Section 2 ■ Creation of Intellectual Assets of Mankind - Creation of Knowledge -

1 Results of the creation of knowledge

The dramatic advancement of basic science in the 20th century gave rise to completely new technologies, which in turn advanced science further. As a result, things that the original researchers did not even imagine have become realities. Through this remarkable advancement of science and technology, mankind has learned much about nature, and his awareness of it has changed drastically.

2 Exploring mysteries of space and matter

Mankind's interest in and intellectual curiosity about the paths of the sun, the moon, and stars have caused mankind to shift from the geocentric view to the heliocentric view, completely revolutionizing their worldview and the way they view nature. The knowledge of astronomy has made significant contribution in establishing fundamental laws of physics such as Newtonian mechanics and the general theory of relativity.

Atoms became a subject of experiments and observation in the 20th century. Particle physics, supported by revolutionizing theories such as quantum theory and relativity theory, made tremendous progress. Particle physics continues to grow in pursuit of the ultimate theory and is changing into a discipline that addresses deep and enormous problems such as why the universe exists in the form it does. Japanese scientists have been making original contributions that lead the world in these fields.

(1) Pioneers of particle physics

Dr. Hideki Yukawa, the first Japanese Nobel Prize laureate, submitted a paper in 1935, predicting that protons and neutrons are connected by a force (nuclear force) generated by exchange of mesons[1]. This theory is a result of Prof. Yukawa's high ambitions and his endurance in hard work since his days as a student. Also behind his success were discussions with superior young researchers like Dr. Sin-itiro Tomonaga and the new, liberal research environment, provided by a pioneer of Japan's electronic engineering, Dr. Hidetsugu Yagi, who tore down the wall of the "*Koza* (chair) system" for Dr. Yukawa[2]. Dr. Yukawa's prediction on mesons led to the discoveries of many other elementary particles, ushering a new era of the theory of elementary particles.

Around 1940, there were major problems in "quantum field theory[3]," which describes elementary particles: there was a problem with its relation to the theory of relativity, and the calculations suggested that the mass of an electron might become infinite. Dr. Tomonaga resolved these problems by publishing "super-many-time theory" in 1943 and "renormalization theory" in 1947. Today, quantum field theory and the renormalization theory provide the foundations of a

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[1] Meson: Dr. Yukawa predicted that a particle that mediates the force connecting protons with electrically neutral neutrons has a mass about 200 times the mass of an electron. Today, the mesons predicted by Dr. Yukawa are called pi-mesons.
[2] *Koza* (chair) system: Under the university setup standard, this system first determines the major fields of study required for education and research and then places teaching staffs required for the education and research.
[3] Quantum field theory: theoretical framework that can integrate generation, decay, and other phenomena of particles including photons (electromagnetic waves), electrons, protons, and all other particles; this theory was born as an extension of quantum mechanics.

theoretical framework not only in particle physics and nuclear physics but also in condensed matter physics, dealing with properties unique to various substances such as semiconductors and super conductors, forming one of the most critical pillars of modern physics.

In 1955, Dr. Shoichi Sakata proposed what is known as the “Sakata model,” which was to become the prototype for the quark model[4] today. In 1962, together with Drs. Jiro Maki and Masami Nakagawa, he made the hypothesis that neutrinos, a type of elementary particle whose mass had been assumed zero, might have a mass, and proposed the theory of “neutrino vibration,” suggesting that a neutrino could change to a different type of neutrino.

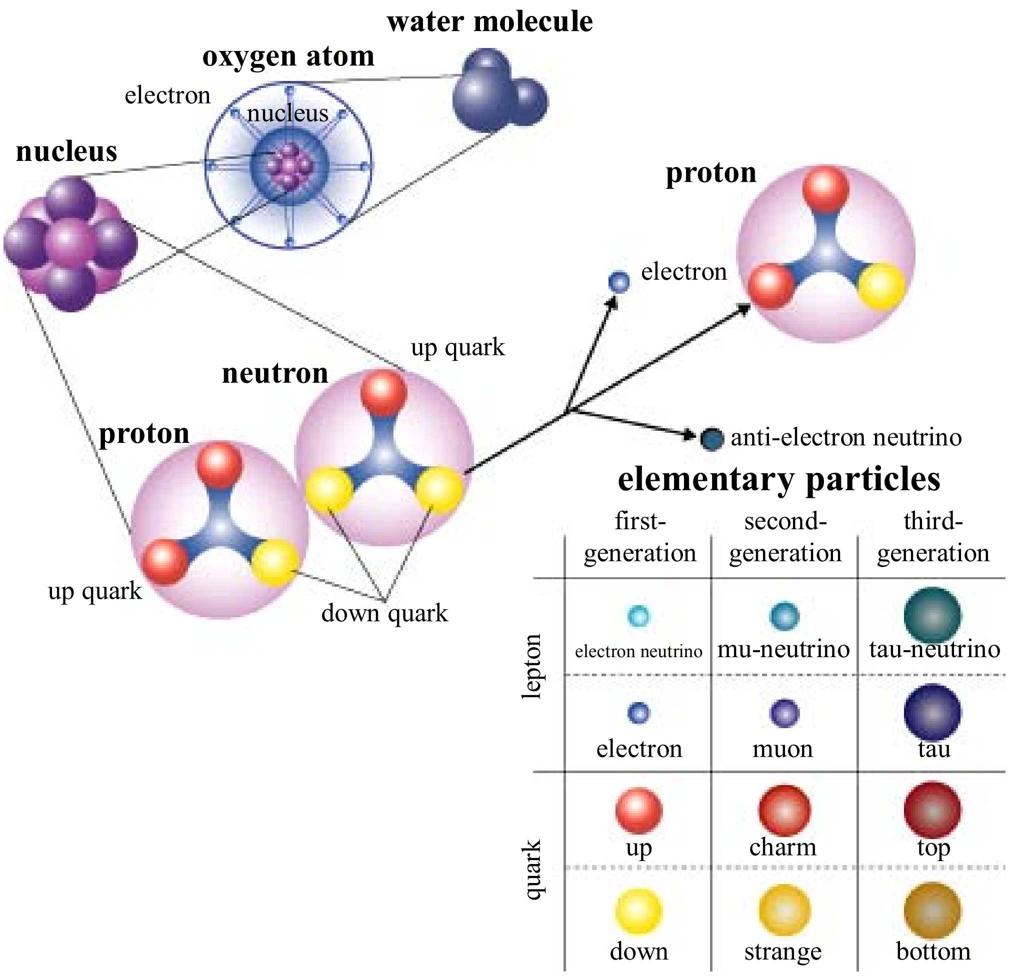
When the universe was created, “particles” and “antiparticles,” having opposite properties, must have existed in the same quantity. However, today the world consists only of the “particles.” This implies that the particles, at some time, became more numerous than the antiparticles; this is called the problem of “violation of CP symmetry[5].” In 1973, two researchers who had been in the Sakata Research Group, Dr. Makoto Kobayashi and Dr. Toshihide Maskawa, published a paper explaining this violation of CP symmetry. In doing so, they predicted that, while there were only three types of quarks known at that time, in fact at least six types of quarks must exist. Later, indeed six types of quarks were discovered (Figure 3). This “Kobayashi-Maskawa theory” has now become a critical element of the “standard theory[6],” which is at the foundation of today’s particle physics and continues to have significant impact.

[4] Quark: elementary particle that forms protons and neutrons, each of which consists of three quarks of two types.

[5] CP symmetry violation: The “C” stands for the conjugation of the electric charge or a unique value that the particle has, and the “P” represents the parity of the space axis. If both C and P are switched (CP transformation), i.e., replacing the elementary particle with its anti-particle and performing a mirror-image transformation, most of the time the physical laws remain unchanged—this is called CP symmetry. However, it was discovered that, by rare breakdown of K mesons, CP symmetry is slightly violated.

[6] Standard theory: Currently known forces include the “weak force,” which triggers breakdown of mesons, “electromagnetic force,” “strong force” such as nuclear power, and “gravity.” The standard theory is the combination of three theories: quantum chromodynamics, which explains the strong force, a theory that explains electromagnetic force and weak force in an integrated way, and the Kobayashi-Maskawa theory.

■ Figure 3 Hierarchy of matter and elementary particles



Source: Prepared by the Ministry of Education, Culture, Sports, Science and Technology, based on sources of the University of Tokyo

The High Energy Accelerator Research Organization (KEK) built a B factory accelerator (KEKB) which can create B mesons and anti-B mesons to conduct experiments to measure the size of the violation of CP symmetry, proving the “Kobayashi-Maskawa theory.”

The remarkable contribution made by Japanese researchers in the physics of elementary particles provides vivid examples of the trend that theoretical physicists learn and carry on the insights of their predecessors and then boldly propose innovative theories that exceed those, which are then validated by experimental physicists so that the theorists and experimenters form a pair to advance the creation of knowledge.

(2) Further development of particle physics and its integration with cosmology

Dr. Chushiro Hayashi, who used to be an assistant at the Yukawa Research Group, published a theory in 1950 concerning the origin of the elements in the universe in the early stages of the Big Bang. He then went on to publish a process of evolution from the birth to the death of a star as well as a model in which the origin of the solar system is theoretically analyzed. More recently, due to the remarkable progress made in radio waves, optical/IR telescopes, and detectors, it has become possible to measure the domain of planet formation outside the solar system. Many of the facts discovered through such measuring provide new evidence that the model constructed by Dr. Hayashi should be correct.

In 1983, Dr. Masatoshi Koshiba completed “Kamiokande” to search for a phenomenon known as proton decay[7] and modified it later so that it can detect neutrinos coming from the sun and supernovas. Consequently, in February 1987, he became the first person in the world to detect neutrinos generated by an explosion of a supernova that occurred in the Large Magellanic Cloud. This showed that the theory of supernova explosions is very likely correct, giving rise to neutrino astronomy, in which neutrinos are the means of measurement.

The Kamiokande was further expanded to the Super Kamiokande, established by Dr. Yoji Totsuka and others who were taught by Dr. Koshiba. In 1998 they published that they had confirmed a phenomenon called “neutrino vibration,” in which generated neutrinos change to another type of neutrinos in flight. This phenomenon implies that neutrinos have a mass and that there is a need for a grand unified theory[8] that goes beyond the standard theory. Neutrino vibration was further confirmed by a series of experiments conducted from 1999 to 2004 in which, for the first time ever in the world, an artificial neutrino beam generated by a proton synchrotron of the KEK was caught in Kamioka, 250 km away.

Dr. Atsuto Suzuki and others, who had been involved in the construction of the Kamiokande, built “KamLAND,” with which super-low energy neutrinos can be identified, and they detected, in 2005, antineutrinos (earth antineutrinos) generated by the decay of uranium and thorium in the interior of the earth. The fact that the earth’s antineutrinos, which directly contribute to producing heat in the earth’s interior, can now be observed implies that we now have a new method for

[7] Proton decay: While the standard theory states that protons last indefinitely, the grand unified theory predicts that they decay over a very long period of time; this is referred to as proton decay. As of now, this decay has not yet been confirmed.
[8] Grand unified theory: an attempt to integrate weak force, electromagnetic force, and strong force into one. This theory predicts phenomena like proton decay and neutrino vibration. The smallest model of this theory was proved wrong by measurement results of the life of protons through the Super Kamiokande and other experiments.

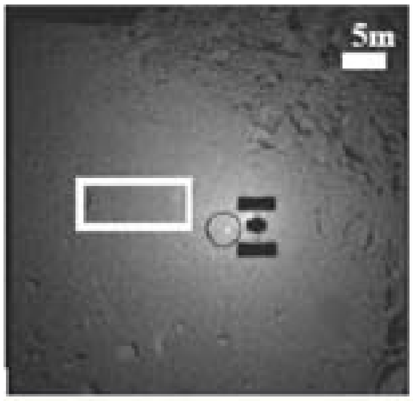
research of the earth's interior, which has conventionally been done using seismic wave analysis, etc. A new research field called "neutrino geophysics" was thus born.

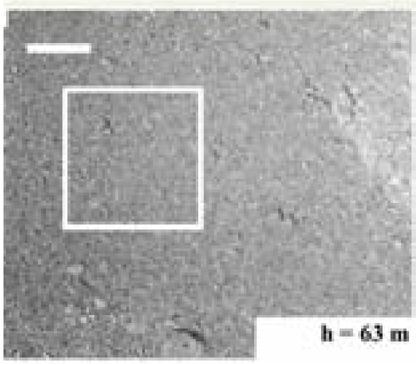
When we see stars, the light emitted from those stars long ago is reaching us over a long period of time. By observing the appearances of heavenly bodies farther and farther away, we can understand what the universe was like in its early stages.

"Subaru," operated by the National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences, is a large-scale optical-infrared telescope with a diameter of 8.2 m, largest in the world for a single mirror, and the galaxies observed by "Subaru" are considered as some of the farthest galaxies whose distances have been accurately measured. These galaxies are young galaxies, born about 900 million years after the birth of the universe.

On planets such as the earth and Mars, diastrophism, weathering and erosion by the atmosphere and water have left us with no surface evidence from the time of birth. On the other hand, it is thought that small bodies such as asteroids are like time capsules, retaining the conditions when the solar system was born. From September to November 2005, "Hayabusa," an engineering experimental explorer, equipped with a variety of revolutionary technologies including a highly efficient engine necessary for planet exploration, autonomous navigation, sample gathering, and sample collection by re-entry capsule from an inter-planetary orbit, made a rendezvous with the asteroid Itokawa, which is so far away that it takes a radio wave from the earth 17 minutes one way to reach it. Various scientific observations were made, and "Hayabusa" succeeded in landing and taking off from Itokawa. The observation made by "Hayabusa" has shown that the asteroid Itokawa is highly likely to be a "clump of debris." It has discovered, for the first time in history, a theoretically conceived celestial body that is in an intermediate stage of the formation process of a planet, revealing in detail the image of a very small asteroid drawing near to the earth (Figure 4).

■ **Figure 4 Asteroid explorer "Hayabusa"**





Top left (i): Explorer "Hayabusa" before launch
Top middle (ii): Cover of the special issue on "Hayabusa" of the scientific journal Science
From Science Vol. 312, No 5778, 2 June 2006.
Reprinted with permission from AAAS.

Top right (iii): Unprecedented landing and take-off from the surface of an asteroid
Bottom (iv): Most detailed image ever of the surface of an asteroid (the white scale represents 1 meter)

(i), (iii), (iv): Photos provided by the Japan Aerospace Exploration Agency
(iii), (iv) Photos by H. Yano, et al., Science (2006)

Generation of all substances in the universe involves nuclear reactions, but we do not yet know much about the reactions of about 10,000 kinds of unstable nuclei called radioactive isotopes (RIs). At the Institute of Physical and Chemical Research (RIKEN), Dr. Isao Tanihata, et. al. invented a technique for producing and using RI beams in the mid-1980s and discovered a phenomenon called neutron halo[9], which cannot be explained using the standard nuclear model. Triggered by this discovery, the exploration of the world of atomic nuclei by RI beam experiments[10] has begun. At RIKEN, researchers are pursuing their hope of understanding the process of element synthesis in space and pioneering a wide range of application research in physical properties, materials, chemistry, and living organisms.

(3) Results derived from quantum mechanics and particle physics

Derived from high energy physics, synchrotron radiation[11] is used in nano-size fabrication of

[9] Neutron halo: condition in which excess neutrons are spread thin around the atomic nucleus, a core, with an extremely large radius. In stable nuclei, protons and neutrons exist together in a mixed state, and the volume taken by protons is about the same as the volume taken by neutrons (common knowledge in conventional nuclear physics). However, in recent experiments using RI beams, when one examines the structures of the unstable nuclei of light elements with excessive neutrons (e.g., ^{8}He and ^{11}Li) in detail, it was found that neutrons are distributed to those located in the normal core part and those excess neutrons that spread afar.
[10] RI beam experimentation: method of producing high-speed particles of unstable nuclei (radioactive isotopes: RI) and using them to cause diffusion or reactions in order to study the properties of the RIs.
[11] Synchrotron radiation: When the motion of electrically charged particles (electrons and protons) moving at speeds near the speed of light is bent by a magnetic field, electromagnetic waves are emitted in the direction of motion. This is synchrotron radiation and has many superior properties such as being extremely bright and highly directional, and the polarization characteristic of the light can be freely changed. Initially this was considered merely a loss of energy resulting from accelerators used in particle experiments.

semiconductors, non-destructive inspection, analysis of the structure of protein, and ultramicro analysis. The medical field uses diagnosis by positron emission tomography (PET), which uses positron emission nuclides as tracers, image diagnosis of coronary arteries via synchrotron radiation, photon therapy to target and shoot cancer cells, and heavy-particle radiotherapy using carbon ions. Another example close to home is cathode-ray tubes in television sets, which use the principle of an accelerator.

Quantum mechanics has become a foundation for the development of various fields such as IT, laser technology, magnetic resonance imaging (MRI)[12], and nanotechnology. As an example of applying a concept of quantum mechanics in the field of electronic engineering, Dr. Leo Esaki validated the quantum tunnel effect[13] with solids in 1957 and invented a tunnel diode. Since then, the tunnel effect has been applied in a variety of fields such as flash memory and scanner-type tunnel microscopes. In 1952, Dr. Kenichi Fukui applied quantum mechanics in the theory of chemical reactions and published “Frontier Orbital Theory[14],” which reversed the conventional organic electronics theory.

The idea of quantum mechanics will likely gain acceptance among the people in the future and will likely make further contribution to our life. For example, the performance improvement of computers by size reduction of CPUs is believed to have limitations; however, basic research is being carried out to explore the possibility of creating a completely new type of information system by controlling quantum behaviors.

Column 1: “Joy of quantum computer research, where new paths are opened up by changing the frame of mind” (Dr. Kae Nemoto, associate professor of the National Institute of Informatics, Research Organization of Information and Systems)

3 Challenging the mysteries of the earth and the oceans

Oceans and the deep parts of the earth are frontiers of mystery, even today. In particular, the oceans and crust surrounding Japan form a very complicated environment, and it is thought that many unknown organisms exist there.

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been using “Shinkai 6500,” with the capability to submerge deeper than any other manned exploratory vessels in the world and “Kaiko,” an unmanned exploratory vessel that can reach the deepest trench in the world for exploration, making contribution to the research on topics including deep-sea earthquakes, earth’s activities, and life in the deep sea. One of the recent results is the discovery, made during a study in 2003 and 2004 in the region of hydrothermal activity in Okinawa, of a special environment called a liquid carbon dioxide pool, revealing, for the first time in the world,

[12] Magnetic Resonance Imaging, MRI : method of using the nuclear magnetic resonance phenomenon to create an image based on information inside a living organism.

[13] Quantum tunnel effect: phenomenon wherein quantum effects enable very small particles to be filtered through a potential (energy) wall, which they cannot go through by the classical theory.

[14] Frontier orbital theory: the theory that the main process of chemical reactions is the mutual action between the molecular orbit in one molecule where the electrons with highest energy are distributed (highest occupied molecular orbital) and the molecular orbit of the other molecule with the lowest energy where no electrons exist (lowest unoccupied molecular orbital). This theory has contributed significantly to the understanding of reaction mechanism in organic chemistry and has been used in the new field of molecular synthesis.

that there exist microbes whose nutrient source is carbon dioxide.

In addition, in another sea region of Okinawa, a blue hydrothermal spurt (blue smoker) was discovered, also for the first time in the world, erupting out of a hydrothermal spout in August 2006. Hydrothermal vents are thought to be an environment very similar to that of the ancient Earth. Many thermophilic bacteria have been found in hydrothermal vents. Further studies of these thermophilic bacteria may solve mysteries involved in the origin of life.

Discoveries at deep oceans

Left: Blue smoker is erupting out (red arrow). White smoker is also erupting on the left (yellow arrow).
Middle: Spiral shell with scales of nano-crystal iron sulfide that appears like armor.
Right: Super-thermophilic bacteria of a new species and a new genus, isolated from a 365℃ hot-water chimney on the deep ocean floor

Photos provided by the Japan Agency for Marine-Earth Science and Technology

Super-thermophilic bacteria-based enzymes are used in biological research and DNA amplification reaction, which is indispensable to DNA testing. They are also believed to play a crucial role in studies of protein denaturation, which causes various illnesses such as Alzheimer’s disease and Prion brain disease.

“Urashima,” a deep-sea exploring cruiser in operation, is an automatic unmanned vessel capable of carrying out sample-water analysis and ocean floor analysis. It is producing results through hydrographic sounding, like capturing the detailed structure of the surface of mud volcanoes on deep ocean floors.

There have been accomplishments on the interior of the Earth as well, such as the discovery of a group of microbes inside the Earth’s crust and an explanation of the mechanisms of the formation of continental crust and of the occurrence of earthquakes.

Meanwhile, through advancement in various measuring methods and analysis using the methods of molecular biology, Japanese researchers have gained some crucial knowledge concerning the behaviors of organisms close to us. For instance, in June 2005, Dr. Katsumi Tsukamoto, et. al. of the University of Tokyo discovered that Japanese eels (Anguilla japonica) lay eggs on the day of the summer new moon at Ocean Mountain Suruga seamount off the coast of the Mariana Islands.

Through this success it is hoped that more analysis will be carried out to determine the evolutionary reason for fish migration and the mechanism by which the migrating fish sense the earth’s magnetic field. Further, it is expected that gaining understanding of the reproductive behaviors of eels in nature will lead to useful knowledge for farming eels, a resource whose depletion is feared.

With regard to Antarctic observation, the Deep Ice Coring Project at Dome Fuji, a 3-year plan, was started in 2003. Digging began to reach the rock plate estimated to exist 3,030 meters below the ice sheet. In January, 2006, a team led by the 47th Antarctic region observation team succeeded in collecting an ice sheet core (ice sample) down to a depth of 3,028.52m. The analysis of the ice sheet core has shown that the deepest part of the sample represents ice from about 720,000 years ago, which makes it the second oldest ice sheet core in the world. Further digging carried out by the 48th Antarctic region observation team led to successful collection of rock particles of a few mm, considered to have come from an ice sheet core or a rock bed down to a depth of 3,035.22m on January 26, 2007.

Because ice sheet cores (ice samples) contain enclosed substances and air in their air bubbles, analyses of the ice sheet cores can lead us to the understanding of past global environmental and climate changes. Currently, various analyses and studies in relation to climate prediction are being carried out jointly by universities and the National Institute of Polar Research under the Research Organization of Information and Systems.

4 Exploration of life

About 30 million years ago, the family hominidae[15] of organisms diverged from monkeys, and about 5 million years ago, chimpanzees and humans split, and from the branch of humans came Homo sapiens about 200,000 to 300,000 years ago.

The search for answers to the question of what these living creatures called humans are is under way currently through a variety of scientific approaches, such as through research on genes, on the immune system, on the brain, and on primates, in which humans are compared with other primates besides humans to find out what humans are.

(1) Genome analysis

In 2003, the “International Human Genome Project,” which had begun in 1991 through international cooperation of the U.S., U.K., Japan, France, and Germany, completed the decoding of all of the base sequences of the human genome, the basic human blueprint. Japan participated in this project chiefly through the Genomic Sciences Center of RIKEN, led by Dr. Yoshiyuki Sakaki. The team played a central role in the analysis of chromosomes Nos. 21 and 11, making a 6% contribution in the total project, which is the third highest percentage following the U.S. and the U.K. Further, the team played other major roles in that it contributed to the development of high-performance human genome analysis equipment such as an automatic DNA sequencer to decode the genes.

Now, the research in this field is said to have entered the next stage—the post-genome era. Supported by current results of decoding all base sequences, this new research studies the functions of the genes, various proteins formed from the genes, the formative process of our complicated human bodies, development of new medicines, and “tailored medication[16],” in which individual

[15] The family hominidae is one family under the order primates under the class mammalia. The family includes, in addition to humans (Homo sapiens), chimpanzees, gorillas, and orangutans.
[16] Medical treatment in which gene information is used to select the most effective treatment or medicine with the least side effects for each individual patient.

differences in the base sequence are applied to medical treatment and many other issues.

The 3 billion base sequences of the human genome vary from person to person by 0.1%, causing different appearances, body shapes, and physical properties of individuals. HapMaps, which are the maps of these differences in base sequences, provide crucial basic information to determine the likelihood of diseases and the effectiveness of medicines and to discover the gene factors contributing to side effects, etc., so they are indispensable to the implementation of tailored medication, etc. The "International HapMap Project" was a project whose purpose was the creation of a database of HapMaps. It began in 2002 under international collaboration and was completed in 2005. From Japan, the RIKEN SNP Research Center, led by Dr. Yusuke Nakamura, participated in the project, contributing 24.3% (following the U.S.'s contribution of 32.4%). It was the largest contribution among the participating research organizations.

In addition, post-genome research has made the important discovery that hereditary information is not determined by genes alone but many other factors besides the genes contribute to it. For example, we now know that some domains besides those containing genes are actually crucial domains containing information such as RNAi (RNA interference), which controls the manifestation of DNA information. Additionally, it has been discovered that the formation of proteins from the gene information depends in part on the information-control mechanism (epi-genetics), different from the genes, contained in proteins and chemical substances surrounding the DNA.

(2) Immunology

The research field of immunology has become a fundamental research area common to cutting-edge medical treatment involving medical transplantation and cancer treatment and challenges such as new and recurring infections including allergies (like pollen allergies), atopic dermatitis, and AIDS.

Dr. Shizuo Akira of Osaka University found receptors called TLRs (toll-like receptors) and discovered that cells originally have these receptors that can sense the invasion of pathogens and that, when such a pathogen enters the body, these receptors are activated by the constituting elements of the pathogen, inducing subsequent inflammation and immune reactions. Further, he discovered that the action of acquired immunity gets induced only by the recognition of pathogens by the TLRs. These discoveries are significantly changing the way people think about vaccines against infectious diseases, allergies, and immunity against cancer. Currently, research is being done to study the mechanisms of activation of the natural immune system from TLRs' recognition of disease-causing pathogens and of activation of the acquired immune system from the natural immune system.

Dr. Hiroshi Takayanagi of Tokyo Medical and Dental University discovered that T cells[17] of the immune system not only produce molecules that promote the formation of osteoclasts but also produce, significantly, the molecules that inhibit the operation of these promoter molecules; his discovery shows that autoimmune arthritis is a disease caused when the balance of these molecules

[17] T-cell is one of the immunity cells, controlling the reaction of acquired immunity and attacking foreign objects that have entered the body.

is broken and a large number of osteoclasts are produced, proving that molecules in the immune system contribute to bone metabolism. These discoveries have given rise to a new research field called “Osteoimmunology.”

(3) Brain science

Through progress of research in brain science and by accumulating various knowledge concerning the brain, it is expected that we can obtain fundamental solutions to brain aging as well as mental and neurological illnesses; applications to engineering such as the development of computers via information-processing methods emulating the brain function; and solutions to the problem of the relation between the brain and the heart.

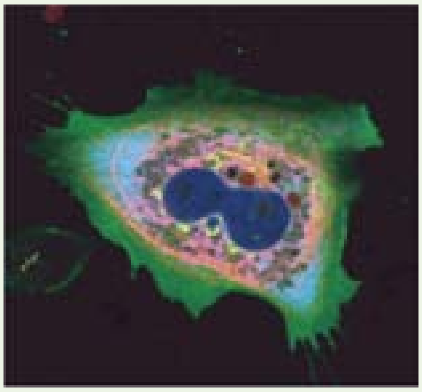
In recent years, research in brain science is advancing in a variety of fields, taking advantage of cutting-edge technology such as molecular biology, research results from hereditary studies, MRI (Magnetic Resonance Imaging), and PET (Positron Emission Tomography).

At the RIKEN Brain Science Institute, research is being carried out with the four investigative target areas: “understanding the brain,” “protecting the brain,” “creating the brain,” and “nurturing the brain.” In particular, many research results related to mental and neurological illnesses are being reported, including the discoveries of the genetic abnormality associated with autism and of the group of genes associated with the outbreak of schizophrenia, understanding of the mechanism of neurological growth to repair damaged nerves, and understanding of the mechanism of decomposition of substances causing Alzheimer’s disease.

Dr. Yasushi Miyashita of the University of Tokyo has clarified the memory mechanism of the cerebrum, answering questions such as “Where is the memory stored?” “How is the memory built?” and “How is the memory recalled?” He discovered a neurological cell group in the cerebral temporal lobe that is used to memorize shapes. He also discovered that the memory nerve cells solidify the memory not only by information from the cerebral sensory area but also by signals from the part called the hippocampus of the brain. In addition, he discovered that the basic mechanism of recalling what is memorized is not by physical signal of sensory organs but by the neurological cell group in the cerebral temporal lobe getting activated by signals from the interior of the brain. He also went on to find a signal that originates these in-brain signals. It is expected that these discoveries will contribute to further understanding of the causes of dementia, amnesia, etc. and to the development of how to treat these diseases.

Dr. Atsushi Miyawaki of the RIKEN Brain Science Institute is developing various fluorescent proteins, indispensable to imaging of living cells. In the field of biology, there are various phenomena that cannot be decisively answered without observing what is happening in living cells; these new fluorescent proteins have enabled us to visualize, spatially and chronologically, the various phenomena occurring in individual cells like neurological cells, real-time. This has now become a tool indispensable in research laboratories around the world (Figure 5).

■ **Figure 5 Imaging of cells with fluorescent proteins**



Multi-color imaging using 6 colors
Cell membrane: green
Small cell: light blue
Golgi body: yellow
Microtube: red
Nucleus: dark blue
Mitochondrion: pink

Photo provided by Dr. Atsushi Miyawaki

(4) Primate studies

What is the difference between mankind and other animals? What are the origins of mankind and their society? To answer these questions, it is natural to study other primates besides human beings, such as chimpanzees.

While much of the basic research originated in Western Europe, studies of primates originated in Japan, and it is one important area of research where Japan is leading. Drs. Kinji Imanishi and Junichiro Itani of Kyoto University began studying the social structure of Japanese monkeys for the purpose of discovering the origin of human society in the society of wild animals, back in 1948. They successfully found that Japanese monkeys have social structures like people, as evidenced by their hierarchical social relations. In 1958, they extended their research scope to chimpanzees and gorillas living in Africa to study anthropoids and discovered that they too have social structures. In 1953, they made a new discovery that Japanese monkeys adopt pre-cultural behavior such as washing sweet potatoes and explained mechanisms like propagating their behavior to the entire group and passing them down to next generations.

One remarkable work in recent years is the results from the “Ai Project” by Dr. Tetsuro Matsuzawa of Kyoto University. This project seeks to show, both experimentally and objectively, how chimpanzees recognize this world as well as their intelligence and thoughts; it is a project of “comparative cognitive science” which seeks to clarify the evolutionary origin of recognition and thoughts of humans. Research up to the present has shown the high level of intelligence of chimpanzees, in that the color recognition ability in chimpanzees is basically the same as that in humans and that chimpanzees’ immediate memory capacity is about as high as the capacity of a normal human adult (Figure 6). In their habitats in Africa, some wild chimpanzees have been observed using a variety of things such as stone tools, and it has been discovered that such knowledge and techniques have been carried down over the generations as cultural traditions and that each group has different culture of its own. At present, research is being conducted to simulate the beginning and propagation of wild chimpanzee culture by studying how the knowledge obtained at a research center is propagated over generations or throughout a group. Research is also under way to study the recognition development of child chimpanzees.

■ Figure 6 Chimpanzees at the Primate Research Institute, Kyoto University

Top left: Outdoor playground at the Primate Research Institute. The physical environment is made similar to the environment which wild chimpanzees inhabit to provide a natural place for the chimpanzees.
Top right: Ai's son Ayumu, taking a "test of numeric memory span"
Bottom right: Ai, facing Prof. Matsuzawa in the lab, and Ayumu, held by the professor

Photos provided by the Primate Research Institute, Kyoto University

5 Exploring the mysteries in history

A regional study by Japanese scholars is showing unique advances particularly in the region of Southeast Asia. Since 1991, a Sophia University international study group on Angkor ruins (group leader: Yoshiaki Ishizawa, president of Sophia University) has been carrying out preservation and repair work as well as archeological excavation at the Banteaysrey ruins inside the Angkor ruins. While making this study, the team came upon 274 Buddha statues and the “Thousand Buddhas Over a Quadrilateral Pillar” (“Mille bouddhas sur un pilier quadrangulaire”) in 2001.

In the 140-year history of studies and research of the Angkor ruins, which began in late 19th century, this is the first time so many Buddha statues were uncovered.

Most of the excavated statues of Buddha had been cut asunder into heads and bodies before they were buried. This was done because the new Hindu king, who fought battles against Buddhist powers to win his kingship, had these statues (which the earlier kings worshipped) destroyed and buried to teach a lesson. This discovery suggests that it was an era when the authority of the new king was sufficiently established and the government functioned normally. It thus overturned the traditional view that the Angkor dynasty had “deteriorated and degenerated” and proved that the dynasty actually “kept a certain level of prosperity,” rewriting the history of the latter part of the Angkor dynasty.

Since its entry in Cambodia in 1982, the international study group on Angkor’s ruins from Sophia University has been actively involved in training personnel, Cambodian officers to preserve the ruins, through various means such as workshops on archeology and architecture, along with their work on excavation and protection of Angkor's ruins.

Column 2: "Most famous Japanese person on wall street" (story about Dr. Kiyoshi Ito, professor emeritus of Kyoto University, who received the Gauss Prize)