JST HIGHLIGHTS

Spotlight on Two JST Programs:
- JST’s New Challenge: Contributing to International Development through Science and Technology
- International “Dream Teams” Drive the Emergence of Research Hubs

Introducing Five Recent Research Project Topics:
- Human iPS Cells Open a New Frontier in Medical Research
- From Transparent Transistors to a New Family of Superconductors
- Robots Help to Deepen Our Understanding of the Human Brain
- Ostrich Antibodies: Potential Weapon in the War on Bird Flu
- Science and Technology for Art

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JST HIGHLIGHTS

Profile
The Japan Science and Technology Agency (JST) is one of the core institutions responsible for the implementation of science and technology policy in Japan, including the government's Science and Technology Basic Plan.

From knowledge creation—the wellspring of innovation—to ensuring that the fruits of research are shared with society and Japan’s citizens, JST undertakes its mission in a comprehensive manner. JST also works to provide a sound infrastructure of science and technology information and raise awareness and understanding of science and technology-related issues in Japan.

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JST HIGHLIGHTS 1
Looking Ahead from 2010: Promoting Science and Technology for the Future of Our Planet

Motivating young people through the message of science and technology

A few days ago, I gave a guest lecture at a high school in which I asked the students several questions. My final question was, "Do you think that science and technology has harmed our planet?" Until that point, most of the students had been rather tentative in putting up their hands and many seemed to be hedging their answers based on their perception of how the majority of the class was reacting. This final question, however, brought an immediate and clear response from the entire class. A resounding "Yes!" was the reply as all hands went up for the affirmative. These were students who had already chosen to focus their studies on mathematics and science-related subjects. Their response to my question was quite a shock for me.

These students have developed an instinctive antipathy toward the science that my generation has so vigorously pursued. Despite this apparent antipathy, they have chosen to study science and engineering. This fact leads to a number of thought-provoking implications. My interpretation is that these students have a strong desire to do something worthwhile for the good of the planet and the environment.

What must we do for students such as these? What we can do is offer encouragement. They need to know that if they are willing to take up the challenge, there will be a way forward. We must convey the message, "Let's work together to improve the future for our planet." I believe that it is very important for the science and technology community to send out clear messages to young people so that they can then act on their own initiative.

Promoting a leadership role for the newly launched Center for Low Carbon Society Strategy (LCS)

What are the specific messages that the science and technology community should be sending out to young people? Reframing that question, what are the issues and challenges we want young people to take up? I believe that one of the most crucial challenges is the realization of a low-carbon society. We need to clearly articulate the importance of meeting the challenge of a low-carbon society, and particularly address this message to the younger generations on whom our future depends. It is essential to present a realistic path toward this low-carbon goal and enable young people to participate in the efforts necessary to reach this objective.

In December 2009, JST launched the Center for Low Carbon Society Strategy (LCS). JST sees LCS in a leadership role—forging a vision to take us toward the goal of a low-carbon society. We have tasked LCS with formulating a picture of what a low-carbon society will look like—what is achievable by 2020. What will be the characteristics of a low-carbon society in 2050? LCS will build up this picture by undertaking original research and analysis, and publishing forecasts based on this work. LCS will construct scenarios comprising a range of elements necessary for the realization of a low-carbon society—modes of living, social infrastructure, industrial structure, technology systems, and others. LCS will also propose specific policies to ensure that the fruits of research and development activities are applied widely throughout society. The ultimate role of LCS is to facilitate the work of current and future generations hand in hand for the benefit of our planet and its environment.

Science and technology diplomacy—nurturing human resources and enhancing affinity for Japan

Simultaneous with efforts to realize a low-carbon society, JST is focusing on "science and technology diplomacy." Although this phrase may not yet be a familiar term to many people, it refers to the use of science and technology as a means of enhancing the relationship between two countries. Science and technology can be a very effective sphere through which a bilateral relationship is developed. It is an area in which Japan has particular strengths and cooperation is welcomed by many of Japan's partners.

In 2008, Japan launched the Science and Technology Research Partnership for Sustainable Development (SATREPS) as part of its science and technology diplomacy efforts vis-à-vis developing countries. Although Japan's official development assistance (ODA) to developing countries is carried out principally by the Japan International Cooperation Agency (JICA) under the auspices of the Ministry of Foreign Affairs (MOFA), SATREPS has been established as a means of realizing "science and technology ODA" through a partnership between MOFA, JST, JICA, and other parties. By further strengthening such linkages, Japanese scientists will have increased opportunities to conduct research abroad within programs that contribute to Japan's international diplomacy efforts.

However, unlike ODA projects that involve the construction of such infrastructure as bridges or industrial facilities, science and technology diplomacy does not usually generate results that are immediately visible, and the sums of money involved are comparatively small. Notwithstanding, this new form of ODA plays a vital role in fostering collaboration between scientists of the two countries involved as they work together to help create a brighter future. Such joint research nurtures mutual respect and trust and is an important opportunity for both Japan and its partners to develop human resources.

Finally, I would like to reiterate JST's key mission in developing and supporting such world-renowned scientists as Professor Shinya Yamanaka, who has been a pioneer in the field of iPS cell research, and Professor Hideo Hosono, who discovered a new family of high-temperature superconductors. JST is committed to helping Japan produce more breakthrough research results in the future. At the same time, I believe it is also our mission to foster young people who are striving to turn their dreams and ideas into reality. While that mission—to help young people reach their potential—is a specific goal of JST, it also belongs to each of us as adult members of society in 2010.

Koichi Kitazawa, D.Sc.
President, Japan Science and Technology Agency
JST’s New Challenge: Contributing to International Development through Science and Technology

Finding solutions to global issues by utilizing Japan’s science and technology capabilities

From environmental and energy issues to epidemics, natural disasters and food security, the international community must address an increasing number of global issues. To find solutions to such large-scale problems, coordinated, international efforts utilizing science and technology are essential. JST is working to leverage Japan’s strengths in science and technology to bolster the country’s diplomatic and international cooperation efforts. In doing so, we aim to enhance Japan’s leadership role in developing and implementing solutions to global issues. We see the “Science and Technology Research Partnership for Sustainable Development (SATREPS)” as one of JST’s important challenges.

Program Outline: Science and Technology Research Partnership for Sustainable Development

Global problems cannot be solved by individual countries or regions. Above all, there is a need for the international community to work collaboratively with developing countries to find sustainable solutions. In response to such needs, in 2008 we launched the Science and Technology Research Partnership for Sustainable Development. This program promotes linkage between collaborative international research with developing countries and official development assistance (ODA). Through such international joint research projects, JST will work toward the realization of solutions to global issues and aims to contribute to the advancement of science and technology. This program will be undertaken through a partnership between JST and the Japan International Cooperation Agency (JICA), and is designed to reinforce Japan’s “science and technology diplomacy.”

Through international collaborative research, we hope to foster capacity development in the area of research and development in developing countries and assist partner countries in building their own sustainable systems for promoting and conducting research and development.

In December 2009, to coincide with the 2009 United Nations Climate Change Conference (COP15), which was held in the Danish capital of Copenhagen, JST and JICA jointly hosted a side-event symposium called “Towards Green Growth and Green Innovation.” The symposium’s presenters were drawn from a diverse array of backgrounds and countries, including the United States, the European Commission, China, India, Brazil, the African Union and media organizations. Its theme focused on environmental science and technology cooperation between developed and developing countries, and the potential for achieving both CO2 emission reductions and economic growth. A summary of the symposium’s results was presented at an official COP15 side event hosted by the Government of Japan, and may be viewed at the following URL: http://www.jst.go.jp/global/sympos091207/e/index.html

For further information, please refer to the SATREPS web page: http://www.jst.go.jp/global/english/index.html

Science and Technology Research Partnership for

- **Peru**
  - Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru

- **Bolivia**
  - Study on the Impact of Glacier Retreat on Water Resource Availability for the Cities of La Paz and El Alto

- **Brazil**
  - FY2008: Research on Ethanol Production from Sugarcane Wastes
  - FY2009: Carbon Dynamics of Amazonian Forests
  - Development of Genetic Engineering Technology of Crop Species with Stress Tolerance against Degradation of Global Environment
  - New Diagnostic Approaches in the Management of Fungal Infections in AIDS and Other Immunocompromised Patients

- **Burkina Faso**
  - Sustainable Water and Sanitation Systems in Sahelian Region in Africa: Case of Burkina Faso

- **Ghana**
  - Studies of Anti-Viral and Anti-Parasitic Compounds from Selected Ghanaian Medicinal Plants

- **Sudan**
  - Improvement of Food Security in Semi-Arid Regions of Sudan through Management of Root Parasitic Weeds

- **Gabon**
  - Conservation of Biodiversity in Tropical Forest through Sustainable Coexistence between Human and Wild Animals

- **Zambia**
  - Conservation of Rapid Diagnostic Tools for Tuberculosis and Trypanosomiasis and Screening of Candidate Compounds for Trypanosomiasis

- **Croatia**
  - Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia

- **Tunisia**
  - Valorization of Bioresources in Semi-Arid and Arid Land for Regional Development

- **South Africa**
  - Prediction of Climate Variations and its Application in the Southern African Region
  - Observational Studies in South African Mines to Mitigate Seismic Risks

- **India**
  - Research Partnership for the Application of Low-Carbon Technology in India
  - Information Network for Natural Disaster Mitigation and Recovery

- **Philippines**
  - Project on Integrated Coastal Ecosystem Conservation and Adaptive Management under Local and Global Environmental Impacts in the Philippines
  - Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines
  - Prevention and Control of Leptospirosis in the Philippines

- **Thailand**
  - FY2008: Improved Study Project on Hydro-Meteorological Prediction and Adaptation to Climate Change in Thailand (IMPRAC-T)
  - Research and Development for Water Reuse Technology in Tropical Regions
  - Research and Development of Therapeutic Products against Infectious Diseases, Especially Dengue Virus Infection
  - FY2009: Innovation on Production and Automotive Utilization of Biofuels from Non-Food Biomass

- **Indonesia**
  - FY2008: Anti-Fire and Carbon Management in Peat Swamps and Forests in Indonesia
  - Multi-Disciplinary Hazard Reduction from Earthquakes and Volcanos in Indonesia
  - FY2009: Climate Variability Study and Societal Application through Indonesia - Japan “Maritime Continent COE” - Radar-Buoy Network Optimization for Rainfall Prediction
  - Identification of Anti-Hepatitis C Virus (HCV) Substances and Development of HCV and Dengue Vaccines

- **Tuvalu**
  - Eco-Technological Management of Tuvalu against Sea Level Rise
Helping Tuvalu—where the threat of climate change is very real

The tiny island state of Tuvalu, located just south of the equator in the western Pacific Ocean, has received worldwide attention in recent years. Awareness of Tuvalu’s plight rises in tandem with the sea level—a grim reminder that the threat of climate change is morphing from theory to reality. Tuvalu comprises nine coral atolls and reef islands whose total land area is just 26 square kilometers. With a population of just over 12,000, the country relies on foreign aid as its principal income source. The average height of the island group is a mere one to two meters above sea level, meaning high seasonal tides pose the risk of serious flooding. Owing to the islands’ geological structure, the situation is even worse: for生活在 the islands, the tidal range is very real—flooding not only threatens the coast but also inland areas where seawater can come bubbling up through the porous coral-based rock. If the situation continues to deteriorate, there are fears that the islands may be either completely engulfed by the sea or become uninhabitable through loss of freshwater sources and arable land. To address Tuvalu’s problems, Professor Hajime Kayanne of the Department of Earth and Resources Management at Hokkaido University in Japan is leading a group of scientists and engineers in a project titled “Eco-Technological Management of Tuvalu against Sea Level Rise.”

In February and March each year pose the risk of serious flooding. With the islands’ shallow riverbeds and small catchments, the sudden influx of rainwater leads to rapid runoff. In Tuvalu’s case, fragments of dead coral. In Tuvalu’s case, a particular feature is the presence of a large amount of foraminifer fragments—sometimes called star sand—in addition to coral,” he says. Foraminifera are very small unicellular-shelled organisms that are related to coral and often live in coral reefs. Foraminifera are usually one to two millimeters in size and, similar to corals, they secrete calcium carbonate to form a shell and live symbiotically with algae.

The research conducted by Professor Kayanne and other project participants has revealed that Tuvalu’s corals and foraminifera are increasingly under threat. Some of the islands’ domestic sewage and livestock effluent is released into the sea, and this is killing the coral and foraminifera. If this is allowed to continue, Tuvalu will lose an important component of its land, thereby increasing the threat of flooding,” he tells us. In other words, the researchers believe that the prevention of waste discharge and runoff, which will improve the habitat for coral and foraminifera, would be one effective strategy for flood prevention on the islands. Professor Kayanne adds, “While it is, of course, important to create an environment conducive to the healthy growth of coral and foraminifera, it is really only a strategy for solving long-term problems. In the shorter term, the islands will need to apply a range of measures, including the construction of breakwaters. Hence, it is crucial to design an overall response that achieves the correct balance.”

Another important point is that the measures must be undertaken by the local people themselves. Through sustained efforts, a project such as this takes on a much wider significance. In the context of the project, there are many of the other projects in the Pacific facing dangers similar to Tuvalu’s. So we hope that the current project in Tuvalu will act as a catalyst to bring these countries together in search of sustainable solutions.

Coral reef and foraminifera regeneration seen as key to finding a solution

Professor Kayanne’s research fields are Earth system science and coral reef studies, with his principal research in the area of the response of coral reefs to global change. He explains, “Corals are small, sea anemone-like marine organisms, or polyps, which secrete calcium carbonate to form a hard exoskeleton. Over many generations, coral reefs form from colonies of these living organisms, with reefs’ structures primarily comprising a build-up of skeletal material.” These biologically formed terrains are extremely sensitive to climate change. “In Tuvalu’s case, a particular feature is the presence of a large amount of foraminifer fragments—sometimes called star sand—in addition to coral,” he says. Foraminifera are very small unicellular-shelled organisms that are related to coral and often live in coral reefs. Foraminifera are usually one to two millimeters in size and, similar to corals, they secrete calcium carbonate to form a shell and live symbiotically with algae.

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Case 01 Tuvalu

Developing strategies to protect coral reefs and ensure Tuvalu’s long-term survival in the face of rising sea levels

In developed countries, when people talk about tuberculosis (TB) they tend to assume it is a disease of the past. In reality, however, the World Health Organization (WHO) estimates that each year there are approximately nine million new cases of TB globally, with around 1.7 million people dying from the disease. In August 2005, the WHO declared a TB emergency in Africa in response to an epidemic that has seen escalating numbers of new TB cases in the Africa region. Although Africa has only 11% of the world’s population, it accounts for over a quarter of TB cases and deaths annually. One of the principal factors driving the growth in TB cases and deaths is the HIV/AIDS epidemic. People infected with HIV are particularly susceptible to TB due to their weakened immune system, and if these people contract TB they are likely to infect other individuals. A project titled “Establishment of Rapid Diagnostic Tools for Tuberculosis and Trypanosomiasis and Screening of Candidate Compounds for Trypanosomiasis” is working to prevent epidemics of both TB and trypanosomiasis (sleeping sickness), which is spread by the tsetse fly in sub-Saharan Africa. The lead researcher in this collaborative project is Professor Yasuhiko Suzuki of the Hokkaido University Research Center for Zoonosis Control (CZC), while the project counterparts include the Zambian Ministry of Health.

A one-dollar diagnostic kit is the main weapon in the fight against the spread of TB

Early diagnosis is crucial in the effective treatment of TB. However, for countries in Africa, this is one of the most difficult hurdles. Professor Suzuki explains, “In Japan, TB diagnosis costs about $50, which is not affordable in African countries.” This situation spurred him to embark on the development of a “one-dollar diagnostic kit.” Since it takes just one hour to confirm the presence of TB bacteria after taking a sample of the patient’s sputum, it is hoped that this kit will become a major weapon in the quest for early TB diagnosis. At a cost of just one dollar per kit, Professor Suzuki is confident that it can achieve widespread use in Africa.

In addition to early diagnosis, for the effective treatment of TB it is important to prevent the spread of multidrug-resistant (MDR) bacteria. For TB, different drugs are used to treat different strains. For example, even if you give a patient four different drugs, if the strain of TB infecting the patient is already resistant to two of those drugs, there is the possibility that the bacteria may become resistant to the other two drugs during the course of treatment. Consequently, it is very important to rapidly identify which drugs are effective in treating the particular strain of TB carried by the patient,” continues Professor Suzuki. To solve this problem, his research group has developed a method of identifying TB strains using a low-density oligonucleotide DNA chip (microarray) that can analyze a large volume of DNA simultaneously. At this stage, because it still costs over $20 to use the newly developed method, it will be necessary to further improve the technology to make it more affordable.

The issue of affordability is, of course, critical. No matter how good the testing methods are, it is pointless if they are not adopted in the countries affected by the TB epidemic. For this project, the main goal is to facilitate a system of effective TB diagnosis and testing that is accessible to the people of Zambia. When Professor Suzuki visited Zambia in August 2008, he conducted lectures on TB diagnosis and testing for medical practitioners. The test procedure itself is relatively simple—it involves the use of a pipette (glass tube). However, owing to health care workers’ lack of familiarity with the procedure and Zambia’s lag—compared with Japan—in basic technology acquisition, there was a high failure rate in applying the procedure among local personnel. Since it takes 30 hours to fly from Japan to Zambia, frequent visits to conduct training are not practical. In these circumstances, the diagnostic kit, which represents a potential breakthrough for TB treatment in Zambia, would go to waste.

Faced with this problem, Professor Suzuki holds very high hopes for the current research project. “If we can establish a strong framework for collaboration with research institutions in Zambia, it will be possible for the people of Zambia themselves to implement programs enabling the widespread use of the diagnostic kit. If we can then capitalize on the project’s results to improve TB treatment systems in other African countries, it will represent a major advance. For this reason, we need to think about how these efforts can be continued after the current five-year project is completed.”

The “one-dollar kit” for early diagnosis of TB. The patient’s sample is dissolved in caustic soda (sodium hydroxide) and then undergoes centrifugal separation. A reagent is then added to the precipitate and kept at 60°C for one hour. If the sample becomes fluorescent, the test is positive. This method enables diagnosis using simple procedures that are similar to those used in high school biology experiments.

Yasuhiko Suzuki

Graduated from the Faculty of Science, Shizuoka University, in 1989. He received his doctorate from the Graduate School of Science, University of Tokyo, in 1993. Currently, he is a professor at the Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo.
International “Dream Teams” Drive the Emergence of Research Hubs

Centers of excellence draw leading domestic and overseas researchers

JST programs support the creation of regional research hubs to attract leading researchers from Japan and overseas. In this article, we profile two such hubs—Nagano and Yamagata—where “dream teams” are at the forefront of research in key emerging-technology fields. Stories of scientific endeavor often contain many of the classical elements of history-making drama—world-renowned experts in a particular field gather together in a bid to make the next great breakthrough that will reverberate around the world. An unexpected twist in these stories is their setting. Rather than Tokyo, Osaka or Kyoto, hubs are being created in smaller cities where academia and industry can evolve and flourish symbiotically with backup from regional government and JST. This university-centered research hub concept encourages each region to focus resources on a specific field. Where there is strong potential for commercialization of new technologies, researchers who achieve the most outstanding results are invited to join a strategic “dream team.” This tiered system aims to foster the most advanced research possible while accelerating the R&D cycle. Both Nagano and Yamagata are striving to become internationally synonymous with key emerging-technology fields.

Research Hub Example 01
Shinshu University Shinshu University Nagano Prefecture

Exotic Nanocarbons: Synthesis and Application

Professor Morinobu Endo
Faculty of Engineering
Director of the Institute of Carbon Science and Technology (IEST)
Shinshu University
• Obtained his PhD in 1975 from the University of Orleans, France, and was a visiting researcher at CNRS.
• Co-author of the paper “Filamentous Growth of Carbon via Chemical Vapor Deposition (CVD) growth of nanometer-scale carbon fibers.” (և. Vol. 32, 1976). This was the first report of chemical vapor deposition (CVD) growth of nanometer-scale carbon fibers.

At Shinshu University in Nagano Prefecture, researchers are exploring practical applications for exotic nanocarbons, or ENCs, thereby pushing beyond the boundaries of existing carbon nanostructured materials. Nanocarbons are fabricated by minutely controlling the structure and form of carbon at the nanometer scale in order to obtain novel functions and advanced properties that are not present in conventional forms of carbon. By deliberately introducing heteroatoms or ions, ENCs offer the potential of even more innovative properties. The integration of heterogeneous elements enables the synthesis of new materials whose basic structure remains carbon but which are, in fact, quite unlike carbon. In the near future, ENCs are likely to play important roles in critical fields—from the environment and energy to IT and medicine.

Leveraging “harmony in diversity” to generate bold ideas

In Japan, there is an ancient proverb that says, “Strove for harmony, not uniformity.” It tells us to value teamwork while respecting individuality. Professor Morinobu Endo, leader of the ENCs project, sees this as the spirit from which bold ideas are born. The need for a research environment based on this philosophy was the driving force behind the creation of the ENCs research team. Professor Endo comments, “If one looks at research teams in the United States, naturally there are many researchers from the Americas and Europe, but there are also many from India and China. Hence, one can observe the pursuit of research involving a high level of cross-pollination and collaboration among members who bring a diverse array of cultural traits. For example, American culture tends to emphasize the pursuit of one’s dream, while India is renowned for the mathematical mind and China has a reputation for business acumen. No matter how much perspiration one expends, research efforts in Japan that utilize only homegrown talent are not going to generate the kind of multinational creativity one finds overseas. Inevitably, the similarity in the team members’ backgrounds leads to a similarity in thinking, making a breakthrough much harder.”

The concept behind the ENCs team is to build a “Nanocarbon Valley” cluster of excellence in Nagano Prefecture, which already boasts a high level of expertise in carbon-related research. There is an established network of companies in Nagano aiming to leverage the region’s strength in carbon materials. Combining this with Shinshu University’s laboratories and other research infrastructure will enable Nagano to stay at the leading edge of nanocarbon research internationally. However, the ENCs project is not simply about stimulating Nagano’s industrial base. Rather, the idea is far bolder, as Professor Endo explains, “Exotic nanocarbon research is about helping the planet—it’s about the future of humanity.”

Future Applications

ENCs: potentially useful in the electric double-layer capacitor (EDLC) and as an anode material or as an additive in lithium-ion battery systems, which are likely to be used in electric vehicles.

Research Hub Example 02
Yamagata University Yamagata University Yamagata Prefecture

Global Leaders in Organic Electronics

Professor Junji Kido
Graduate School of Science and Engineering
Yamagata University
Director of the Research Institute for Organic Electronics (RIOE)
• Received his PhD in 1989 from Polytechnic University, New York, and was a research scientist at Brookhaven National Laboratory (1988–1993).
• Co-author of the paper “Multilayer White Light-Emitting Organic Electroluminescent Device” (Science, Vol. 267, 1995). This paper reported a breakthrough in organic EL.

At the Research Institute for Organic Electronics, established seven years ago in Yamagata Prefecture, Professor Junji Kido has been at the forefront of vigorous efforts to develop practical technologies that harness the potential of organic semiconductors in partnership with companies in Yamagata and beyond. Professor Kido’s research has been instrumental in the application of organic electroluminescence (EL) technology to the commercial production of organic EL display devices and lighting equipment. New commercial applications for organic EL are being rapidly developed by the private sector. To facilitate the development of applications for organic devices and accelerate the formation of a regional industry cluster focusing on organic electronics, Yamagata University has taken the lead by bringing top-class researchers from Japan and around the world to participate in basic and applied research. This program focuses not only on organic EL research but also aims to build an internationally recognized center of excellence in the field of organic electronics. As well as having a galvanizing effect on the university, this program has the objective of providing impetus to the regional economy and industry in Yamagata Prefecture. Ultimately, the participants envisage Yamagata as the world’s preeminent “Organic Electronics Valley.”

Creating an attractive research hub for personnel and enterprises

To attract top researchers, Yamagata highlights its existing strengths and future potential. The area has a large number of manufacturing firms with cutting-edge technical capabilities, while local government agencies proactively support the development of an organic electronics cluster. This infrastructure—transforming basic research output into commercial technologies—is a key advantage. It is often said that for researchers at the vanguard of scientific discovery, there are no prizes for runner-up. Thus, in an era of 24/7 global competition, there is an enormous incentive to make a breakthrough and stay one step ahead of the pack. Professor Kido, too, is very conscious of the global picture. “By bringing together a team of top researchers, we are able to expand our scope from organic EL to the broader field of organic electronics while also accelerating the pace of R&D. I hope that this will contribute to shorter lead times from basic research to application of new technologies. We are targeting the creation of a self-sustaining cycle for organic electronics in Yamagata. Breakthroughs draw significant international attention, which enhances our access to the latest information. It draws talented people, research funding and dynamic business enterprises. These factors help propel further research advances. By maintaining the momentum of this positive cycle, we will bolster our standing as an international research hub.”
Since 2006, a research team in Japan led by Professor Shinya Yamanaka of Kyoto University has achieved a string of breakthroughs in the crucial field of stem cell research. Their work has been hailed around the world and has even led to speculation that it might be a candidate for recognition through a Nobel Prize.
Kyoto University group leads the world in the important area of basic medical research

At Kyoto University, Professor Yamanaka is director of the Center for IPS Cell Research and Application (CiRA), which is part of the Institute for Integrated Cell-Materials Science (iCeMS). He is also a professor in the Department of Stem Cell Biology at Kyoto University’s Institute for Frontier Medical Sciences. His research group was able to generate human induced pluripotent stem (iPS) cells—equivalent to human embryonic stem (ES) cells—from human adult fibroblasts taken from skin cells. This breakthrough was subsequently reported in the research journal Cell on November 20, 2007.

This result not only proved that it was possible—under normal laboratory conditions—to revert adult cells to an embryonic state, but also means that there is now a way of generating ES cells without the ethical issues that surround the use of human ES cells for research. Further, it potentially clears the way for the treatment of patients using stem cells induced from their own cells, thereby eliminating the risk of transplant rejection. For these reasons, this work has been recognized as an extremely important breakthrough in the field of regenerative medicine.

After the publication of these results, the U.S. government quickly announced that it had commenced funding to assist iPS cell research projects, while the Vatican welcomed this new development in stem cell research. It would not be an exaggeration to say that the results achieved by the Kyoto University team have taken the world by storm.

Skin cells induced to differentiate into an array of cell types

Previously, reprogramming research—which attempts to revert somatic cells to an embryonic state—had been pursued in the United States and other places as a means of obtaining pluripotent stem cells from a patient’s own cells. Reprogramming research may take one of two approaches—nuclear transfer and cell fusion. In the nuclear transfer method, the nucleus from an adult somatic cell is inserted—under a microscope—into an egg whose nucleus has been removed. In the cell fusion method, an ES cell and somatic cell are fused by treatment with an electric current. In either of these methods, not only is there the problem of biotech issues relating to the use of germ cells but also the issue of low efficiency in the success of reprogramming owing to the generation of abnormal chromosome numbers. However, iPS cell research opens up a way to generate patient-specific stem cells: iPS cells are generated from cultured somatic cells by introducing defined factors.

Professor Yamanaka first announced that his group had generated iPS cells from mouse somatic cells in August 2006. This reprogramming research breakthrough, published as an article in Volume 126 of the journal Cell, also coined the term “iPS cell.” This research established an elegant method for generating pluripotent cells from mouse skin cells.

Four factors—or genes—were introduced into the mouse skin cells via transfection with a retrovirus vector. Introduction of these four factors—Oct-3/4, Sox2, c-Myc, and Klf4—made the mouse skin cells pluripotent, thereby enabling cell reprogramming. However, at this stage some difficulties were raised in terms of the utility of the mouse iPS cell method. The reasons included differences in the gene-expression patterns compared with the original patterns in ES cell lines and the iPS cells’ reduced ability to differentiate in comparison with ES cells.

Human iPS cells produced

From this point, Professor Yamanaka worked even harder to refine his method of generating iPS cells. His team used more stringent techniques for selecting cells to culture from the mouse cells with introduced factors, and successfully reprogrammed the mouse skin cells into ES-like cells. These second-generation iPS cell results were reported in June 2007.

At the announcement, Professor Yamanaka made it clear that there were several groups outside Japan also pursuing further breakthroughs in the iPS cell field. He particularly cited independent papers from researchers at Harvard University and the Massachusetts Institute of Technology published at the same time and noted that he anticipated competition between groups in Japan and the United States to heat up.

Just five and a half months later, the Kyoto University researchers reported in Cell (Volume 131) that they had successfully generated human iPS cells. Surprisingly, another group from the University of Wisconsin-Madison reported on the same day in the online version of Science magazine that they had achieved human iPS cell production.

Professor Yamanaka’s paper was accepted two days before the University of Wisconsin paper, but this certainly showed the highly competitive work being done in this exciting area of medical research.

Two major problems remained. One of the four genes introduced into the adult skin cells, c-Myc, is oncogenic (a cancer-causing gene) and the retroviral transfection system used to integrate genes into the human DNA might be prone to generate hyper-proliferative cells. By further modifying the method used, Professor Yamanaka’s group successfully generated mouse iPS cells in the absence of the exogenous c-Myc gene.

In this case, the mice chimeras (mice produced with the iPS cells) did not exhibit tumors. This result was published just 10 days later in Nature Biotechnology (online edition) on November 30, 2007. Kyoto University has applied for several patents for these research methods.

Professor Yamanaka at work in his laboratory Recently he has often been away from the lab, attending symposia in Japan and abroad.

When does human life begin?

Embryonic stem cells (ES cells) are pluripotent. This means they can differentiate into nearly all of the cell types in the adult body. When grown in vitro, ES cells maintain pluripotency through multiple cell divisions, hence they are stem cells with unlimited capacity for self-renewal and growth. ES cells are only generated in early-stage embryos in a fertilized egg. Such an embryo is the start of human life and, if left to grow in the womb, will develop into a new human being. Consequently, the use of human ES cells in research involves many difficult ethical issues. Ethical debate centers on research involving the creation, usage and destruction of ES cells and questions regarding the start of human life and whether an early-stage embryo should be regarded as a human being or not. If it is, some people ask, “Do we have the right to take that life away?”
Japanese researchers become the center of global attention

The intense level of news coverage around the world was unprecedented for a scientific announcement from Japan. On the day the results were announced (November 20, 2007), the White House issued a statement that President George W. Bush was very pleased to see important advances in stem cell research reported in scientific journals. From the Vatican, Bishop Elio Sgreccia, head of the Pontifical Academy for Life, said that the announced results were historic and would likely put an end to debate concerning the necessity of using human embryos and cloning technology in medical research. Reactions in the international press included “Skin cells behave like stem cells” (USA Today) and “Skin transformed into stem cells” (BBC).

On December 11, the New York Times printed a feature article and interview headlined “Risk taking is in his genes” about Professor Yamanaka and his achievements.

iPS cells open new frontier in regenerative medicine research

At the press conference announcing his human iPS cell breakthrough, Professor Yamanaka was asked about the usefulness and applications of the new cells. “First of all, I hope this will lead to the discovery of new medicines,” he replied. What he had in mind was making iPS cells from the skin cells of a patient and then using them to test which medicines would be the most effective for that patient. A particularly promising area of research was the extremely rare disease Werner’s Syndrome (a genetic disorder causing premature ageing), for which the cause is unknown. iPS cells could be induced to differentiate into normal cells in the affected tissue. By comparing normal cells and affected cells, researchers could look for causes of the disease and try to develop drugs to prevent the disease from progressing.

Other areas for possible application of iPS cells are in a situation where a patient experiences a failure related to the heart or central nervous system and an application of biopsy is not possible. In such cases, iPS cells could be used to generate cardiac cells or neurons in a test tube, which could then be examined to discover the cause of the disease and be useful for drug discovery.

In bioscience research, there is extensive use of mice but the use of higher-order animals, such as dogs and monkeys, is now extremely difficult in view of animal rights-related ethical issues. By utilizing iPS cells, it may be possible to eliminate the use of such animals in research.

In Japan and other countries, clinical trials are being pursued using tissue stem cells. Regenerative medicine is no longer in the realms of science fiction but is rapidly moving closer to yielding advanced therapies. Although there are still many difficult issues to overcome, compared with tissue stem cells, iPS cells can be differentiated into many more kinds of tissue. This means there are strong expectations that iPS cells will open the way for definitive cures for many diseases and that many more people can be helped by regenerative medicine.

In the past, regenerative medicine development was focused on the transplantation of cells from a third party. However, using iPS cells, patients might be successfully treated with their own cells. This may be considered as ushering in an era of truly regenerative therapies. However, among the many hurdles to be cleared before iPS cells can be practically applied, the problem of hyper-proliferative cells prone to cancer is particularly pressing.

Gene delivery based on the use of a retroviral vector system has shown the risk of causing tumors and cancer. As a way of solving this problem, Professor Yamanaka’s group has demonstrated that generation of iPS cells can be accomplished via a plasmid vector, a circular DNA molecule separate from chromosomal DNA, instead of a retrovirus vector. This method is expected to have a much lower risk of causing tumors or other abnormalities, since its use is unlikely to cause alterations in the cellular genomes. In research using mice, this method was shown to have a lower incidence of cancer.

The type of cutting-edge discovery represented by the iPS cells is said to occur only once in a generation. Researchers around the world are now working to understand the mechanism of cell reprogramming into ES cell-like states via introduced defined factors. iPS cell research is also expected to have a direct impact on therapeutic research relating to a myriad of diseases.

Werner Syndrome
Werner Syndrome (also known as “adult progeria”) is a very rare genetic disorder characterized by the appearance of premature aging. Some sufferers of this syndrome die during childhood. The disease is named after Otto Werner, who first documented the syndrome in 1903. At the time, he was a medical student at Kiel University in Germany undertaking ophthalmology training. Individuals affected by this syndrome can exhibit symptoms as early as six months after birth. It is more common, however, for symptoms to appear after puberty.

Utilizing regenerative medicine at the clinical level through teamwork
Even if stem cells are transplanted, they do not simply transform themselves into organ tissue. The cells require both a “stepping stone” phase on the way to transforming into the eventual organ tissue and a mechanism for acquiring the functions of the organ cells. To achieve success in transplants, specialist researchers from a variety of disciplines, such as bioengineers and tissue engineers, must work together. Without such research, it would be impossible to apply stem cells to actual medical treatments. It is fair to say that partnerships among these fields are essential to the development of regenerative medicine.

At present, collagen and other proteins are bio-absorbable materials used as a “stepping stone.” Such materials are harmless to the body and can be broken down inside the body.

CREST (Core Research for Evolutional Science and Technology)
The CREST program targets team-oriented research that can generate the seeds necessary for further innovation. Ideally, CREST research projects have far-reaching impact. An optimal research leader is chosen to manage research in a “virtual institute” type setup.

For more information: Please visit the website of the Yamanaka Laboratory at Kyoto University:

Several important research breakthroughs were announced through the online edition of the U.S. journal Science.

Mouse iPS cells generated using a plasmid vector. The iPS cells were differentiated into skin tissue, nerve tissue and a range of other cell types.

Recent milestones achieved by Professor Yamanaka

September 18, 2003
The project led by Professor Yamanaka, entitled “Clinically Applicable Pluripotent Stem Cell Development,” is chosen for the JST Core Research for Evolutional Science and Technology (CREST) program in fiscal 2003 under the category of “Advanced therapeutics technologies for intractable immunity diseases and infectious diseases.” The human iPS cell breakthrough was achieved as part of this project.

August 11, 2006
Reports success in inducing stem cells from mouse skin cells (JST press release). Announced through the online edition of the U.S. journal Cell.

June 7, 2007

November 21, 2007

February 15, 2008

October 10, 2008
Reports generation of iPS cells without the use of retrovirus vector (JST press release). Announced through the online edition of the U.S. journal Cell.
From transparent Transistors to a New Family of Superconductors

Hands-On Philosophy Wins International Recognition

Professor Hideo Hosono

In the exciting world of materials science, groundbreaking discoveries often come from unlikely sources and turn conventional wisdom on its head. One of Japan’s leading researchers in this field revels in his reputation as an experimentalist with a knack for world-first discoveries.

Materials through the Ages

Stone Age, Bronze Age, Iron Age — these are names given to some of the early eras of human history. They highlight the strong linkage between mankind’s advancement and the increasing sophistication of the materials people used. The creation of new materials — those that do not exist in the natural world — through the power of science has contributed greatly to the advancement of civilization. The value of materials science lies in its ability to create materials useful to human beings. Even though breakthroughs often do not appear to have much practical effect straight away, they often help to solve issues that society is grappling with and open the door to a new era.
Birth of the transparent, flexible semiconductor

Imagine a high-performance display device that is just one or two millimeters thick and bends like a desk mat. Such a radical device may be closer to reality than you realize. A major step in realizing a thin, flexible display was the recent discovery of a new type of material—the transparent amorphous oxide semiconductor (TAOS). Professor Hideo Hosono of Tokyo Institute of Technology heads a team of researchers responsible for this breakthrough discovery. In contrast with a crystalline solid, an amorphous solid exhibits no long-range order in the positions of its atoms. Uniform thin films can be produced at low-cost using amorphous materials. Thanks to this advantage, amorphous silicon-based semiconductors are already commonly used in such applications as liquid crystal displays (LCDs) and photovoltaic cells. However, a major drawback of amorphous hydrogenated silicon (a-Si:H) is that it provides low electron mobility and hence low transistor performance. For this reason, amorphous silicon is not deemed suitable for computing applications or high-performance displays. Instead, organic semiconductors became the focus of mainstream research. Professor Hosono, however, challenged this conventional wisdom.

"Until now, amorphous materials were all covalently bound. I thought it would be worthwhile to try to make an ionically bonded material amorphous." With an ionically bonded material, it would also be possible to create a material that had previously not been achieved—a transparent semiconductor. After carrying out a long series of experiments, in 1995 Professor Hosono proposed the first ever TAOS with electron mobility substantially equal to crystalline semiconductors. From 1999, research was conducted under the auspices of the ERATO HOsono Transparent ElectroActive Materials (TEAM) Project, and then from 2004 through the "Exploration and Applied Engineering of Novel Functions Based on Nanostructures in Transparent Oxides" (ERATO-SORST). The "flexible transparent transistor" announced as one of the results of the project is receiving worldwide attention as a Japanese-developed, high-performance display device. He describes the transistor comprising a thin layer of transparent amorphous oxide semiconductor (TAOS) material fabricated by conventional vacuum deposition and having excellent performance—enough to drive organic LED displays and next-generation LCDs. Electron mobility is more than 10 times greater than hydrogenated amorphous silicon, which is widely used now.

Cement transformed to electrically conductive metal

Professor Hosono continues to explore widely in his search for a variety of exciting new materials, in addition to his interest in flexible transparent transistors. He describes one of the fundamental principles driving his research as "a desire to make discoveries that will cause the scales to fall from my eyes." Such a breakthrough happened in 2002 when he discovered "a cement with electrical conductivity." This remarkable discovery revolved around mayenite—a calcium aluminate (referred to as C12A7 in cement-chemistry nomenclature). Its chemical formula—12CaO.7Al2O3—may look formidable but it is actually comprised of very common substances (see table). What really caught Professor Hosono's attention was the crystal structure of C12A7. The crystal's atoms form sub-nanometer-sized cages, which are strongly bound together. Each crystal cell has 12 cages, with negatively charged oxygen ions (O2-) present in two of the 12 cages (see diagram).

A flexible transparent transistor

A transistor comprising a thin layer of transparent amorphous oxide semiconductor (TAOS) material is fabricated on a thin, transparent plastic film. The transistor is easily fabricated by conventional sputtering and has excellent performance—enough to drive organic LED displays and next-generation liquid crystal displays.
resulting material behaved like a metallic electrical conductor— as the temperature was lowered conductivity increased. C12A7 had been transformed into a "transparent metal."  

Transparent metals are an essential material in the manufacture of liquid crystal displays. At present, indium-tin-oxide (ITO) is the most commonly used substance in this application, but since indium is a rare metal one million times rarer than iron in the Earth’s crust, future supplies are uncertain. The common availability of C12A7 constituents means high expectations are held for it as a TIOF replacement substrate.

Discovery of a new family of iron-based high-temperature superconductors

Superconductivity was not a field that particularly interested Professor Hosono. The phenomenon of superconductivity— whereby electrical resistance can be reduced to zero at extremely low temperatures—was discovered in 1911. When superconductivity was first discovered, the threshold temperature—or transition temperature—required was 4.2 kelvin, or −269°C. Prior to 1986, superconductivity was found in various metal elements and alloys. The transition temperature also gradually rose (see chart).

A dramatic change occurred in the 1980s, when a completely different type of superconductor was discovered. These cuprate superconductors all contain copper oxide. From that point on, the highest recorded transition temperature for superconductivity increased at an unprecedented pace as this new type of superconductor, known as high-temperature superconductors, became the subject of vigorous research around the world. If superconductivity could be achieved at room temperature, it held the prospect of electricity distribution with no electrical loss and many other innovations.

A "superconductivity boom" ensued, but Professor Hosono stood on the sidelines. The common thread of his research had been "transparency" but high-temperature superconductors were plain old black. "For me, clear is beautiful. It is one of the things that drives me, my curiosity," he explains.

Eventually, the new cuprate-based superconductor research boom petered out. Then suddenly, in February 2008, Professor Hosono announced that his group has found a new family of high-temperature superconductors—this one based on iron. The unlikely source of the discovery was the "transparent semiconductor" research project.

From transparent transistors to a new family of superconductors

Hosono’s group with iron—oxypnictides, superconductivity and iron had been considered particularly incompatible. In conventional superconductors, superconductivity is destabilized by a magnetic field, and iron is a typical magnetic substance. So we might say that Professor Hosono transformed iron from its lowly status as "classroom troublemaker" into a superconductor. There are hopes that future research may yield significant benefits from iron’s high tolerance to magnetic fields—turning what once was its weakness into its strength. Possible applications include bulk power transmission and high-powered motors. It seems the classroom troublemaker is turning into a star pupil.

The wisdom of a former boss

One day, Professor Hosono (at the time, an assistant professor) took a new material he had developed to show a senior professor who was his boss at the time. "All of a sudden, he began tapping it on the desk. Then he smiled and said, ‘It makes a lovely sound!’" recalls Professor Hosono. He says that it was at this time he began to understand how important it is to use all five senses. In the laboratory, researchers subconsciously absorb all kinds of information, such as sound and color. A laboratory is like a treasure trove of information. That is why the laboratory is often the place researchers get their greatest flashes of inspiration.

From classroom troublemaker to star pupil? Until the recent breakthrough by Professor Hosono’s group with iron—oxypnictides, superconductivity and iron had been considered particularly incompatible. In conventional superconductors, superconductivity is destabilized by a magnetic field, and iron is a typical magnetic substance. So we might say that Professor Hosono transformed iron from its lowly status as “classroom troublemaker” into a superconductor. There are hopes that future research may yield significant benefits from iron’s high tolerance to magnetic fields—turning what once was its weakness into its strength. Possible applications include bulk power transmission and high-powered motors. It seems the classroom troublemaker is turning into a star pupil.

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Separate from the main TAOS research, another strand of research realized a p-type transparent semiconductor utilizing a layered crystal structure. In 2006, while the researchers were experimenting with the substitution of certain elements within the structure to see what characteristics this might produce, they found that some compounds based on iron and phosphorus exhibited superconductivity. Since superconductivity was conventionally seen as incompatible with magnetic properties, iron was considered to be the last constituent for superconductors. Although the results seemed to disprove the conventional wisdom about iron’s unsuitability, the transition temperature the researchers achieved at this stage was only 5 kelvin. Since this was much lower than 130 kelvin that had been achieved for copper-based oxides (and 160 kelvin for oxides under high pressure), the results did not create a lot of interest.

However, when the research was repeated with arsenic substituted for phosphorus—giving what is known as an oxypnictide compound with a chemical formula of LaFeAsO—its transition temperature for superconductivity rose to 26 kelvin. In February 2008, when the team announced its latest results, the transition temperature was much higher and beginning to move into the range achieved with the cuprate compounds. A renewed flurry of research had been sparked in the superconducting field. Rather than merely disproving iron’s unsuitability for superconductivity, Professor Hosono thinks that this discovery may be the harbinger of much greater things to come. “With copper oxide based compounds, superconductivity did not occur if the electrically conductive CuO2 layer was replaced by other elements. I call it a ‘Mount Fuji phenomenon’—quite a high peak but no other higher mountains nearby. In our new discovery; we have the possibility of a mountain range. Replacing the iron and arsenic with other elements still gives us superconductivity. We haven’t yet reached the high temperatures exhibited by the cuprates, but maybe we are still only in the foothills. If we keep exploring, who knows, we might even find our own Everest.”

Proud to be known as an “observation-inspired researcher”

The value of materials science lies in its ability to create something new. It does not matter how many hundreds of books one reads and understands, that alone will not achieve anything new. The realizations and insights one gains in the lab, doing hands-on research, can turn conventional wisdom on its head and lead to new concepts and revolutionary breakthroughs. Professor Hosono has held this core philosophy ever since he worked under Professor Yoshihiro Abe at Nagoya Institute of Technology, whose approach was very much hands-on. “Utilizing all five senses is very important,” says Professor Hosono. “One could describe physics and chemistry as the foundations and materials science as the applications. But I think it is crucial not to be boxed in. One should keep moving back and forth between basic and applied research. That’s the most appealing part of materials science, in my opinion,” he confides.

Professor Hosono describes himself as an “observation-inspired researcher” with the mettle to take on the theorists, and is proud to try the colors for material scientists.
Dr. Mitsuo Kawato

The electrical neuron signals from the brain of a monkey in the United States are relayed over a distance of more than 10,000 km to Japan. The signals are received in real time by a robot in Japan, which reproduces the physical movements of the monkey. This groundbreaking experiment and the background research leading up to it provide a fascinating insight into the possibilities created by brain-machine interface.
Unlocking the mysteries of brain information processing by controlling a robot with human brain activity

I

It is no exaggeration to say that Japan leads the world in various aspects of robot research, as illustrated by such breakthroughs as the first humanoid robot to successfully walk upright on two legs (erect biped locomotion). Meanwhile, in recent years there has been a flurry of advances in research of the brain—the most complex living organ and most advanced information processing device known. As a result, we are seeing increasing convergence and crossover between neuroscience and many other fields. One of these leading-edge areas of research is technology that connects the brain with information and telecommunication devices—brain-machine interface.

In the Computational Brain Project, a JST international cooperative research project (ICORP), brain activity that occurs through human behavior is reproduced using computers and verified using humanoid robots. This research is being carried out jointly with researchers from Carnegie Mellon University (CMU) in the United States. In Japan, research is being led by Dr. Mitsuo Kawato, director of ATR Computational Neuroscience Laboratories. Dr. Kawato explains, "Although advances in robot research have enabled us to develop robots that are capable of movements similar to humans, we are still nowhere near developing the level of artificial brain power that would be needed to control complex human movement. We thought it would be valuable to approach this problem from the opposite side—getting a better understanding of the human brain by harnessing brain activity to control the movement of robots." In a forerunner ERATO research project that ran from 1996–2001, Dr. Kawato’s group used a humanoid robot called "DB" (dynamic brain) to unravel how the human brain learning function works. DB was able to watch and imitate human movement. It learned approximately 30 types of complex movement, including air hockey and juggling. Through this research, the project was able to clarify what kind of information processing occurs when the human brain learns a new movement. This contributed to the formation of a new paradigm in brain research.

ICORP (International Cooperative Research Project)

This JST program supports international cooperative relationships at the institutional level. Its aims are to support projects that have strong potential for achieving breakthrough results and creating key knowledge as well as setting trends for science and technology research around the world.

Do Japanese people have a special affinity for robots?

H

However, DB was still unable to control its own posture and its walking capabilities were very rudimentary. To elucidate the information processing functions of the brain by projecting human brain activity onto a robot, it would be essential to develop a humanoid robot with complex movement capabilities as close to humans as possible. With this in mind, the humanoid cognitive systems group of the Computational Brain Project developed a new humanoid robot, called "CBI" (computational brain interface). By having high-ratio reduction gears on its joint actuators, many walking humanoid robots achieve high torque, thereby enabling them to support their own weight. In contrast, CBI has hydraulic cylinders on its main joints, giving it exceptionally good torque as well as high-speed force feedback control. Thanks to this design, the robot achieves very flexible, human-like movement.

As humanoid as possible

The humanoid motion learning group—Jun Morimoto (left) and Sang Ho Hyun.

Brain-machine interface

A brain-machine interface is a direct communication pathway between a brain and an external device. Such an interface measures brain activity or sends stimuli to the brain and is aimed at assisting augmenting or repairing human cognitive or sensory-motor functions. One example of a brain-machine interface is a cochlear implant (artificial ear), a treatment available for the severely hard of hearing. It provides a sense of sound by directly stimulating any functioning auditory nerves inside the cochlea. In the inner ear—with an electric field. Another brain-machine interface application being developed is for spinal cord injury patients. Neural activity is measured and used to operate external devices such as a wheelchair. It is envisaged that this technology will provide patients with a means to compensate for their affected motor functions.
Since CBi was designed to have its movements activated by information relayed from human brain neural activity, it was built to stand 1.55 m tall and be as human-like as possible. It has 51 moving joints—or “51 degrees of freedom” in robotics jargon—giving it near-human flexibility of movement. In the milestone experiment mentioned above, electrodes were implanted into the brain of a monkey at Duke University in North Carolina. Electrical signals given off by neurons in the monkey’s cerebral cortex were minutely measured. This data was then transmitted in real time to Japan, where it was used successfully to activate the movements of the CBi robot.

Dr. Kawato further explains, “Professor Miguel Nicolelis of Duke University is a long-time friend. He’s known as the ‘brain-machine interface hero’ because of his pioneering work. The brain electrodes he developed have excellent capabilities for reliably detecting neural activity, so we asked him to collaborate on this experiment. CBi’s movements are only shown to the monkey on a video screen. In future experiments, we plan to stream the monkey’s neural information in almost real time. At present, CBi’s movements are relayed to the United States. Future experiments will include also sending sensory data from CBi as feedback.”

Real-time two-way network streaming

To achieve this result, it was necessary to activate CBi’s movements in real time in response to the monkey’s neural signals. If there were a time lag between the neural signals from the monkey and CBi’s movements, it would be hard for the monkey to recognize that CBi’s movements were being constructed from its own walking motion. For this reason, it was essential to stream the data in real time between the United States and Japan.

Gordon Cheng, leader of the Computational Brain Project’s humanoid cognitive systems group, explains, “If we used an ordinary network interface, the data would have to be routed through a large number of computers as it traveled back and forth across the Internet. This slows down data transmission. To eliminate this problem, we developed a new system for high-speed data transfer that would route it through as few computers as possible between the United States and Japan.” Consequently, it was possible to control CBi’s movements using the monkey’s neural information in almost real time. At present, CBi’s movements are only shown to the monkey on a video screen. In future experiments, however, the group is considering taking this a step further by also transmitting information from the various sensors built into CBi directly to the part of the monkey’s brain that controls sensory functions—the somatosensory area.

If this technology advances further, what might be some of its practical uses? One possible area of application is in prosthetics and other medical devices. For example, people whose limb movement is impaired after a cerebral infarction (stroke) or spinal cord injury could wear a “powered suit” to aid movement, which could be controlled by signals from their brain.

Already, work is advancing in the development of a powered suit that uses myoelectric potential (muscle potential) as its control signals. Although such a device is very close to the practical application stage, the number of potential users is relatively small owing to the fact that many patients do not have detectable myoelectric potential in their affected limbs. For such reasons, brain-machine interface technology, which harnesses neural signals rather than muscle signals, is seen as a very promising field that could help remobilize a large number of people. Dr. Kawato and his team relish the challenge of contributing to such solutions through robot research.

For more information:
ATR Computational Neuroscience Laboratory website: http://www.cns.atr.jp/
indexE.html
Dr. Kawato’s website: http://www.cns.atr.jp/~kawato/
Producing antibodies for therapeutic or industrial use by means of conventional technology is expensive and slow. With help from a JST program designed to transform seed ideas into innovative business ventures, however, a university-based research team in Kyoto is using ostriches to revolutionize the antibody manufacturing business.

**Professor
Yasuhiro Tsukamoto**

Born in 1968, in Kyoto, Japan. Graduated from the Osaka Prefecture University, Faculty of Agriculture, Department of Veterinary Science in 1994. In 1999, received his doctorate from the Graduate School of Life and Environmental Sciences of the same university and was appointed as a research assistant. Commenced research into infectious diseases among domestic fowl. In April 2008, was appointed professor in the Graduate School of Life and Environmental Sciences at Kyoto Prefectural University.
Could enormous eggs mean huge potential? Venture company develops groundbreaking technology for antibody production

Inside our bodies, we have an immune system to protect us against attacks from external threats. This system wards off incursions by foreign organisms, such as viruses and bacteria. Immunity is an extremely complex mechanism for repelling foreign matter, and antibodies are at the first line of defense, suppressing the proliferation of viruses and bacteria.

Through immunization, even if a person is infected with a disease-causing virus or bacterium, the symptoms can be diminished. This is done by pre-exposing the immune system to a pathogen—usually by infection—that has been rendered harmless. Immunization works because the body’s immune system produces antibodies in response to the presence of the virus or bacteria. The properties of these antibodies not only protect the body from disease but also may be applied to a myriad of uses.

An antibody’s basic function is to attach itself exclusively to the protein inside a foreign organism to render harmless the disease-causing agent. With the utilization of this property of attachment only to proteins, antibodies are now employed as a way to screen for specific proteins. For example, if we can use antibodies to detect proteins produced only by cancer cells inside the body, this will enable us to diagnose the cancer. Such applications for antibodies are becoming more common, and the potential market for antibodies is attracting considerable attention.

Avian influenza
Avian influenza (often referred to as “bird flu”) is the general name for the type-A influenza virus that is transmitted among bird species. The virus mainly infects domestic hens and turkeys, but only rarely infects wild birds. Ordinarily, humans do not contract the avian flu virus, but rare cases have been reported of humans becoming infected after close contact with infected birds or their remains. Humans that have contracted the virus exhibit such symptoms as sudden high fever, coughing and other respiratory inflammation, severe fatigue and muscle aches. In Japan, there have been no reported cases of human infection from bird flu. Around the world, there have been many reported cases of avian influenza infections, mainly in Asia, with a high percentage of fatalities among those contracting the disease. It is feared that this bird flu virus could mutate into a new strain of flu that could be transmitted among humans, causing a severe pandemic.

Ostrich Antibodies: Potential Weapon in the War on Bird Flu

Up to now, antibodies have been manufactured mainly by injecting antigens into mice, rabbits and hens. The antibodies produced by the immune systems of these animals are refined from blood in the case of mice and rabbits, or from the egg yolk in the case of hens. Manufacturing antibodies using this type of method is very costly, and high-volume production is problematic.

To overcome such problems, Professor Yasuhiro Tsukamoto of the Graduate School of Life and Environmental Sciences at Kyoto Prefectural University developed new technology for mass-producing antibodies at low cost using ostriches.

Professor Tsukamoto had originally been pursuing research on infectious diseases among domestic fowl, but he turned his attention to ostriches because the large flightless bird is notably resistant to viral infections and its egg is 25 to 30 times the size of a chicken egg. He thought that by utilizing ostriches, it might be possible to manufacture antibodies on a large scale.

Professor Tsukamoto explains, “The antigens injected into animals for the manufacture of antibodies are very expensive. Obviously, if only a small quantity of antibodies can be produced from a single animal, the cost is high. With ostriches, since we can produce about 4 grams of high-purity antibodies from one egg yolk, we use fewer antigens. On top of that, there is no need to build complex breeding facilities, so we can produce large quantities of antibodies at low cost.”

A very productive individual ostrich can lay approximately 100 eggs in a six-month period. Based on this level of productivity, 400 grams of antibodies can be produced from one ostrich. If rabbits were used, on the other hand, 400 grams would be equivalent to the production from 800 animals. Just as Professor Tsukamoto had intended, by using ostriches— and taking advantage of the large size of their eggs—the project achieved much higher productivity than is the case with conventional manufacturing methods.

Ostrich breeding and research
Ostriches are reared at a farm in Hyogo Prefecture for the purpose of manufacturing antibodies. At the research farm, light is controlled so that the ostrich’s breeding season extends throughout the year. Research is conducted into ways of increasing egg production.

Ostriches live 40–50 years. The average female begins laying eggs from two years old and continues laying for approximately 40 years. The average ostrich lays 40–50 eggs per year. Ostriches have a very long intestinal tract, they can be reared with high efficiency.

1. Low breeding costs
Ostrich manure does not have a strong odor and does not attract flies. The ostriches do not fight among themselves except for during the breeding season. A space of 1,000 m² can support 20–30 ostriches and no barn is required. Ostriches make very little vocal sound. Since ostriches have a very long intestinal tract, they can be reared with high efficiency.

2. Strong breeding capabilities
Females begin laying eggs from two years old and continue laying for approximately 40 years. The average ostrich lays 40–50 eggs per year. Ostriches have a high adaptability to climate. In Japan, they can be reared from the far north to the far south of the country.

3. With one ostrich egg you can make scrambled eggs that would be the equivalent amount to 20–25 hen eggs. Ostrich eggs have a rich taste and can be prepared in myriad ways.

Many advantages from ostrich breeding

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2. Strong breeding capabilities
Females begin laying eggs from two years old and continue laying for approximately 40 years. The average ostrich lays 40–50 eggs per year. Ostriches have a high adaptability to climate. In Japan, they can be reared from the far north to the far south of the country.

3. With one ostrich egg you can make scrambled eggs that would be the equivalent amount to 20–25 hen eggs. Ostrich eggs have a rich taste and can be prepared in myriad ways.
Antibodies from ostrich eggs: higher volume as well as better performance

A significant advantage was gained from producing a large volume of antibodies from a single ostrich. "Even when using a single species of animal for antibody production, there are slight differences in the antibodies you get from each individual animal. Consequently, conventional production methods involve variable quality within a product. With ostriches, because we can produce a large quantity of antibodies from a single bird, the variation in product quality is extremely small," says Professor Tsukamoto.

The project team conducted an experiment in which they made antigens from multiple influenza viruses whose ability to replicate had been inactivated. The experiment involved neutralizing a highly pathogenic strain of the avian influenza virus. Compared with conventionally produced antibodies, the experiment showed that the ostrich antibodies have a high capacity for rendering a virus harmless.

Another advantage from using ostrich antibodies relates to heat resistance. Ostrich antibodies showed much greater heat resistance than those produced by chickens. If antibodies remain active at high temperatures, the potential opens up for a wide variety of processing. Hopes are high that ostrich antibodies can be utilized to develop a range of new industrial applications.

"Early on in the project, we focused on the potential advantages available in antibody production based on the size of ostriches. As we got further into the project, we found that the ostrich antibodies performed even better than we expected."

Recognizing the potential competitive advantages of ostrich antibodies as the seed technology for a business, Professor Tsukamoto approached an ostrich farm in Hyogo Prefecture and began working with the farm to set up a system for large-scale antibody production.

The project was also accepted into the JST program for developing innovative business seeds based on university research. From that point, Professor Tsukamoto worked on R&D to fully realize the business potential of the new technology. He received the support of graduate assistant Kazuhide Adachi, as they worked to develop original technologies for refining antibodies from ostrich egg yolks. To commercialize their ostrich antibody system, they established a venture business called Ostrich Pharma Corp.

Through such processes as centrifugal separation, the company has developed various technologies for refining high-purity antibodies.

What specific applications have been developed? Although Professor Tsukamoto’s initial idea was for ostrich antibodies to be used in a diagnostic agent for lung cancer, he received a number of alternative suggestions from the many business people he talked to. The first idea to be commercialized was a surgical mask treated with antibodies, which was launched on the market in autumn 2008.

The specter of a flu pandemic remains a significant fear for health authorities around the world. A mutant bird flu spreading from human to human is a disaster waiting to happen, according to some. With studies suggesting that such an epidemic could cause more than two million fatalities in Japan alone, surgical masks are seen as a key defense for preventing droplet transmission of viruses. Professor Tsukamoto says, "By treating masks with antibodies, we can render a virus harmless so that even if the virus did penetrate a mask, the risk of infection is greatly reduced."

Moreover, by realizing low-cost mass production of antibodies, the potential exists to use antibodies in applications that would not have been viable under conventional production methods. For example, ostrich antibodies retain their effectiveness even when freeze dried, which opens up the potential to develop products in tablet or capsule form.

Prevention of norovirus food-poisoning outbreaks is one such potential application. Since norovirus is spread via fecal matter, treating toilet systems with antibodies may be an effective strategy. For example, norovirus antibody tablets, made at low cost from ostrich eggs, could be put into toilet water tanks to neutralize the norovirus with each flush. If such a product were successfully developed, the potential market among elderly-care facilities would be large.

Of course, the original application Professor Tsukamoto had in mind, the lung cancer diagnostic agent, is under development, and the production of antibody drugs for therapeutic use in the future also holds much promise. Professor Tsukamoto comments, "Our strength is our ability to respond to a diverse range of business opportunities wherever there is a need for antibodies." Future demand for antibodies is expected to grow considerably, from industrial applications to pharmaceutical applications. As such demand grows, so does the potential to utilize ostrich antibodies.
Even after hundreds—or in some cases thousands—of years, great artistic treasures still inspire a profound sense of beauty and wonder among those who gaze upon them. Many of Japan’s most celebrated and world-renowned historic art works are being given a new lease on life. Thanks to some of the latest scientific and technical advances, many of these treasures are casting their light further, wider and more vividly.

Byobu: Folding screens featuring scenes of Tosen and Nanbansen
Approximate date: early 17th century
Material: color on gold-leaf paper
Dimensions: height: 155.8 cm; width: 360.4 cm

This early-17th century painting on gold leaf depicts a man dressed in the Nanban style, the name given by contemporary Japanese to the fashions and manners of people arriving on trading ships of European origin. The man’s features can be seen in very delicate detail, and it is apparent that red pigment from his hat and patches of gold leaf have peeled off. A viewer of such a finely detailed painting might assume that it was a stand-alone portrait. But in reality, this is only a tiny portion of a much larger work.

Born in 1952, Professor at the Graduate School of Engineering, Kyoto University. Specializes in research on materials analysis and processing using particle beams. In 2004, his project was selected by the JST program for key seed projects focusing on regional R&D. From 2006, he embarked on research that utilized the output of previous research—a large high-resolution scanner. He is originally from Iran, and came to Japan in 1972. He moved to Kyoto the following year.
Faithfully preserving the value of cultural treasures through high-resolution digital imaging

First, take a look at the picture on page 28. It could be a finished work in its own right. But actually, it is just a tiny part of a much larger picture—many hundred times larger, in fact. The reproduction of this artwork in such fine detail was made possible through the efforts of a team of researchers led by Professor Ari Ide-Ektessabi of Kyoto University’s Graduate School of Engineering. They developed a large, ultra-precision scanner to capture this image. Professor Ide-Ektessabi’s specialist area of research is nanoscale analysis and processing using ion, electron and photon particle beams. In recent years, he has also turned his attention to the field of cultural heritage. He was drawn to this area because he thought it offered good opportunities for fruitful collaboration between university-based and industry-based researchers. This view was also shared by the people at JST Innovation Plaza Kyoto.

Kyoto is known around the world as a city of culture. There are important cultural treasures and heritage sites almost everywhere you go. Likewise, there is a strongly felt desire to preserve and research this heritage. Kyoto is also known as a high-tech region where many world-leading companies are clustered. JST and Professor Ide-Ektessabi believed there was great potential for local companies to commercialize the results of university-based science and technology research, which could substantially benefit Kyoto’s cultural heritage. “What if we could digitize cultural treasures and then use this as the basis for further research?” they thought. With this goal as an important motivation, in 2004, a new project was born as part of JST’s Comprehensive Support Programs for Creation of Regional Innovation. As a key seed project for regional R&D, the Project to Develop a High-Resolution Large Flatbed Scanner and Non-Destructive Pigment Estimation System got underway.

Visible light analytical imaging to ensure that the cultural heritage is unharmed

A major part of this project was the development of a high-resolution large flatbed scanner. Although there were previously many examples of attempts to build digital archives of cultural heritage, these had been limited to simply the capture of electronic image data. To faithfully preserve the full value of cultural treasures, in addition to producing the highest resolution digital images possible, it was essential to develop equipment that could extract detailed scientific data for further analysis.

Professor Ide-Ektessabi explains, “Some analytical imaging techniques, such as X-ray, run the risk of causing damage to the item being imaged. However, in the case of cultural heritage, we are talking about extremely precious items, which must remain completely unharmed by the imaging work we do. Since I am a scientist whose forte is analytical work, solving this problem appealed to me strongly as a very interesting challenge. We had to develop a hardware and software system that was not only non-destructive and non-invasive but also capable of capturing very high-resolution images.”

The professor thought that he could solve this key problem by using visible light for analytical imaging. Rather than using photography, which may vary in quality depending on the skill of the photographer, he believed scanning was the most suitable approach since it could produce reliable results as long as the correct operating procedures were followed. However, to enable in-depth analysis of a cultural treasure, it would be necessary to capture not only very precise color information but also data relating to subtle contours and other aspects. Furthermore, among the historical works of art the project would be covering, some were very large—several square meters—and others were wall paintings. Transporting such items to a studio would not be possible. Working through such problems in collaborative research with local companies, the project successfully developed a large, ultra-precision scanner in October 2006.
Developing a secure-dynamic display system for digitized cultural heritage

The scanner they developed weighed approximately 100 kilograms. It could be disassembled into three parts for transportation and practical use. A local company commercialized the scanner equipment, it was rapidly deployed all over Japan and work was begun on making images of a wide range of cultural treasures.

As a way to deepen our understanding of historic artworks using the valuable scientific data yielded from imaging activities, from the beginning the project included the development of a non-destructive pigment estimation system. The detailed image data are used as the basis for inferring pigments and other materials contained in the cultural heritage items, and have already contributed to some important achievements, including the development of the Pigmalion software system for pigment estimation.

Although Professor Ide-Ektessabi’s main research area is materials analysis, the project has whetted his interest in a wider array of fields, and he is enthusiastic about maximizing the project’s potential. “If you take a photo of your family, you don't want to just store it away. You want to enjoy looking at it. I think the same goes for cultural heritage,” he says. He particularly saw the need for an efficient system to display the high volumes of data collected from cultural heritage on personal computers.

He soon got to work in conjunction with another local company to develop such a system. The resulting Amaterasu software system allows users to browse easily through extremely large image files, including zooming and rapidly moving around to the different parts of the image. He explains, “With this software, in the future, researchers anywhere in the world will have access via the Internet to very precise, high-quality data on cultural heritage.”

Amaterasu has already enabled researchers to make new discoveries by using the software to examine artworks much more closely than is possible with the human eye alone. The software can also be adapted to operation using a touch panel system.

Bringing the figures on a byoubu painting to life

The project has also embarked on various ways to utilize the information gathered on cultural heritage as “digital content,” including the production of educational DVDs about particular artworks. They have tried to incorporate features that make the information both educational and fun. One such case is an original animation called “Amaterasu.” The name they chose derives from Amaterasu-omikami—the sun goddess—considered the most powerful deity in Japanese mythology among a pantheon of eight million deities. She is said to have been born from the left eye of her father, the deity Iamagij. In Greek mythology, Athena was born from the forehead of her father Zeus. One of the 12 Olympian gods, Athena was the goddess of wisdom and strategic battle. Owing to such apparent similarities, Amaterasu and Athena are often compared and contrasted by scholars of Japanese mythology literature.

Amaterasu
Professor Ide-Ektessabi’s project developed a secure-dynamic display system for digitized cultural heritage, and named this software “Amaterasu.” The reason was, in fact, the tendency from Amaterasu-omikami—the sun goddess—considered to be the most powerful deity in Japanese mythology among a pantheon of eight million deities. She is said to have been born from the left eye of her father, the deity Miamagi. In Greek mythology, Athena was born from the forehead of her father Zeus. One of the 12 Olympian gods, Athena was the goddess of wisdom and strategic battle. Owing to such apparent similarities, Amaterasu and Athena are often compared and contrasted by scholars of Japanese mythology literature.

Nanbanjin
Nanbanjin is the name first general name applied to Europeans by Japanese people in 1640, when the first Portuguese ships arrived in Japan, they came from the south. The Nanbanjin had neither seen such ships before, nor had they ever seen people with European features or clothing. Hence they were given this name, whose Chinese etymology means “southern barbarians.” The word Nanban came to denote all things European in this period of Japanese history. Nowadays, of course, foreigners are never referred to as Nanbanjin, but Nanban retains its connotation of a certain type of exoticism. It lives on in the names of various dishes, including Nanbanzuke (Nanban pickles), Kare Nanban (meat with curry soup) and Nanban-kaiseki (Nanban confections).

For more information:
International Innovation Center, Kyoto University (KU-IIC)
http://www.iic.kyoto-u.ac.jp/
soze/htdocs/ide.htm

Letting everyone enjoy our cultural heritage

Professor Ide-Ektessabi has one major concern—the problem of how digital archives will be managed. For example, if a museum creates a digital archive of the artifacts it houses, who will hold the rights relating to that archive and what procedures will need to be carried out before the archive is opened to the public? The answers to such questions are not yet clear. In 2003, the UNESCO General Conference adopted the Charter on the Preservation of the Digital Heritage. Since then, some countries have embarked on projects to realize the principles outlined in this charter, but Japan is still very much at the beginning stage of such a process.

“I think it is crucial not only to preserve cultural heritage but also to use our intellectual and financial resources to create a system that can be utilized within society and help increase awareness of this heritage. By doing so, we can contribute significantly to the long-term cause of cultural heritage preservation,” argues Professor Ide-Ektessabi.
Promoting the Dissemination of Information on Science and Technology

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JST HIGHLIGHTS

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Japan Science and Technology Information Aggregator: Electronic
Electronic journal site for Japan's academic societies
Over 500,000 journals comprising a scientific heritage.
Full texts of 540 journals are available either for a fee or free of charge.
More than 80% of abstracts are available in English.
http://www.jstage.jst.go.jp/browse/

Journal@archive
Academic journals scanned through the Electronic Archive Initiative
Archive of journal back issues in Japan
Over 960,000 archived articles comprising a scientific heritage.
Articles include papers authored by Japan's Nobel Prize winners.
Archived back to 1677.
http://www.journalarchive.jst.go.jp/english/

ReaD
Directory Database of Research and Development Activities
Comprehensive database for finding research information in Japan
Researcher profile database with professional career records and achievements.
Records and achievements on some 200,000 researchers in Japan are registered for promotion of collaboration between academy-government-industry.
http://read.jst.go.jp/index_e.html

J-STORE
JST Science Technology Research Result Database for Enterprise Development
Database for patents and other research results
Web-based database to encourage academia-government-industry collaboration.
Information on technical seeds/undisclosed patent applications held by academia to be searched.
http://jstore.jst.go.jp/EN/

JREC-IN
Japan Research Career Information Network
Career database for S&T personnel
Job search service for researchers seeking positions at domestic institutes.
Job seekers can receive via E-mail the job opening information, which matches the preferred conditions.
http://jrecin.jst.go.jp/eak/SeekTip/Sort/1

Science Links Japan
Gateway to Japan's scientific and technical information
A comprehensive (English-language) portal site of links of Japan's S&T institutes/polices/database/news with daily updates.
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