TSUKUBA, JAPAN

A tale of two cities

The Japanese city of Tsukuba, home of Tsukuba Science City, is a leading centre of pure research that aims to become Japan's flagship science and technology hub. **Matthew Salter** looks at the progress so far.

"A lot of the research carried out in Tsukuba is cutting-edge work, but it is basic, 'seed' research...one of the challenges for Tsukuba is to transition from 'seed' research to 'needs' research."

Kenichi Ichihara, Mayor of Tsukuba

Tsukuba is a Japanese city like no other. Located in Ibaraki prefecture approximately 50 kilometres to the northeast of Tokyo, the area was, until the late 1970s, a collection of sleepy agricultural hamlets known principally for their fragrant *fukure mikan* oranges, lawn turf and rice so good that before the Second World War it was for a time supplied to the Imperial Household.

Although the area still produces its famous oranges, and turf from its fields continues to grace the parks and gardens of Japan, in the past 40 years virtually everything else about Tsukuba has changed. Since 1970 the area has blossomed into a city of over 215,000 centred round Tsukuba Science City — one of the highest concentrations of international-level research centres and high-tech companies anywhere in the world.

The rise and rise of Tsukuba

The remarkable story of Tsukuba's development began in 1963 when the Japanese government decided to construct a new purpose-built research and education city outside Tokyo, which even at that time was becoming overcrowded as the Japanese economic miracle picked up speed. Wanting to build a city that could function on an international level, the government turned to the experience of planned metropolises overseas such as Brasilia, Bethesda and Palo Alto for inspiration. The project was enshrined in law by the passing of the Tsukuba Science City Construction Act in 1970, following which development progressed rapidly. By 1980, the heart of the Science City Area, at the time consisting of 43 research institutes and educational establishments built on 2,700 hectares of former farmland, was virtually complete. The metropolitan city of Tsukuba was created as it appears today in 1987 when the three towns and one village were merged into a single local government authority. A major step in the development of the city came in 2005 with the inauguration of the Tsukuba Express rail link, also called the *TX*. The high-speed line, which carries in excess of 230,000 passengers a day, connects central Tsukuba with Akihabara in downtown Tokyo, a journey of just 45 minutes, cutting the previous journey time in half.

None of this has come cheap. Although Tsukuba no longer receives financial support from central government, most estimates put the cumulative cost to the tax-payer of the Tsukuba Science City project alone — not including the construction of the *TX* — at more than ¥2,500 billion (approximately US$29 billion), unadjusted for inflation. According to Kenichi Ichihara, current mayor of Tsukuba, it's money well spent. "In many ways, I think the decision to build Tsukuba city was a remarkably far-sighted one. At the time there were no other programs in science and technology of a comparable scale anywhere else in world."

Basic research with Nobel connections

That scale is still expanding, and in recent years the number of research institutes and universities has grown to over 60. The first public research institute to relocate was the National Institute for Research in Inorganic Materials, which reopened in Tsukuba Science City in 1972. By 1980 a total of 43 institutes had moved to the area. Consolidation and reorganization has reduced the number of public institutes to the current total of 31 including such bodies as the RIKEN Tsukuba Institute, the National Institute of

SUI-SETZ/WIKIPEDIA

The Tsukuba Express high-speed rail line connects Tsukuba to Tokyo in 45 minutes.

Agrobiological Sciences (NIAS), the Japan Aerospace Exploration Agency (JAXA) and the High Energy Accelerator Research Institute (KEK), where the 2008 physics Nobel Laureate Makoto Kobayashi is professor emeritus. The city also boasts two universities as well as the Science Academy of Tsukuba. The largest of these is the University of Tsukuba, which was created in 1973 when the Tokyo University of Education relocated to the then embryonic new city of Tuskuba and which allows the city to claim association with three more Nobel laureates in science: Shin-Itiro Tomonaga (Physics, 1965), a professor at the forerunner to the University of Tsukuba; and Leo Esaki (Physics, 1973), a former president of the university and current president of the Science Academy of Tsukuba. Hideki Shirakawa (Chemistry, 2000), too, carried out much of his prizewinning work while a professor in the University of Tsukuba's materials science department. The concentration of research excellence in Tsukuba has led to it having one of the best-qualified citizenry of any Japanese city — it is estimated that around 3% of the city's population hold doctoral degrees.

From 'seed' research to 'needs' research

That much of the pure research carried out at Tsukuba is of high quality is not in dispute. Translating this into commercial success is another matter. Although 260 high-tech companies have R&D operations based in nine business and research parks around Tsukuba, there is still some way to go according to Ichihara. "A lot of the research carried out in Tsukuba is cutting-edge work but it is basic, 'seed' research," he explains. "One of the challenges for Tsukuba is to transition from 'seed' research to 'needs' research. This will require interdisciplinary cooperation across a wide range of fields." This approach chimes with the theme of coordination and integration of R&D activities across public- and private-sector institutions for the long-term development of the research environment, which forms a key plank of the Third Science and Technology Basic Plan approved by the Japanese cabinet in 2006. A current initiative encapsulating the spirit of cooperation is the Tsukuba Innovation Arena for Nanotechnology (TIA Nano) project, which brings together key centres of academic and industrial research in Tsukuba such as the University of Tsukuba, the National Institute for Materials Science (NIMS) and the National Institute of Advanced Industrial Science and Technology (AIST). Funded by the Japanese government to the tune of ¥18.2 billion (US$210 million) in its first year, the TIA Nano project aims to create a commercially focused global centre of nanotechnology innovation in Tsukuba.

These efforts may soon get a further boost as Tsukuba is applying for Strategic Global Innovation centre status, which would result in tax breaks for small- and medium-sized businesses and other benefits such as infrastructure development and training as well as support for overseas personnel. This is particularly important in Tsukuba, which is an example of the unusual phenomenon of a relatively small rural Japanese city with a very international flavour. Calling Tsukuba home are over 7,000 residents from 131 countries, accounting for some 3.6% of Tsukuba's population, many of whom work at the city's research institutes and companies. International ties are further strengthened by its Sister City program, which sees Tsukuba twinned with two cities in California — Irvine and Milpeters — as well as well as Cambridge, Massachusetts, and Friendly City links with Shenzhen in China's Guangzhou prefecture.

In the 30 years since the original facilities were completed, much has changed in Tsukuba. This particular anniversary also comes at a time that many regard as a turning point for Japan, recently replaced as the world's number-two economy by China and with the twin problems of a rapidly ageing population and low birth rate threatening further difficulties in the future. How Japan meets these challenges and moves forward in the years to come will be influenced in no small measure by the innovation and solutions that will come out of the people and institutions of Tsukuba — a city that not so long ago was nothing more than a glint in a politician's eye.

Matthew Salter is an editor at NPG Nature Asia-Pacific.

JAXA, KEK, NIMS, KANRIKA/WIKIPEDIA

Some major research facilities in Tsukuba. Clockwise from top left: the National Institute of Agrobiological Sciences (NIAS), the Japan Aerospace Exploration Agency (JAXA), the High Energy Accelerator Research Institute (KEK), the University of Tsukuba, the National Institute of Advanced Industrial Science and Technology (AIST) and the National Institute for Materials Science (NIMS).





TSUKUBA SCIENCE CITY

Tsukuba style

The year 2010 marks the thirtieth anniversary of the completion of the initial phase of the Tsukuba Science City project. The current mayor of Tsukuba, Kenichi Ichihara, looks forward to the challenges and opportunities for the area's future growth and development.

Mayor Ichihara is in the executive conference room on the fifth floor of the brand-new Tsukuba City Hall. It's a bright autumn day and he points out the twin peaks of Mount Tsukuba, which can be seen from a panoramic window. The foothills of the mountain merge into rice paddies and farms growing oranges, blueberries and the lawn turf that is supplied to gardens and parks around the country. In the foreground is an experimental field station of one of Tsukuba's many research institutes. An aide points out a nearby branch of a well-known convenience store chain, indistinguishable from thousands of others around the country save for the solar panels on its roof that provide power for the city's experimental electric car program. Out of another window, the nearest stop on the Tsukuba Express rail link can be seen alongside the site of a soon-to-be-opened national centre for robotics. "Not so long ago this was all just fields," remarks Ichihara.

Variety, they say, is the spice of life. But for Tsukuba, it's a way of life itself. "One of the unique things about Tsukuba is that there are so many different types of environment all concentrated into one small city," says Ichihara. "Part of it is a metropolitan city, another part is like a provincial town, and still other areas resemble the original farming communities with old-fashioned village schools and the like. There's nowhere like it in Japan. People actually come to study us as a national test-bed for agricultural, town planning and social projects."

Twenty-three years have passed since Tsukuba was officially established in its current form, and it is thirty years since the original facilities of Tsukuba Science City were completed. This anniversary of sorts has provided a convenient opportunity for taking stock. "As mayor, I have been thinking a lot about what sort of city Tsukuba is and asking what kind of city we want it to become," says Ichihara. It's a timely consideration as Japan is very different from the country it was in the 1960s when Tsukuba Science City was planned and built. The Japanese economy, then at its height of growth, has since stagnated and the plummeting birth rate, coupled with the rapidly growing number of seniors in Japanese society, are matters of serious concern.

Kenichi Ichihara, elected in 2004 and re-elected in 2008, is the fourth mayor of Tsukuba.

But while the population in general may be ageing, Tsukuba is a young city both figuratively and literally — substantially more of its 215,000-plus residents are in the 20–40 age group and substantially fewer in the 60–80 age group compared with the national average. Despite the overall youth of its citizens, its age cohorts are somewhat unevenly distributed, resulting in certain areas — such as the centre of Tsukuba Science City — having very few elderly residents while others in the suburbs have a high proportion of seniors, who are tactfully referred to as members of the 'silver generation'. Ichihara does not deny that this situation poses difficulties for the provision of transport, social services and healthcare appropriate to the requirements of the community, but he is confident that Tsukuba will be able to meet the challenge by bringing together its creative talents and developing its commercial know-how to create new systems for delivering the care its citizens need. To address the needs of the next generation, a new general hospital with state-of-the-art maternity facilities is being discussed.

On this point, Ichihara is keen to stress that the city is still very much in the process of *machizukuri*, a term literally meaning 'making the city' but one that embodies the idea of an ongoing process of creating a city along with and around the community and responding to emerging needs. The current round of development is being carried out on 1,400 hectares of land, adding to the more than 2,400 hectares that make up the site of the original planned city, and is expected to further boost the population of the city, which is already the fastest growing of the 43 Special Cities created in Japan to date.

The location of the new development, on land either side of the Tsukuba Express or *TX* line, is in itself significant. The high-speed train service that connects central Tsukuba with the heart of Tokyo carried its first passengers in 2005 and has reduced the journey to the centre of the capital from a tedious trip of an hour and a half to a brisk 45 minutes, vastly improving accessibility for visiting scientists, businesspeople and conference participants. Not only this, but the *TX* has also opened up the possibility of working in the capital while living in Tsukuba, thus benefiting from the high quality of life offered by its open spaces, relatively affordable housing and excellent schools. So integral is the *TX* to Tsukuba, it's difficult to imagine life without it. But as Ichihara explains, in the beginning, not everyone was convinced. "Believe it or not, there were some people who were against the *TX* early on because they wanted to preserve the unique local flavour of the city and were worried that it might

lead to an exodus of people to the capital," he says with a wry smile. "In the end, though, it has had an enormously positive impact on the city and on our research institutes and companies."

These research institutes, 61 in all including 31 national centres and 260-plus companies, which with the University of Tsukuba and the Science Academy of Tsukuba make up the largest concentration of industrial and academic science and technology-based organizations in Japan, have established a high benchmark for research quality. But appreciation of these achievements has been frustratingly slow. "These days it is incredibly hard for any discovery in a narrow field to gain widespread recognition unless it finds some kind of application," says Ichihara. In a city designed to foster world-class academic research transitioning from what Ichihara calls 'seeds' research to 'needs' research — that is, research focusing on providing concrete solutions to problems — is no small task and necessitates a lot of cross-disciplinary interaction. Here, Tsukuba is fortunate as much of the area adjacent to the *TX* line is still not built-up, affording researchers great flexibility in constructing new collaborative test facilities close to existing research sites. "It's much easier to set up interdisciplinary projects between a number of different stakeholders here in Tsukuba where there is room to build, compared with other locations where there may literally be no space close to existing facilities," he explains. These efforts may soon get a welcome boost as Tsukuba is applying for Strategic Global Innovation Hub status under a government initiative that includes a package of measures including tax incentives for small start-up and mid-sized developing businesses as well as infrastructure development and training, and support for recruitment of international staff.

One area of applied research at which Tsukuba excels is robotics. The city holds a popular annual competition — the Tsukuba Challenge — for robot builders and is home to several robotics research centres and venture capital companies engaged in developing robot technology for a range of societal needs, such as caring for the elderly, robotic exoskeletons for heavy lifting and intelligent transport systems. The only stipulation is that the work should benefit mankind — military applications are not welcome.

Technology in the service of people is a frequently recurring theme in Tsukuba. An example of this is the 'Tsukuba Style' initiative started by the municipal authorities as part of the ongoing experiments in *machizukuri*, which has the ambitious target of cutting the city's per capita emissions of CO_2 to half of current levels by 2030. One part of the initiative is the Green Crossover Project, a collaboration between Tsukuba City and a number of Japanese industrial partners to introduce an electric-car-sharing scheme that allows participants to charge a number of specially adapted small cars with electricity generated from solar panels placed on the roofs of buildings around the central district. A 'full tank' of eco-electricity gives the cars a range of about 100 kilometres on an urban cycle, and the project has drawn interest from city planners around the world.

Tsukuba is also examining a number of other innovative transport solutions including the use of personal mobility devices such as the Segway, and has built especially wide test sections of pavement to accommodate them. From 2011, conventional buses will be supplemented with a 'dial-a-ride' bus service that will allow passengers to request pick-up from a number of designated locations around the city, providing on-demand transportation at a competitive price. Cyclists and pedestrians are not neglected either and the city is proud of its 48 kilometres of walkways connecting downtown residential areas with parks, shopping areas and cultural centres such as the Nova Hall, a popular venue for concerts and theatrical performances. Small but important details such as installing power lines under arterial roadways, thus eliminating miles of unsightly cables, contribute to a feeling of light and space that is missing in many metropolitan areas of Japan.

The Green Crossover Project is an electric car-sharing initiative established by Tsukuba City.

All these efforts are aimed squarely at creating an ever more convenient and environmentally friendly Tsukuba and go to the heart of Ichihara's vision for his city. Even the new headquarters of the Tsukuba City government, opened in May 2010 at the cost of ¥7.7 billion, was designed to maximize the use of natural light and wind to reduce electricity consumption, incorporating rooftop gardens to provide thermal insulation as well as advanced solar-panel technology to partially meet the building's energy requirements. In Tsukuba at least, it would seem, there's no need to fight City Hall.




Sadamu Saito

TSUKUBA INTERNATIONAL CONGRESS CENTER/SCIENCE ACADEMY OF TSUKUBA

Putting creativity to work

The Science Academy of Tsukuba is an integral part of Tsukuba Science City, and with the Tsukuba International Congress Center as its centrepiece, is forging closer ties among researchers from all walks of science.

Japan has made remarkable progress in science and technology over the past decades. Industries and research areas that did not exist twenty years ago now enjoy pride of place in many of the amenities that support the high quality of life that residents of Japan now expect. With a powerhouse economy, world-class health and medical services, infrastructure and advanced information technology, Japan is well-placed to address the many new challenges of the twenty-first century, such as climate change, the energy crisis and depletion of natural resources. To meet these challenges, collaborations among scientists with diverse expertise will become increasingly important.

"For science to progress, we need individual creativity. However, the dynamic interaction between researchers is also very important," says Leo Esaki, the 1973 Nobel Laureate in Physics. Esaki is now chair of the Science and Technology Promotion Foundation of Ibaraki, executive director of the Tsukuba International Congress Center (TICC), and president of the Science Academy of Tsukuba (SAT).

In 1963, the Cabinet of Japan approved a budget worth 2.5 trillion yen — an amount comparable to the money spent on the Apollo project — for building a science city at Tsukuba in Ibaraki Prefecture. The aim was to bring together scientists from academia and industry to form one of the world's largest research communities. There are now more than 20,000 scientists and engineers working in Tsukuba City.

Esaki took on the role of chairman of the Science and Technology Promotion Foundation of Ibaraki in 1998. The foundation aims to foster information exchange among researchers in various fields, arouse social interest in science and technology, and assist in technology transfer from research and development to industrial applications. The foundation also manages the finance and administration of various projects, ranging from construction to award ceremonies.

In June 1999, Esaki inaugurated the TICC, a US$200 million meeting facility located in the heart of Tsukuba City. The TICC has a large convention hall that can seat up to 1,258 people, small seminar rooms, a rooftop garden and a restaurant. "We aim to provide a congress centre that satisfies every visitor," says Esaki.

Later that year, to mark its inauguration, the TICC hosted the International Conference on Science Frontiers Tsukuba 999 (SFT999), a multidisciplinary conference focusing on new frontiers in science and technology. Six distinguished scholars, including three Nobel and two Japan Prize laureates, delivered plenary speeches at the conference.

"On the last day of SFT999, we had a panel discussion about scientific challenges in the coming century," says Esaki. "We talked about the importance of interaction and collaboration among different fields. In the end, we came to the conclusion that we needed some form of integration. I therefore proposed the establishment of a new organization to help further our visions."

Consequently in 2000, Esaki established the SAT, an organization that aims to create pioneering fields of study through interactions among researchers and engineers from different fields in Tsukuba. The Science and Technology Promotion Foundation of Ibaraki merged with the SAT in 2009.

The SAT regularly publicizes innovative discoveries made by researchers in Tsukuba. Every year, the SAT gives out three prestigious awards: the Tsukuba prize, established in 1989, honours researchers who have received international acclaim for remarkable results in science and technology; the Tsukuba Encouragement Prize, established in 1990, is awarded to researchers whose results have been put to practical use or young researchers who have great potential for producing remarkable results in science and technology; and the Leo Esaki Prize, established in 2003, honours researchers who have received international acclaim for outstanding achievements in nanotechnology.

Leo Esaki is a Japanese physicist who shared the Nobel Prize in Physics in 1973 with Ivar Giaever and Brian David Josephson for his discovery of the phenomenon of electron tunnelling.

The SAT also runs an annual event called the Technology Showcase, attended by 500–1,000 researchers from Tsukuba. High-school students and postdoctoral fellows also participate. One hundred participants give a one-minute presentation on their research, and the best presenter is selected by a poll among the audience.

"Looking back, history has taught us that individual effort is an important driver of development and creativity, fostering cutting-edge research and development. I hope that with the establishment of the TICC and SAT, we have created an environment in Tsukuba that is ideal for cross-fertilizing ideas and cultivating creativity," says Esaki.

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UNIVERSITY OF TSUKUBA

Imagine the future

The University of Tsukuba is leading the way in reforming higher education in Japan. From its efforts in creating an open-style university system fit for the next generation, to its commitment to establishing a truly international centre of study, the University of Tsukuba is continually challenging the status quo.

Established in 1973, the University of Tsukuba is one of the newer top-ranked seats of learning in Japan, placing ninth in Japan in the 2010 Academic Ranking of World Universities. Although founded in its current form less than 40 years ago, its predecessor, the prestigious Tokyo University of Education, was established in 1872 in central Tokyo where it remained until it was moved to its current location, some 60 kilometres northeast of the capital to be reformed as the University of Tsukuba. The timing of the move, according to its president, Nobuhiro Yamada, was propitious. "At that time, Japan had just become the world's second-largest country in terms of GDP, the student movement was at its height and all sorts of experiments in education were being carried out around the world," he says. "There was a feeling that it was time for a radical rethink about the purpose and meaning of universities."

Seizing on this pioneering spirit, the University of Tsukuba was founded with the aim of creating a new type of university, one eschewing the narrow, closed confines of traditional learning for a university based on "looking at the world from the student's perspective" that is open to society, both regionally and internationally. As it looks to its 40th anniversary in 2013, this philosophy continues to inform the next stage of development of the university, which, Yamada notes, coincides with Japan's changing role in the international community.

Not surprisingly for a former university of education, teaching has long been — and continues to be — an important aspect of the academic life of the University of Tsukuba; research, and particularly scientific research, however, is also very strong and the university counts no fewer than three Nobel laureates amongst its current and former staff: Shin-Itiro Tomonaga (Physics, 1965), Leo Esaki (Physics, 1973) and Hideki Shirakawa (Chemistry, 2000). Testifying to its continued strength, the university recently secured two grants out of 30 on offer under the Japanese government's prestigious 'Funding Program for World-Leading Innovative R&D on Science and Technology'. It also maintains extensive academic, research and economic links with Tsukuba Science City, a conglomeration of almost 60 national institutions and 200 private companies, many of whom employ the cream of University of Tsukuba graduates every year.

As well as a world-class research environment, the university offers an educational experience unequalled in Japan. Not only is the campus, which is based on two main sites in Tsukuba with a satellite campus in central Tokyo, more spacious than many of its Japanese rivals, but it also offers a truly international environment for learning. The international undergraduate and research student population currently exceeds 1,700 — just over half of whom are women — drawn from over 100 countries, making it the second most international university per head in Japan after the University of Tokyo. Tsukuba City itself is also very diverse, and is home to over 7,000 international visitors out of a total population of just under 210,000. For foreigners with families, the excellent local schools and closeness to nature are an important attraction. "This is an extremely international city. And it's a very convenient place for foreigners to live and work in," says Yamada.

The university has made broadening access to overseas students a priority for development and is one of only 13 institutions in Japan to be chosen for the Global 30 program, an initiative that aims to have 300,000 foreign students studying in Japan annually by 2020. Key aspects of the program are the teaching of courses in English and the creation of a framework that supports foreign students in both life and study so that they can interact with local students in an environment without barriers. In many areas of globalization, the university is ahead of the G30 curve as it is already taking steps to nurture foreign students and begun setting up international centres in countries of current and future strategic importance. To date, the university has established five such offices around the world, with a further planned for the UK in the near future. With initiatives such as these, the university seeks to raise the number of foreign students to one in four and foreign faculty members to one in ten by 2030.

The University of Tsukuba is also different to other Japanese universities in placing great importance on extra-curricular activities such as cultural pursuits and sport, which are seen as necessary for students to realize their academic potential. "Research and study is important, but so is the cultural and intellection foundation of society," remarks Yamada. "Artists and sportspeople are an important part of the equation." The university is particularly strong in judo, having a close association with Jigoro Kano (1860–1938) who invented the sport, and regularly sends current students and alumni to the Olympic Games and the World Judo Championships. As with all other aspects of life at the University of Tsukuba, the focus of these activities is on getting the best out of each and every student. "It may be a truism, but young people really are the future," says Yamada. "We have to find the best way to empower them to give their best. During the period of economic growth, Japan was a 'quantity-driven' country. I think that we are on the verge of a new period where we need to be 'quality-driven'. This requires us to change gear in every area of life and this includes universities." In this it is clear that the University of Tsukuba has a major role to play.

Prof. Sankai, University of Tsukuba/Cyberdyne Inc.

UNIVERSITY OF TSUKUBA, CYBERNICS LABORATORY AND CENTER FOR CYBERNICS RESEARCH

Cybernics: enhancing human function

The Cybernics Laboratory and Center for Cybernics Research at the University of Tsukuba conduct unique research at the nexus between human, machine and information technology with the aim of developing hybrid robotic systems to augment human abilities.

Cybernics, the fusion of human, machine and information systems, is a new domain of interdisciplinary research pioneered by scientists and engineers at the University of Tsukuba's Graduate School of Systems and Information Engineering. The unique research conducted at the school's Cybernics Laboratory and Center for Cybernetics Research integrates fields as diverse as cybernetics and social science, ergonomics and information technology, and systems engineering and physiology with the aim of augmenting human activity physically, physiologically and cognitively. This is future-oriented science that could one day support a long-lived, healthy society.

A wearable-type robot called Robot Suit HAL® based on Hybrid Assistive Limb® technology is one of the major accomplishments of the program's Cybernoid Project, which aims to bring together cybernic technologies for human, machine and information systems to form a cybernoid hybrid. HAL technology was developed with the goal of physically supporting the wearer's daily activities, particularly in heavy manual work, and is envisaged to have many possible applications, including in medicine, welfare and labour.

A critical component of the system that provides effective, customized physical support for each wearer is the control algorithm, as well as the mechanisms of supporting devices. The HAL unit is powered by two interacting control systems that help the user to stand, walk, climb stairs and hold a heavy load, and to generally enhance the capabilities of the human wearer. The dual hybrid cybernic control systems adapt to the wearer whether they be healthy or physically challenged.

One of these core control systems, the Cybernic Voluntary Control system, provides physical support for actions according to the operator's voluntary movement through the aid of bioelectrical signals and muscle activity. The HAL's power units generate power-assisted torque by amplifying the wearer's own joint torque estimated from bioelectrical signals, providing controlled support motion. This level of control is designed for use in power assist situations to support a healthy person's activities. Bioelectrical signals, including myoelectricity, represent useful and reliable information for estimating intended human motion because the signals are measured just before the corresponding visible muscle activities. The wearer thus receives physical support directly via an unconscious interface based on bioelectrical signals, providing much easier and more reliable control than achievable using manual controllers such as joysticks.

The HAL can support healthy people as well as patients with limb motion impairment through the wearable robot's multiple-joint functional motion. Multiple joints are moved simultaneously to compensate for all movements of the lower limbs.

The voluntary control system, however, cannot be taken advantage of by wearers with gait disorders or spinal paralysis because of the lack of correct bioelectrical signals in such patients. To assist these impaired users, the Cybernetic Autonomous Control system plays an essential role. The autonomous system generates desired functional motion according to the wearer's constitution and condition, and the purpose of motion support. Whereas bioelectrical signals are mainly used in the voluntary control unit, various other kinds of information, such as reaction force and joint angle, can be used to provide comfortable physical support via the autonomous control system. This system is particularly suited to rehabilitation and walking support, as well as in power assistance for healthy people, and enables the HAL to be used to fulfil body functions when the wearer is impeded by a handicap or muscular weakness. The HAL in this case monitors the wearer's condition and motion intentions based on non-bioelectrical information.

One application of Cybernic Autonomous Control of particular interest is in providing walking functionality to paraplegia patients. Human intentions are essentially independent of physical interactions between a body and the environment. Although there is yet no reliable technology for measuring human intention directly, it is possible to estimate human intentions from appearance or motion, especially when those characteristics are closely connected with the intention. 'Intention-based support' aims to provide physical support for the wearer's next desired motion based on prediction from the current state or of the motion to be induced by intention.

The HAL and cybernics projects involve extensive fusion of research from many fields of science, technology, sociology and engineering. Some of the international patents related to HAL have been recognized for their innovative nature by the World Intellectual Property Organization. Now supported by funding under the World-Leading Innovative R&D on Science and Technology program of the Japanese government, the Cybernics Laboratory and Center for Cybernetics Research will continue to advance cutting-edge research to improve medical outcomes and daily life through cybernics technology.

IMAGINE THE FUTURE.

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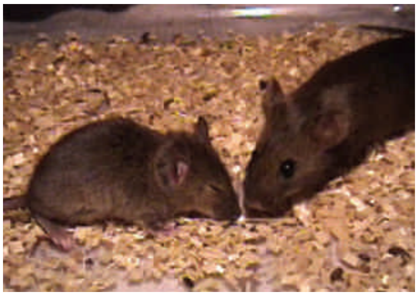
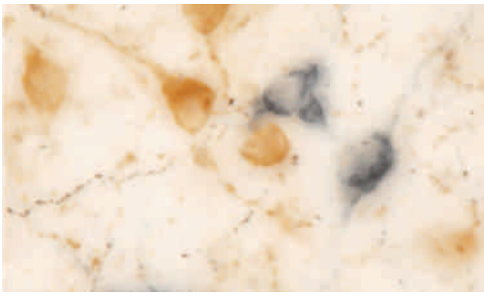




UNIVERSITY OF TSUKUBA, CENTER FOR BEHAVIORAL MOLECULAR GENETICS

Coming home to Tsukuba

While a graduate student at the University of Tsukuba Institute of Basic Medical Sciences, Masashi Yanagisawa discovered endothelin, a potent vasoconstrictor hormone secreted by cells of the inner lining of blood vessels. The paper he published on the finding in 1988 brought him instant fame and has since been cited more than 9,000 times. After many years in the United States, he is now setting up a second lab at the University of Tsukuba with an ambitious new research target in mind.

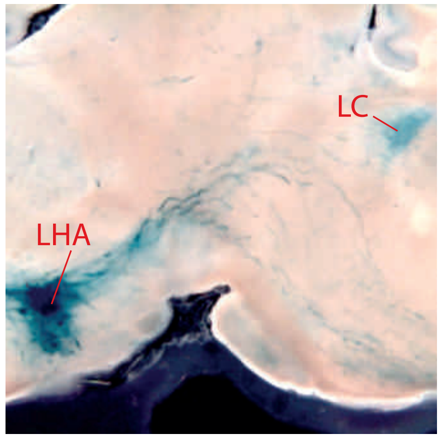
"The discovery of endothelin would have been utterly impossible if not for the medical school's uniquely collegiate atmosphere, where I felt that there were no psychological or administrative barriers among departments or research groups — a rare environment in Japan at that time," testifies Yanagisawa. His discovery led to the creation of a new field of cardiovascular research and to a new field of medicine that aims to specifically block the action of endothelin. Drugs with this activity are now being used as the first-line therapy for pulmonary hypertension, a life-threatening disorder in which lung blood vessels become progressively clogged.

Shortly after his endothelin discovery, Yanagisawa was recruited in 1991 by the Nobel laureates Joe Goldstein and Mike Brown to the University of Texas Southwestern Medical Center in Dallas, USA, to start his own lab. In Texas, he continued his hormone-hunting endeavour, and in 1998 discovered orexin, a brain peptide regulating sleep and wakefulness as well as body weight. His team then unexpectedly found that mice lacking orexin suffer from narcolepsy, a disorder characterized by severe daytime sleepiness and pathological signs of rapid eye movement sleep, such as a sudden loss of muscle tone. It was soon found that the majority of human narcolepsy patients lack orexin due to a selective loss of brain cells that produce the hormone. "In other words, the mysterious disorder of narcolepsy can now be described biochemically as orexin-deficiency syndrome," says Yanagisawa. "This immediately suggests orexin replacement as a mechanistic therapy."

Indeed, Yanagisawa's team subsequently showed that orexin-deficient narcoleptic mice can be successfully treated by orexin injection into the brain ventricle. Unfortunately, however, orexin itself is a small protein molecule that is not conducive to formulation as a drug, as it does not cross the blood–brain barrier. "All we need then is a small chemical compound that acts on the orexin receptor and mimics orexin's action," declares Yanagisawa. "If we could develop an orally active orexin receptor agonist, then it will not only be the fundamental cure for narcolepsy, but may also help a much larger number of people with other conditions characterized by excessive daytime sleepiness, such as jet lag, shift-work drowsiness, certain mood disorders and even night-time insomnia."

Development of such agonists, in collaboration with the medicinal chemists Hiroshi Nagase at Kitasato University in Tokyo and Jef De Brabander at UT Southwestern, is one avenue of research that Yanagisawa plans to pursue with his Tsukuba team. He has been selected as one of 30 investigators to be included in the Japanese government's FIRST program, and is now assembling a new research team back at the medical school where he graduated more than 20 years ago. But a larger part of his new project will focus on the fundamental mystery of sleep: how sleep is regulated and what is 'sleepiness'. Ten years of sleep research triggered by the orexin–narcolepsy connection have convinced Yanagisawa that an entirely new approach is necessary to tackle the question.

Towards the ultimate goal of cracking open the black box of sleep regulation, his Tsukuba team will investigate the 'forward' genetics of sleep in mice. In collaboration with the mouse geneticists Shigeharu Wakana of the RIKEN BioResource Center in Tsukuba and Joe Takahashi at UT Southwestern, Yanagisawa intends to produce thousands of mice with random genetic mutations. His team will then record and analyse the brain waves of each of these mice in order to screen for mutant mice that show abnormalities in sleep or wakefulness. Fortunately, finding causal gene mutations has become easier in recent years. "It is really exciting to start a new lab back at the University of Tsukuba, my *alma mater*, where possibilities for collaboration abound," says Yanagisawa. "I believe that our approach will lead to a big breakthrough. But the scale of our physiologic–genetic study would never have been possible without the highly collaborative environment that the university provides for my FIRST program."



Projection of orexin neurons visualized in orexin/*tau-lazZ* knockin mouse.

IMAGINE THE FUTURE.

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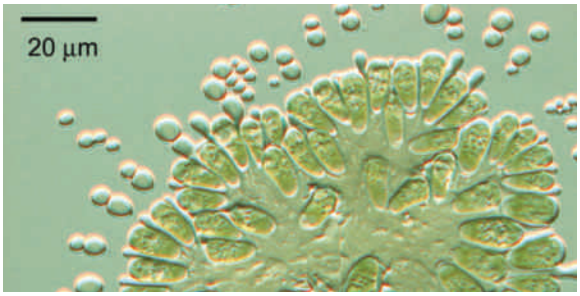


UNIVERSITY OF TSUKUBA, GRADUATE SCHOOL OF LIFE AND ENVIRONMENTAL SCIENCES

A pioneer of the new algae economy

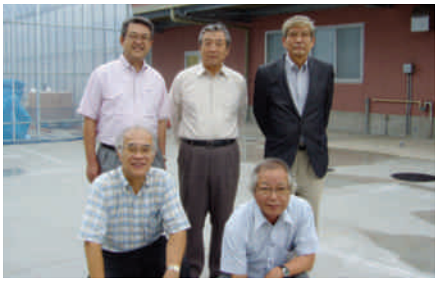
Japan leads the world in interdisciplinary research aimed at establishing algae-based hydrocarbon production as a core component of a future low-carbon society.

Tsukuba is home to a unique research project aimed at establishing algal fuel technology as a replacement for conventional fossil fuels. This Japan-led international research collaboration has already sparked intensive interdisciplinary research in biology, chemistry and engineering.

Microalgae are microscopic photosynthesizing organisms that are ubiquitous in freshwater and marine environments. They are thought to be responsible for up to half of total atmospheric oxygen production and act as a huge carbon sink, but their potential is so far almost entirely untapped. Less than ten percent of the estimated hundreds of thousands of species of microalgae have been identified, and far fewer have been studied in detail. Yet some species produce up to 120 times the amount of oil as terrestrial oil crop plants by mass, and oil can exceed 80% by weight of dry microalgae biomass.

Research on microalgae for oil production has been conducted for over 20 years, but it was not until recently that the crises of impending climate change and skyrocketing fossil fuel prices drew renewed attention to the field. Competition is now accelerating rapidly, with a number of groups around the world investigating various species and strains for their potential in oil production.

In 2008, Makoto M. Watanabe from the University of Tsukuba Graduate School of Life and Environmental Sciences initiated a government-funded project to develop the microalgae *Botryococcus braunii* for possible hydrocarbon production. *Botryococcus* is a green, colonial microalga with unique liquid-hydrocarbon biosynthetic capabilities — it excretes most of its liquid hydrocarbons from the cells, retaining the oil within the colonial extracellular matrix. *Botryococcus* is therefore of current significance as a potential alternative source of hydrocarbon oil. The many strains of *Botryococcus* differ in the type of hydrocarbon synthesized, the amount of lipid production and growth capacity. As oil production usually occurs in inverse proportion to the growth rate, it is important to identify strains with a good balance between these two desirable features. More than 200 strains of *Botryococcus* have so far been isolated from lakes, reservoirs and ponds in Japan, and many of these have been established as clonal, pure cultures. Several strains with high hydrocarbon productivity and growth rates have been identified and submitted for further research and development. The Japanese strains of *Botryococcus*, including *B. braunii*, are particularly attractive for their high purity of hydrocarbon-oil production.



Leaders of the microalgae project. Clockwise from bottom left: Makoto M. Watanabe, Yoshihiro Shiraiwa, Kunimitsu Kaya, Makoto Shiho and Isao Inouye

Research so far has more than doubled the ultimate level of biomass growth through the addition of organic waste. *Botryococcus braunii* is mixotrophic, allowing it to use both light and chemical sources of energy for growth, further enhancing its already considerable potential as a hydrocarbon production system.

The current project is aimed specifically at improving the cost balance of algae-based fuel generation by increasing hydrocarbon production by an order of magnitude. The project team is composed of biology, chemistry and engineering research groups that work in close collaboration. The biology group, under the leadership of Yoshihiro Shiraiwa, is investigating how to increase hydrocarbon production by screening for other strains and species and by genetic engineering. The chemistry group led by Kunimitsu Kaya is developing low-cost, energy-conservative extraction and refinement methods for the hydrocarbons and other metabolites, as well as investigating the use of the products in society. The engineering group, led by Makoto Shiho, is carrying out detailed life-cycle assessments involving outdoor test plants and clarifying methods for future industrial use of the products.

To accelerate this research, in which Japan is playing a leading international role, the University of Tsukuba has established an international research centre for algae-based environmental energy under the leadership of Isao Inouye. The project, inaugurated in April 2010, has an interdisciplinary focus, bringing together specialists in life science, nano-science and energy engineering. The university will also host the first Asia Oceania Algae Innovation Summit in December 2010, convened by an international organizing committee composed of university and industrial researchers from Japan, China, Korea, Thailand, Australia and New Zealand. The summit represents a key forum for the establishment of international collaboration frameworks for algal fuel research, and given the fragile economic and environmental outlook, could provide a springboard from which oil-based economies can begin the transformation to sustainable, low-carbon fuel production.

IMAGINE THE FUTURE.

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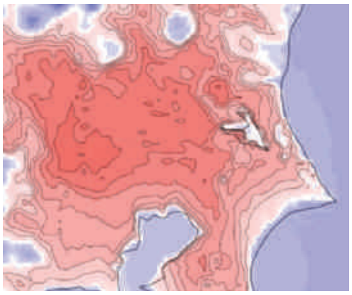



NIPR Japan

UNIVERSITY OF TSUKUBA, CENTER FOR COMPUTATIONAL SCIENCES AND INSTITUTE OF PHYSICS

In pursuit of new physics

Some of the big questions in physics — How did the Universe form? How did primordial elementary particles combine to form protons and neutrons after the Big Bang? — cannot be solved by observations, or even by experiments. Computational science has become indispensable for scientific discovery and technological development in the twenty-first century; making the best use of high-performance computing, however, requires close collaboration between computer scientists and researchers in other scientific disciplines.

There will always remain phenomena in physics that are beyond our ability to recreate. Computational science provides a medium in which such phenomena can be studied *ad infinitum*, limited only by the imagination of scientists and the power of the computing platform.

The Center for Computational Sciences (CCS) at the University of Tsukuba leapt to prominence in 1996 with the development of the CP-PACS massively parallel computer, at the time the fastest platform in the world, in collaboration with physicists. Large-scale computations performed using CP-PACS led to significant progress in particle and astrophysics. Since then, the CCS has developed more major systems through interdisciplinary collaboration: the PACS-CS large-scale cluster system in 2006, and a special-purpose parallel system for astrophysics known as FIRST in 2007.

The CCS's vision for interdisciplinary computational science shapes the future research to be conducted at the centre. The close collaborations the centre has developed with various scientific disciplines are unique in the world, and the CCS believes this approach will be key for the future of computational science in exa-scale computing beyond the current petaflops level.

Combining the pursuit of fundamental problems in science with the development of world-class supercomputing platforms at the CCS has yielded some remarkable scientific achievements since the centre's inception. In particle physics, a fundamental question is how quarks and gluons combined to form the protons and neutrons in the early Universe. The answer to this question involves solving the theory of quantum chromodynamics (QCD). In a landmark study in 2000, Yoichi Iwasaki and collaborators implemented the lattice QCD method on CP-PACS and successfully calculated the mass spectrum of hadrons including protons and neutrons. Sinya Aoki and collaborators also applied lattice QCD methods with the CP-PACS platform in 2007 to successfully calculate the nuclear potential for the binding of protons and neutrons for the first time — a fundamental breakthrough in the development of computational particle–nuclear physics. Using the CP-PACS and FIRST platforms, Masayuki Umemura and collaborators have carried out pioneering studies on the reionization process of the Universe (2001), the formation of primordial galaxies (2006) and the formation of first-generation stars and globular clusters (2009) based on gravity-governed interactions among atoms, radiation and even 'dark matter'.

The CCS maintains its commitment to the support of research in computational science in collaboration with universities and institutes throughout Japan based on the development of leading-edge computing platforms. By implementing large-scale simulations and data analyses in close collaboration with specialist scientists, the CCS continues to help push the frontiers in physics.

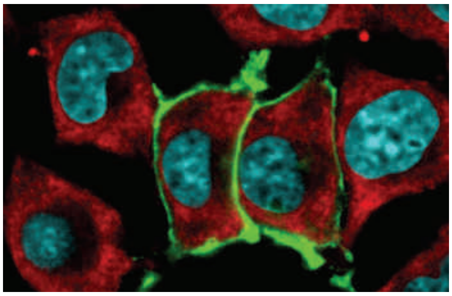
From the cold of Antarctica to the extreme physics of supermassive black holes at the heart of distant and nearby galaxies, researchers from the University of Tsukuba Institute of Physics are going to great lengths to unravel the mysteries of the Universe.

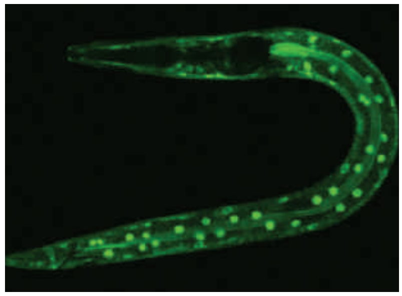
It was long theorized that the intense jets of radiation beaming out from the active nuclei of certain galaxies could originate from supermassive black holes, but it was not until 1993 when a group of radioastronomers led by Naomasa Nakai from the University of Tsukuba Institute of Physics made the first accurate determinations of the mass of such a black hole that the theory became science.

Nakai's group discovered a feature thought to be a supermassive black hole in a galaxy known as Messier M106. The observation was confirmed after the group used radiotelescopes to measure water-vapour maser emission from the compact gas disk rotating around the hole's rim. What they found was astonishing — a black hole thirty-nine million times heavier than our Sun. Nakai and his colleagues have since discovered similar supermassive black holes in other galaxies, providing valuable information that helps our understanding of when and how not only black holes but also galaxies formed and evolved in the history of the Universe.

To aid in their search of the Universe, Nakai's group has begun the installation of facilities for submillimetre and terahertz radioastronomy at Dome Fuji Station, a Japanese astronomical observatory in Antarctica about a thousand kilometres inland. At an altitude of 3,810 metres and with temperatures below –50 °C, the low levels of water vapour and oxygen are ideal for high-frequency radio astronomy.

The radiotelescopes planned for construction at Dome Fuji in the near future will make it possible to perform observational studies of the formation and evolution of galaxies in the early Universe.





UNIVERSITY OF TSUKUBA, TSUKUBA ADVANCED RESEARCH ALLIANCE

A new alliance for life science research

A 16-year experiment in promoting new systems for research and development with a focus on interdisciplinary, inter-institutional and governmental collaboration has grown into a fertile ground for innovative research in the life sciences.

The Tsukuba Advanced Research Alliance (TARA) at the University of Tsukuba has been promoting and supporting advanced interdisciplinary research since the mid-1990s, and with 66 active projects, the alliance centre now acts as the central university body for the management of major government-funded projects. Originally founded to promote programs in all fields of research, with projects on topics as diverse as multimedia information management, novel materials, nanostructures and genomic biology, the TARA Center has in recent years emerged as a regional hub for life science research. The TARA Center is now capitalizing on its new-found expertise and capacity in the life sciences by announcing a whole-hearted focus on innovation in this globally competitive field.

Through its involvement in major national research projects such as the ERATO, CREST and COE programs, the new TARA Life Science Center, under the directorship of Makoto Asashima, has nurtured a core research team and a flexible structure that allows it to capitalize on strategic research projects.

Life science has always been a significant part of the TARA project, and joint research conducted through the centre has received strong international evaluations. The project has also played a major role in developing the careers of young researchers. In addition to the project's core values of expanding creative research and creating new social value, the TARA project has recently introduced a program specifically to identify and develop promising young researchers. This new program promotes research that combines life science with other fields through collaboration among researchers of diverse backgrounds with a focus on discovering young talented researchers from within the University of Tsukuba.

There have been many scientific achievements over the 16 years of the TARA project. Researchers led by Junn Yanagisawa have made a number of discoveries regarding the mechanisms of cancer growth and metastasis, and in particular the relationship between cellular energy metabolism and tumour formation. Through epigenetic regulation of rRNA transcription, the team identified the 'energy-dependent nucleolar silencing complex', better known as eNoSC, which is involved in energy homeostasis. They also identified the ubiquitin ligase CHIP, a tumour-suppressor protein that has lower expression in human breast cancer tissue than in normal tissue. Knockdown of CHIP in breast cancer cells significantly enhanced tumour growth and metastasis in mice. The team are now investigating a new strategy for cancer therapy based on increasing CHIP levels or activity.

Akira Shibuya heads a CREST project aimed at identifying novel immunoreceptors, including the natural killer cell receptor DNAM-1 (CD226), the myeloid-associated immunoglobulin-like receptors (MAIR)-I (CD300a) and MAIR-II (CD300c), and the Fc(α/μ) receptor CD351 — an Fc receptor for IgA and IgM antibodies that is expressed on the surface of immune cells and which is involved in innate immunity. Through molecular *in vitro* and *in vivo* analyses of disease models using genetically engineered mice, Shibuya's group has clarified that these molecules play important roles in tumour immunity, in infectious diseases such as sepsis, and in autoimmune diseases, respectively. The group has also recently identified a novel immunoreceptor, named Allergin-1, that is expressed on mast cells and which inhibits immunoglobulin E-mediated allergic diseases such as anaphylaxis.

The TARA Center, of course, supports many other projects. Kyosuke Nagata revealed the molecular structure of the influenza virus RNA polymerase by X-ray crystallography in collaboration with Sam-Yong Park of Yokohama City University. Nobuhiro Ohkohchi clarified the molecular mechanism underlying growth factor-dependent signals regarding the effect of platelets on promoted regeneration and tissue repair in the liver. Hitoshi Shimano demonstrated that control of fatty acid synthesis and composition through a transcription factor network in the synthesizing organ is extremely important for understanding the biological regulation of energy metabolism, a study with fundamental clinical implications. Jun-Ichi Hayashi proved the existence of mitochondrial interaction and the cause-and-effect relationships between mitochondrial DNA and diseases such as metastasis.

The TARA project is also deepening the level of collaboration in combined research involving life, material and information sciences through the joint work conducted by Akiyoshi Fukamizu, Takeshi Akasaka and Shoji Makino. These researchers search for bioactive molecules of low molecular weight and are developing a new device for measuring the effect of bioactive molecules using model mice with pregnancy-associated hypertension created at the University of Tsukuba.

Interdisciplinary research centred around the life sciences is a major trend in global science, attracting the highest levels of interest around the world. Leveraging its human resources and depth of scientific expertise gained through 16 years of advanced research, the TARA Center is focusing its efforts on supporting and promoting advanced life science-related research that integrates a wide variety of research fields.

IMAGINE THE FUTURE.

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UNIVERSITY OF TSUKUBA, TSUKUBA INNOVATION ARENA FOR NANOTECHNOLOGY

A new arena for nanotechnology

The Tsukuba Innovation Arena for Nanotechnology (TIA Nano) is a new collaboration among the University of Tsukuba, the National Institute for Materials Science (NIMS) and the National Institute of Advanced Industrial Science and Technology (AIST) supported by the Japan Business Federation (Nippon Keidanren) that aims to form an industry-cooperative global 'arena' for nanotechnology innovation in Tsukuba.

Inaugurated in June 2009, the TIA Nano project promotes academic–industrial alliances, providing a point of 'resonance' and opportunity for networking in the burgeoning and multidisciplinary field of nanotechnology. With the support of advanced research and development facilities, TIA Nano has a collaborative focus that aims to bring experts from universities, institutes and industry together under one roof.

TIA Nano focuses on six core research domains of nanoelectronics, power electronics, nano-micro electromechanical systems, carbon nanotubes, 'green' nanotechnology and nano-material safety, taking advantage of the nanotechnology competence of Japan's public and private organizations as well as the state-of-the-art research facilities in Tsukuba.

Leveraging its government funding for the 'Advancement of University–Industry Collaboration', the University of Tsukuba has established within the framework of TIA Nano a doctoral course in nanoelectronics, entitled the 'Tsukuba Nano-Tech Human Resource Development Program'. The program centres around the development of graduate students as key research partners by emphasizing exposure to researchers from a range of fields and research cultures, including industry, universities and national research institutes, as well as a broad range of specializations, from theory to application.

Experts with outstanding research records or business experience are assigned to supervise and coordinate the collaboration on a research topic. By assessing the research skills of the research group and the core needs of business, these 'collaboration coordinators' break down research topics into education and research themes founded on basic science. For each collaboration, an arena is allocated as a place where researcher groups from different fields, such as theoretical and applied research, chemistry and electrical engineering, can share their tacit knowledge and work cooperatively. By adopting this approach, the program aims to facilitate the flow of technology, knowledge and people as an arena for promoting collaborative research and human resource development.

The executive board of TIA Nano. From left to right: Sukekatsu Ushioda (president, NIMS), Tamotsu Nomaguchi (president, AIST), Teruo Kishi (president of the executive board, TIA), Nobuhiro Yamada (president, University of Tsukuba) and Ryoji Chubachi (chair, Committee on Industrial Technology, Nippon Keidanren).

Assisting the establishment of a global-standard set of values and strong international networks, the University of Tsukuba has secured exchange programs with the State University of New York, Albany and Stanford University in the USA among other world-renowned universities. The development program includes lecture and seminar series by leading domestic and overseas researchers, and internships with private-sector companies and public research institutions.

Selected students have the opportunity to undertake an honours program aimed at introducing young graduates to collaborative research by allowing them to experience different research cultures. The topic of their research is teased out through a series of meetings with collaboration coordinators and their academic supervisors, giving the students an opportunity at an early stage to develop the skills to relate industry needs to their own research abilities. The topic development process also involves task analysis to understand the narrow definition of the students' specialization. The collaboration coordinators select for the study appropriate advisors from university, industry and institutes.

As the students advance their research, they have the opportunity to undertake internships at cutting-edge facilities in the Tsukuba area, as well as three months' participation in a training and exchange program with the State University of New York, Albany and Stanford University. Among the students registered in the honours program, up to 12 annually are employed as 'Super-Research Assistants' with researcher or research assistant status and an attractive stipend.

IMAGINE THE FUTURE.

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JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES

Hand-in-hand for a better future

Food security is paramount in many developing nations, where drought, blight and conflict can bring famine and hardship to entire populations. International aid can provide temporary respite, but long-term sustainable development of agricultural resources is needed to bring lasting relief from hunger and poverty.

The Japan International Research Center for Agricultural Sciences (JIRCAS) is entrusted with a unique mission. As a national research centre, the JIRCAS and its predecessor, the Tropical Agriculture Research Center, have been conducting research and development on technologies that address the needs of developing regions for almost 40 years. Through direct collaboration with government organizations, research institutes and universities, the JIRCAS contributes to addressing global issues of hunger and poverty, global warming, environmental conservation and sustainable management of resources.

One of the core premises of JIRCAS's work is its role as partner in research projects conducted in collaboration with developing countries. Projects are enacted on an equal-footing basis with collaborating entities — the JIRCAS dispatches its own staff and researchers affiliated with other research institutes directly to the field and provides scientific equipment, while at the same time hosting collaborating researchers for advanced studies at the JIRCAS and other Japanese research organizations. The centre maintains research projects in all areas of the agricultural sciences, including forestry and fisheries, with active projects in 25 countries across Asia, Africa and South America.

Solutions in the field

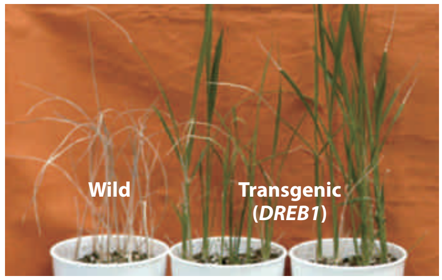
The research conducted at JIRCAS aims to provide technology-based solutions to known problems in developing regions through a combination of basic scientific experimentation and applied studies in the field. Many of these research projects have significant potential to influence and benefit human society. A team led by Kazuko Yamaguchi-Shinozaki of JIRCAS's Biological Resources Division, for example, has discovered several plant genes that mediate response to abiotic stresses such as drought, low temperature and salinity, and genes for certain transcription factors (such as *DREB*) have already been introduced into various crops such as rice, wheat and soybean to improve stress tolerance. All this work has been conducted in close collaboration with research centres of the Consultative Group on International Agricultural Research (CGIAR), the Brazilian Agricultural Research Corporation and other research organizations.

In the Fisheries Division, a JIRCAS team led by Marcy Wilder has been conducting basic research on the hormonal control of moulting and reproduction in economically significant shrimp species. The team's research efforts have culminated in the development of a commercial land-based indoor shrimp production system in cooperation with the private sector in Japan, and hatchery and rearing technology for freshwater prawns in cooperation with Vietnam's Cantho University. Both projects have demonstrated considerable economic benefits for the shrimp culture industry, both in Japan and Southeast Asia.

In Malaysia, Yutaka Mori of the Post-harvest Science and Technology Division has led a team in the development of technology to utilize the trunks of felled oil palm trees — an abundant waste resource in the region — as feedstock for the production of bio-ethanol. In collaboration with Universiti Sains Malaysia and the Forestry Research Institute Malaysia, efforts are now being made to commercialize this technology, which is expected to bring significant economic and environmental benefits to tropical regions by providing additional energy resources and cash income to rural populations.

Research collaboration as a pillar of development

The JIRCAS places priority on the actual implementation of the technologies it helps develop. The newly established Rural Development Planning Division conducts on-site trials to bridge the gap between



Drought-tolerant transgenic rice

the laboratory and the field. One of the JIRCAS's most prominent activities in this area is its leading role in the Coalition for African Rice Development, a Japan-led development initiative that aims to double rice production in Africa within ten years. These activities are supported by close cooperation with national and international development organizations.

International and national networking and collaboration among researchers and related institutions are key activities of the JIRCAS, which acts as a focal point institution of the CGIAR and serves as a gateway for Japanese agricultural research institutes to access various international forums. The JIRCAS also sponsors various programs that build capacity for research and development among junior researchers both in developing countries and in Japan, and promotes the dissemination of information by organizing international symposia and workshops.

JIRCAS scientists are active all around the world, from the arid savannas of Niger to the tropical forests of Malaysia. The centre's ultimate goal is a world without hunger based on sustainable use of our natural environment through technological development. Although the scale of JIRCAS's activities are yet small in comparison to the enormity of today's global issues, from its base in Tsukuba the centre is making a unique contribution towards a better world through face-to-face partnerships with developing nations.

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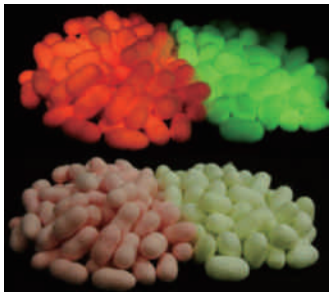


NATIONAL INSTITUTE OF AGROBIOLOGICAL SCIENCES

Stewarding the agricultural genetic heritage

The National Institute of Agrobiological Sciences (NIAS) is at the forefront of Japan's efforts in basic agricultural genome research and the development of new agricultural biotechnologies.

With roots dating back to early initiatives to establish facilities for the preservation of agriculturally important seed resources in the mid-1960s, the National Institute of Agrobiological Sciences in Tsukuba is now the largest agricultural research institute for basic life sciences in Japan.

A key aspect of the work of the NIAS is the conservation, evaluation and classification of genetic samples relating to agriculture, which it carries out via the NIAS Genebank — the central coordinating institute for plant, microorganism and animal agricultural specimens in Japan. Maintaining the Genebank is no small undertaking as the collection, which in the case of the plant section alone exceeds 242,000 registered items, is constantly growing as new accessions are regularly added from organizations in Japan and abroad. In addition to expanding their collection, the NIAS also distributes samples of seeds, microbes and animal genetic material to outside agencies for research and educational purposes at the rate of 7,000–12,000 samples annually. Details of the seed and gene samples held at the Genebank are made freely available on the internet via a website maintained by the NIAS (www.gene.affrc.go.jp).

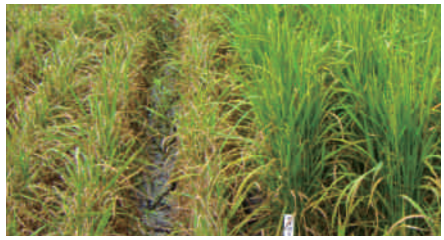
Beyond its conservational activities, the NIAS is also one of the most important centres globally for agricultural genomics research. The institute's transition to a government-supported 'independent administrative institution' in 2001 means that the NIAS is now obliged to set out a series of five-year plans for its development. A commitment to sequencing of the rice genome was a major element of the first five-year plan. The sequencing was completed in 2004, with researchers based at or coordinated through the NIAS responsible for decoding 55% of the total base sequence — by far the largest contribution by scientists from any single country.

With rice being the staple food for nearly one-half of the world's population, including Asia-Pacific nations such as Japan, the motivation for focusing on the rice genome may seem obvious enough, but according to Takuji Sasaki, vice president of the NIAS, there were other reasons for tackling this particular target, among them that "rice has a lot of colinearity with wheat, maize, sorghum and other cereal crops," he explains. This colinearity means that information obtained studying the genetic character of rice can be directly applied to other related crops.

As well as genome sequencing, the NIAS carries out research into advanced biotechnologies, including the development of genetically modified (GM) strains of food crops, silkworms that have been engineered to produce silk fibre with enhanced strength or fluorescence properties, and transgenic pigs that are being studied for potential medical applications.

However, the prime area of research at the NIAS is that of crops, in particular rice and soybean. In the main field of GM rice research, NIAS scientists have succeeded in producing strains with enhanced characteristics such as more robust mechanical properties, improved yields and altered cropping times, and increased drought and pest resistance. One example of this research is the isolation of *qSH1*, a gene involved in determining how easily a rice grain becomes detached from the rice head. A better understanding of this gene will allow the development of less-fragile strains of rice, thus reducing the number of grains lost in the harvesting process. Other projects include engineering rice with improved resistance to rice blast fungus, and creating strains with more robust stalks capable of withstanding attack by the brown planthopper — a pest indigenous to a number of countries in Southeast Asia. As well as carrying out basic research in these areas, the NIAS has acquired intellectual property rights to key technologies discovered during the research.

Commercial growing of GM crops does not exist in Japan even though many GM crop varieties have cleared all the regulatory hurdles required for practical cultivation. Currently, cultivation of GM crop varieties is still confined to experimental plots in greenhouses or isolated fields. This reflects a somewhat negative prevailing view of GM technology that Sasaki ascribes in part to a lack of public understanding. "The average Japanese citizen does not understand GM well. They tend to favour the so-called 'natural situation'," he says. "But only about 28% of our grain is produced domestically, the remaining 72% is imported — and a substantial proportion of the major imported crops such as soybean, maize and rapeseed is GM."



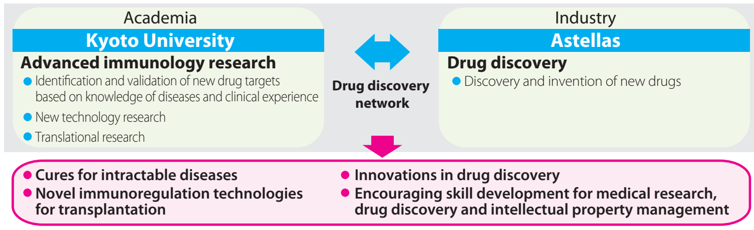
Wild-type Koshihikari rice (left) and the *pi21*-modified version (right) with improved blast resistance.

According to Sasaki, this equates to the importation of around 16 million tonnes of GM crops into Japan annually. Although this fact is not made widely known, it shows the important role that GM technologies already play in the food economy of Japan. Further development of GM is touted as playing a central role in alleviating the increase in food poverty forecast to occur in coming decades. The NIAS will doubtless play an important part in carrying forward this fight into the twenty-first century.




ASTELLAS PHARMA

Changing tomorrow



Astellas Pharma is searching for innovative drug targets to address patients' unmet medical needs. Basing its research hub in Tsukuba is a strategic decision aimed at leveraging the potential of this regional centre for life science research.

Astellas Pharma is a Japan-based pharmaceutical company dedicated to improving the health of people around the world. The company was formed in 2005 through a merger of the pharmaceutical giants Fujisawa Pharmaceutical and Yamanouchi Pharmaceutical. The merger and founding of the new company also heralded a refinement of the business focus to concentrate on the provision of innovative and reliable ethical pharmaceutical products, particularly those that address unmet medical needs. Some of the best-selling products of Astellas Pharma include Prograf, an immunosuppressant for suppressing organ rejection in transplant patients, Harnal, a drug addressing symptoms associated with benign prostatic hyperplasia, and Vesicare, a treatment for overactive bladder.

"In order to respond to unmet medical needs, we are strategically focusing our research on selected key therapeutic areas and diseases," says Shinichi Tsukamoto, senior vice president of drug discovery research at Astellas Pharma. Tsukamoto is responsible for watching over the entire drug discovery process, from basic research to drug and nonclinical development. He plans to expand the capabilities of Astellas Pharma's drug discovery research and improve productivity by utilizing the company's three key strengths of outstanding professionalism and organisational structure, an industry-leading technology platform, and a global research network to form alliances that leverage the most advanced technologies.

Tsukamoto says that in research, people are the determining factor for success. Astellas Pharma has been hiring outstanding professionals and highly capable researchers from around the world, and actively supports their work at the highest level by establishing a streamlined organisational structure to ensure the smooth flow of ideas during development — from beginning to end.

Drug discovery is a comprehensive science, Tsukamoto believes, which requires sophisticated knowledge and technology. Astellas Pharma has extensive experience in high-throughput screening and *in silico* drug design, and drug discovery research in the company is now benefiting from a consolidation of its technology platform by integrating various gene-related technologies — genomics, proteomics and metabolomics. Astellas is also investigating emerging technologies such as small interfering RNA and induced pluripotent stem cells for integration into their industry-leading technology platform.

Tsukamoto emphasizes the vital role played by Astellas Pharma's worldwide research network and alliances for leveraging the most advanced scientific technologies. Astellas Pharma has research sites in Japan, the United States and the Netherlands. In September 2008, the company also completed the construction of a new research building at the Tsukuba Research Center. The research building is one of the most advanced research facilities in Japan and serves as the hub of Astellas Pharma's worldwide research network.

In drug discovery research, Tsukamoto believes that forming alliances and collaborations with external researchers and institutions is extremely important. Astellas Pharma has been developing various forms of alliances and collaborations around the world. Domestically, the company is collaborating with Kyoto University in immunology research. In this particular example, Kyoto University takes the responsibility for basic research while Astellas Pharma takes the responsibility for drug discovery research. The collaboration is novel because the pharmaceutical company and the university fulfil different roles and leverage the expertise of each other in order to achieve a common goal.

The research collaboration between Astellas Pharma and Kyoto University is an example of the close alliances Astellas is building around the world.

In Tsukuba, Astellas Pharma is collaborating with the University of Tsukuba and the National Institute of Advanced Industrial Science and Technology, and also with the High Energy Accelerator Research Organization, where high-energy X-ray beams allow high-speed analyses of protein complexes and low-molecular-weight compounds.

"Astellas Pharma based its drug discovery research activities in Tsukuba because the city is well located, has a good environment and allows scope for future expansion," says Tsukamoto. "Tsukuba is also a city that focuses on research and academia. There are many research institutes, including those from the private sector. We have high expectations that various kinds of alliances will take place when we locate ourselves in Tsukuba."

Astellas Pharma now has leading products in the field of transplantation and urology, namely Prograf, Harnal and Vesicare, which form the basis of its current business. In the future, the company also aims to establish leading products in oncology. "We have compounds from early-stage through late-stage development. I believe that in the near future, we will have new products in the field of oncology that expand our position as a global category leader," says Tsukamoto.

astellas

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RIKEN BIORESOURCE CENTER

Build it, and they will come

The RIKEN BioResource Center is little more than nine years old, but it has already earned a reputation as one of the world's top three resource repositories for life science research.

The turn of the new century has been marked by some remarkable achievements in life science research: completion of sequencing of the human genome in 2001, and derivation of the first human embryonic stem cell line in 1998 and of human induced pluripotent stem cells in 2007. Behind each of these major scientific breakthroughs, however, as well as the thousands of less noteworthy scientific advancements made in laboratories around the world each year, are the biological materials that make it all possible. In years gone by, research on a specific plant, animal or microbe required that the strain or cell line be isolated and propagated individually in each laboratory. Such pioneering endeavours, however, now fall by the wayside in the highly competitive and increasingly global modern era of life science research.

Resource centres such as the American Type Culture Collection (ATCC) and the Jackson Laboratory in the United States were established in the 1920s in recognition of the need to centralize and perpetuate independently developed biological resources for broader use by the scientific community. By contrast, Japan — and Asia — still had no centralized repository for biological resources going into the twenty-first century.

RIKEN foresaw the importance of such a centralized resource bank in the 1980s when it established the Japan Collection of Microorganisms (JCM) in Wako to consolidate Japanese biological collections that would otherwise have been extinguished as individual researchers either moved on or retired. It was not until 2000, however, that the Japanese government finally moved to establish a national, world-class infrastructure for life science research with the country's flagship research organization, RIKEN, at the helm. These moves culminated with the establishment of the RIKEN BioResource Center (BRC) at RIKEN's Tsukuba campus in 2001, subsuming its predecessor the JCM and forging ahead with a strategic mission to become the 'go-to' bioresource centre in Japan. It has rapidly become much more than that.

The BRC continues to accept thousands of deposits of materials — plant, microbe, cell and genetic materials as well as mice — each year, and its collection now rivals that of the much older ATCC in terms of diversity, with almost 5,000 mouse strains, over half a million plant cell lines, 6,000 cell lines, three million genetic clone lines and almost 20,000 microbes — putting it among the top three bioresource banks in the world. The BRC's collection fits neatly among the other major centres around the world, offering an extensive collection that is unique to Japan while minimizing duplication with other banks. It is particularly famous for being the only repository in the world for human induced pluripotent stem cells for research.

The size of the collection, however, is certainly not everything. "When I became director, the first thing I did was have all of our cell lines tested for quality and authenticity," says Yuichi Obata, current director of the BRC. "It took about three years to check all of our lines, and we found about 10% of them to be mislabelled by the depositor." Globally it is estimated that 10% of all cell lines are mislabelled or cross-contaminated, and that 30% have mycoplasma infections. Up to a fifth of all mouse strains, too, have pathogenic infections. It is a widely acknowledged issue that now sees scientists having to provide verification of authenticity before submitting research for publication.

"I had to write a letter to everyone who had used a mislabelled line, and also to the journal editors explaining that the materials were incorrectly labelled," says Obata. "We now offer purified lines of all our resources, with a certificate of authenticity." Obata is proud of the fact that the BRC took out ISO 9001 quality certification before the ATCC; the RIKEN centre has earned a well-deserved reputation for quality among the global life science community.

Obata is pressing on with a program to adapt the BRC to the ever-changing world of life science research. "We are one of the founding members of FIMRe, the Federation of International Mouse Resources," he says. "Through FIMRe you can now search for your mouse online and have it delivered to you by the centre holding that strain, from anywhere in the world." And with an eye to the future, he is devoting a significant part of the centre's activities to developing sustainable methods for propagating mouse strains and cell lines. "Raising mice is very labour-intensive. We have developed cryogenic technology to keep most of our mouse strains as frozen material until we receive a request for supply."

The BRC's initiatives in research on the management of bioresources, including a major information system to go with the extensive collection, differentiate the centre from many of its contemporaries. Already the BRC model is being emulated throughout Asia, and the centre hosts regular delegations from Korea and China who come to see how a world-class resource centre is run. But the challenge of how to thrive as a resource centre is never far from Obata's mind. "We have to give researchers what they want immediately, we have to be ready to change our strategy. We need good, active scientists to see how the fields move," he says. "We are more than just a library, we aim to be a leader by being very proactive in identifying and cultivating new resources." And to maintain that leading position, trust, he believes, is key. "The researchers trust us with the resources they deposit, just as they trust the resources we provide. Build that trust, and the support from the scientific community will follow."

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