceptionally long-lived people and ordinary people; research on how living things develop from fertilized eggs, the kinds of RNA produced at each of the various stages as aging progresses, and how this RNA works; research on the tertiary structure of proteins that fill a variety of functions within the body, as well as making up the body; and research using computers, etc. to understand the actions and interactions of these various components as a complete biological system. There is also continuing development on the basic technology required for the research, including analytical technology.

This research provides the knowledge that forms the foundation for a variety of research, such as molecular biology, cellular biology, developmental biology and immunology that is being advanced at universities, as well as promotes the understanding of life phenomena. It is expected that this will help support the development of medications and an understanding of the causes of various diseases.

### 1.2.1.2 Science and Technology to Improve Social Welfare

In 2004 the Cabinet Office conducted a survey, "Opinion Survey on Normal Daily Activities of the Elderly," with men and women aged 60 and older as the subjects. In response to the question "Are there times you feel any disability in conducting ordinary daily activities?" 86% of all respondents indicated "generally fine," but this drops to 54% among those 85 years or more (Figure 1-2-9). To a separate question, about 70% of all subjects indicated "concern about ordinary daily activity in the future," with the number one reason for the concern being "health and sickness of myself and my spouse," and the number two reason "me or my spouse becoming bedridden or disabled and requiring nursing care."

In the "Public Opinion Poll on Nursing Care of the Elderly" conducted by the Cabinet Office in 2003 subjects were asked a question allowing multiple responses about problems in the case it becomes necessary for a family member to have nursing care. The number one response, selected by over 60% of subjects, was the heavy burden of care and physical burden, with the number two response being the stress and emotional burden.

Increasing the quality of life for the elderly and being able to remain largely independent and able to participate in society throughout life, and reducing the burden on care-givers are important issues for an aging society and are highly demanded by society. The cutting edge science and technology to supplement the functions lost due to age or injury, and to support care-givers and relieve them from the heavy work of nursing care is introduced (Figure 1-2-10).

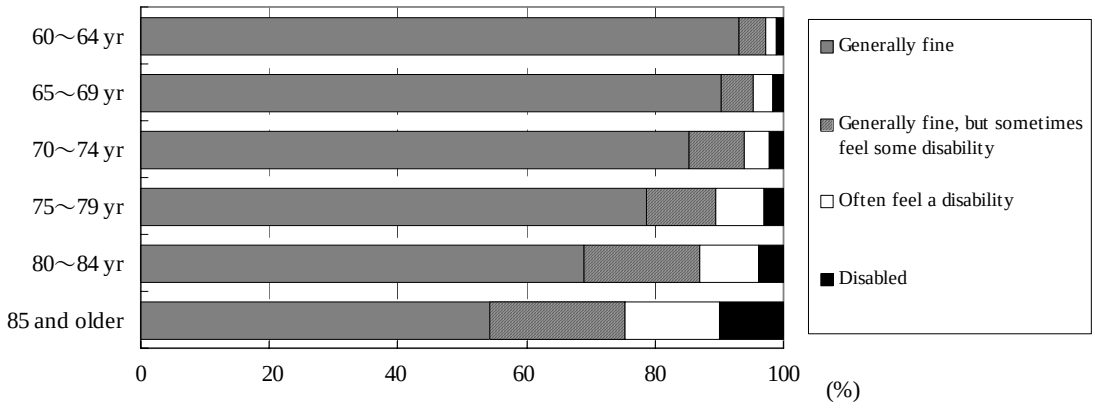



**Figure 1-2-9 Are there times you feel any disability in conducting ordinary daily activities**

Source: Cabinet Office "Opinion Survey on Normal Daily Activities of the Elderly" (2004)

### ●Cyborg technology

Research is progressing on cyborg technology, replacing some of the functions of the body by applying neuro-engineering, which is technology that makes use of brain information. Muscles are the devices that drive the hands and legs, and operate according to electric pulse signals that run through the nerves. If it were possible to read these signals, and feed them to an external drive device (a motor, etc. to produce motion instead of the muscles), it might be possible to cause an external device to move using biological signals. This concept is the origin of neuro-engineering.

Even if you lose an arm in an accident, if you think “move arm,” the same signals are still transmitted from the brain to the nerves that originally were involved in moving your arm. By reading the electrical signals from those nerves and connecting them to the controller for a robotic arm designed to move in response to those signals, it is possible to create a robotic arm that can be moved like your own arm, simply by thinking, without any other special operations.

Furthermore, there is research being conducted on replicating the sense of touch, so that by attaching touch sensors to an artificial hand, the electrical signals from the sensors can be converted and transmitted through the nervous system. By gaining an understanding of the pattern of the signals that flow throughout the nervous system, it is becoming possible to take signals from external devices and send them as signals that the brain will interpret as signals from an actual sense organ. There is already development being done on artificial eyes and ears using this kind of technology, with more than 60,000 people throughout the world already using this kind of artificial ear.

[Column 3]

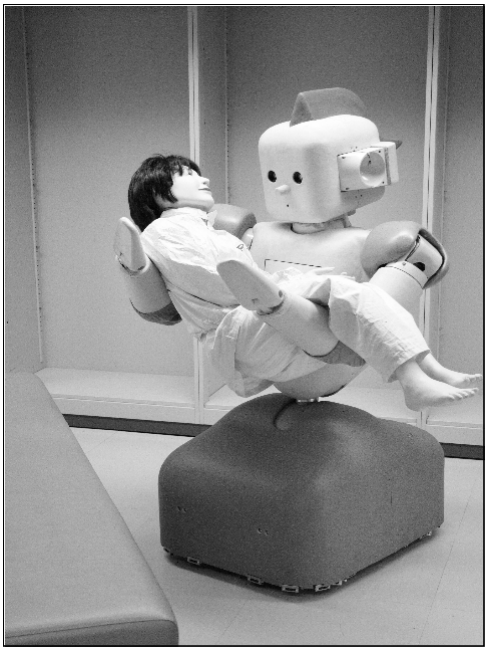
### Wearable Robots (Robot suit HAL (Hybrid Assistive Limb) developed by University of Tsukuba)

Due to the development of a decreasing and aging of population, there are manpower shortages for hard labor, disaster relief, and nursing. A method to help the aged to move, whose physical capability is weak, is also desired. When using robots to cope with these problems, an autonomous/tele-operated robot is desirable for dangerous hard labor or rescue at a disaster site where humans cannot enter. However, for nursing that needs human judgment and communication, or as mobility support to help a person to move as he/she wishes, a robot to amplify and enhance physical functions is desirable.

Robot suit HAL (Hybrid Assistive Limb) was developed for the purpose of assisting the motion of lower limbs, such as bipedalism or standing and sitting. Furthermore, the latest HAL-5 can assist upper body motions and has realized the ability to amplify and enhance human body functions by the combined unit of a human being and a machine. HAL is the first successful robot suit in the world that measures how much power its wearer wishes to use by detecting bio-potential signals of muscle on the surface of the skin and transmitting it to the operation system.

In addition to the "function of voluntary control" that amplifies the power of the wearer as the wearer wishes, HAL has an "autonomous control mechanism" that repeats pre-programmed movements, such as assistance for a standing-up movement, by detecting the preparative movement of standing up from a chair, even for a paralyzed person whose bio-potential signals cannot be measured.

The operator can move flexibly and can push objects with great power, so that its use for hard labor, disaster relief, medical care and welfare, and entertainment is expected. The development of a system combining human beings and machines together is getting attention as new robot technology.



Left: Autonomous daily-activity support robot that is equipped with soft skin, sight, hearing, sense of smell and sense of touch, and can perform tasks with a delicate touch.
Photo courtesy of RIKEN
Below: A therapeutic robot designed to help reduce stress for elderly and caregivers
Photo courtesy of the National Institute of Advanced Industrial Science and Technology

**Figure 1-2-10 Various types of care-giving robots**

### 1.2.1.3 Science and Technology to Enable Diversification of Work Styles

There are various analyses being performed on the impact of an aging society with fewer children on the daily lives of the people. It has been pointed out that there is a concern that the number of buyers of goods and services will be reduced and the domestic markets will shrink, and that a reduction in the number of workers will hinder the productive activity of business.

As a nation of advanced industrial technology, it is extremely important for Japan that individual citizens improve their abilities to support the society. The full utilization of abilities in society throughout life is also important from the perspective of self-realization and living a meaningful life. Furthermore, for a knowledge-based society talented people with superior skills are required, regardless of nationality, and Japan is no exception.

For the “Special Public Opinion Poll on Countermeasures to the Declining Birthrate” conducted by the Cabinet Office in September 2004 the most popular response to the question on specific hopes regarding the policies for measures to counter the declining birthrate (multiple responses allowed) was “promotion of support to balance work and family life and a reform in working styles,” with more than 50% of the respondents choosing this answer. In a “Survey on the Employment Situation of the Elderly” conducted by the Ministry of Health, Labour, and Welfare the same year, employed people between 55 and 69 years of age were asked their main reason for working. Among males between the ages of 55 and 59, 4% indicated reasons such as “to have a meaningful life or active citizenship,” “for health reasons (good for health),” and “because I was asked, because I have extra time.” Among males between the ages of 65 and 69, however, 34% chose these reasons. In the same survey the percentage of employed people who were part-time employees was reported to be 48% for males, and 61% for females between 65 and 69 years of age.

Thus in an aging society with a declining birthrate it is important to have greater flexibility from the perspective of how to spend time throughout life on work, study, leisure, care giving, etc. Furthermore, since the labor force will become a more precious resource, the abilities of individuals must be developed to the fullest, regardless of age, gender or nationality, and the mechanisms must be developed to make full use of these abilities in society.

Up until now science and technology has contributed to replacing the use of physical labor with machines. In the future, science and technology will be able to contribute to enhancing social vitality and making work easier for individuals by way of controlling and compensating for the decrease in mental and physical abilities with increasing age and improving individuals' abilities through lifelong learning, and supporting both work and family activities with domestic work support systems and telecommunications systems, along with reforms of social systems.

### ●Aging and Physical and Mental Function

In order for elderly people with a wealth of life experience to remain active in society it is important to prevent lifestyle diseases and to slow the deterioration of body and nerve functions that accompanies advancing age. Thus, science and technology should be effectively used to maintain and improve mental vigor by delaying the decline in physical function that accompanies physiological aging as well as preventing depression and preserving intellectual ability.

Eternal youth and longevity has been a topic of interest to mankind since ancient times, and research on the mechanisms of aging has progressed since the later half of the 20th century in conjunction with the development of the basic technology for biological research. In the mid 1990s the gene that causes premature aging was identified. Over the past 10 years the genes that affect the lifespan of individual organisms have been discovered using model organisms like nematodes, fruit flies, yeast, and mice. Research on these genes and the associated molecular structures suggests possibilities for the relevance of energy metabolism and stress response pathways to the lifespan. With clarification of the network of the group of genes associated with longevity and aging it may be possible to delay the progress of aging and make it possible for people to age while maintaining good health. It is also possible that this kind of application of technology in society may give rise to a variety of ethical problems, so it is necessary to proceed with research while holding careful and thorough discussion.

For many years it was believed that the cells of the central nervous system (brain and spinal cord) had no ability to regenerate, and that the numbers declined after a person was born. However, the latest results in brain science reveal that there is a process, called "neurogenesis," in which new nerve cells are generated even in the brains of adults, and that new connections between neurons are made even later in life. In addition, it has become clear that human embryonic stem cells[9] can be differentiated to form nerve cells, so it may be possible in the future for regenerative medicine to be applied for Parkinson's disease and spinal cord injuries, areas that had lacked fundamental countermeasures. However, in order for the stem cells in the brain to differentiate into nerve cells and fulfill their role, they need to move to the proper location and form a network with other suitable cells. Therefore, it is necessary to conduct further studies including the elucidation of the molecular mechanisms for this process.

In addition, depression in the elderly is a growing concern. Regarding this topic, it has become clear that stress inhibits neurogenesis and that atrophy of the hippocampus, which plays an important role in memory, is seen in patients with chronic depression. Animal experiments have shown that anti-depressants promote neurogenesis, indicating the possibility that they may be effective for promoting neurogenesis in cases of depression or Alzheimer's. It is known empirically that depression in humans can be improved through daily exercise, like running. It has also been discovered that adult mice produce a large number of new neurons in the hippocampus after they are moved from dull and uninteresting breeding cages into amusing playgrounds. With future scientific discoveries on how memory and judgment ability is improved through exercise, proper diet and adequate sleep, it will be possible to improve the quality of life through daily activities with more consideration of health based on this knowledge.

[9] Embryonic stem cell (ES cells): The stem cell stock made from the inner cell mass associated with part of the blastocyst at the initial formation stage of animals. In theory, these have the potential to be differentiated to form any type of tissue, and can be cultivated nearly without limit, so ES cells are receiving a great deal of attention for applications to regenerative medicine.