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Biopolis, Fusionopolis, and the bridge in-between—the place for multidisciplinary science

Small in size, Singapore packs a powerful research punch. Is it too small to compete against the United States, Japan, and other scientific powerhouses? "These days, you don't see countries competing, you see centres competing," says LIM Chuan Poh, Chairman of the Agency for Science, Technology and Research (A*STAR), Singapore's leading public research agency. And in that multi-centred world, Singapore is fast becoming one of the elite players, led in large part by A*STAR and its constellation of 22 research institutes, consortia and centres. Indeed as research becomes increasingly multidisciplinary to reflect the needs of industry and society, A*STAR is exploiting its unique advantages.

The booming biological research centre, Biopolis, which houses A*STAR's biomedical research institutes and consortia, was put together over the past 8 years. It has become a symbol of Singapore's ability to move quickly into cutting edge fields and attract top international talent.

Now A*STAR has other tricks up its sleeves. Biopolis gazes out to Fusionopolis, the nation's second R&D hub that officially opened its doors on 17 October 2008. It will host pre-existing strengths in materials, high performance computing, microelectronics, data storage, info-communications and manufacturing technologies that reside in A*STAR's physical sciences and engineering research institutes located in various parts of the island. The aim is to draw together the diverse expertise into a unique interdisciplinary arrangement to tackle large-scale, complex challenges including sustainable development and ageing populations.

But the barriers are expected to fall even further. The close proximity between Biopolis and Fusionopolis—less than a kilometer apart—will enhance collaboration between engineers and biomedical and physical scientists for innovative research. A*STAR is backing this up with financial incentives and an environment, which is conducive to fruitful scientific interaction.

All these developments have attracted international talent, ranging from the young and upcoming to the experienced and renowned, who continue to flood in. They are joined by a growing pool of Singaporean researchers that includes young Singaporean scientists cultivated in A*STAR programs.

Neal and Nancy Copeland moved to A*STAR after spending 20 years at the NIH National Cancer Institute.

Biopolis today, the clinic tomorrow

The launch of Singapore's biomedical initiative in 2000 saw the rapid creation of new research institutes under A*STAR to add to the pre-existing Institute of Molecular and Cell Biology (IMCB) and the Bioprocessing Technology Institute (BTI). The Genome Institute of Singapore (GIS) was set up in 2000, the Bioinformatics Institute (BII) in 2001, the Institute of Bioengineering and Nanotechnology (IBN) in 2003, and the Centre for Molecular Medicine (since renamed the Institute of Medical Biology (IMB)) in 2004. The institutes form the core of Biopolis – they are fundamental pieces of a bigger plan to grow Singapore's biomedical industry sector.

However, buildings and institutions alone, no matter how impressive, are not enough – it is talent that matters. Thus, A*STAR recruited Edison Liu, from the US National Cancer Institute (NCI), to head the GIS. A stream of big names followed. Sir David Lane, former director of Cancer Research UK's Cell Transformation Research Group at the University of Dundee, came to lead the IMCB in 2004. In 2007, Lane handed over the reins to another internationally renowned scientist, Neal Copeland, who has been ranked among 50 of the most-cited biomedical scientists in the world. Copeland had moved to Singapore with his

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wife, Nancy Jenkins, a well-established cancer researcher in her own right. Lane continues as Chairman of the A*STAR Biomedical Research Council (BMRC) that oversees the research institutes. Most recently, A*STAR recruited cloning and epigenetics pioneer Davor Solter to the IMB, which now focuses on stem cells and regenerative medicine.

Having internationally renowned researchers at the top has made it easier to do what other countries in the region have struggled to do—recruit a diverse group of top-notch younger scientists that will form the core of the laboratory. For example, when Japan's Yoshiaki Ito, famous for his work on the tumor suppressor RUNX3, moved to IMCB in 2002, nine members of his laboratory followed him.

Singapore is attractive because of the infrastructure and investment. But scientists are also drawn by the rare vision of the policymakers, such as A*STAR's first Chairman, Philip Yeo, and Lim, who engage them and their research while allowing them to follow their instincts. The close connection has led to a type of trust that allows for the government to take chances on its scientists. "A*STAR is basically like the [US] National Institute of Health," says Copeland, who spent 20 years at the NIH NCI before coming to Singapore. "It carries out high risk, high pay off science."

Less than a decade after getting started, the Biopolis complex is showing early signs of success. Publications in biomedical journals shot up from 111 in 2001 to 392 in 2007. The number of biomedical researchers jumped from 540 to 1000.

Academic breakthroughs at the Biopolis carry potential clinical applications. In 2007, a team led by IMCB's Dmitry Bulavin announced results of experiments showing how to induce self-destruction in stem cells that would otherwise cause intestinal cancer. More recently, in February 2008, researchers led by GIS' NG Huck Hui made a breakthrough in understanding the reprogramming of bodily cells to an embryonic state—one of the hottest fields in biology. Ng's team showed that one of factors thought necessary for the reprogramming of bodily cells is not necessary in embryonic stem cells.

The spillover to the economy is evident. From a base of almost zero in 2000, there are now over 30 biotech companies that have set up research centres in Singapore. These include corporate R&D laboratories by global pharmaceutical companies GlaxoSmithKline, Novartis and Eli Lilly that are located at Biopolis. The contribution of the biomedical sciences sector to the overall economy grew, from 2.5 percent of GDP in 2000 to 6 percent in 2007. The manufacturing output in the sector increased almost fourfold, from S$6.3 billion in 2000 to S$24.0 billion in 2007. Employment in the sector almost doubled, from 5,880 jobs in 2000 to about 11,500 jobs in 2007.

Singapore and A*STAR are now ready to move to the next stage—taking research findings and moving them to the clinic. "We want to move up the value chain," says Andre Wan, deputy executive director of A*STAR's BMRC. To do so, A*STAR combined forces with the Ministry of Health (MOH) and the National Research Foundation to create the S$1.5 billion translational and clinical research initiative.

The decisions on how to distribute such money are made quickly in Singapore, earning the country its reputation for fast action. "We locked ourselves up in a building to determine how to spend the 1.5 billion. We can make decisions in one meeting," says Lim.

Edward Holmes moved from the University of California, San Diego (UCSD), where he was vice-chancellor for health sciences and the dean of the school of medicine, to Singapore to lead in the translational and clinical research initiative. He holds a strategic dual appointment as BMRC's Deputy Chairman for Translational and Clinical Sciences and the Executive Chairman of the MOH's National Medical Research Council.

He is joined by his wife, Judith Swain, who also left UCSD to become the founding Executive Director of the Singapore Institute for Clinical Sciences, one of A*STAR's new units that have been set up to focus on translational research.

Together with MOH, A*STAR launched the Translational & Clinical Research Flagship Program, which aims to put Singapore at the very cutting edge of a number of niche areas within cancer, cardiovascular and metabolic disorders, neuroscience, infectious disease, and ophthalmology. The first, Singapore Gastric Cancer Consortium, was allocated $25 million over 5 years in 2007 so that industrial scientists, principal investigators from the four public hospitals, the National University of Singapore, the Nanyang Technological University, and A*STAR research institutes, can work together to "improve the early detection and treatment of gastric cancer with significant clinical benefits to patients." This year, $100 million has been awarded over 5 years to four more flagship programs in glaucoma, severe psychotic disorders, metabolic diseases and dengue.

The initiative will also put tens of millions of Singapore dollars into scientist awards and training programs in an effort to develop human capital, as well as the setting up of an Experimental Therapeutics Centre (ETC), which will translate A*STAR discoveries into commercial opportunities.

Jean Paul Thiery, deputy director of the IMCB and chief scientific officer of ETC, describes the centre as an educational training ground that uses recruits from both the public and private sectors. "Most basic researchers don't want to take the time to show that a discovery is useful. At ETC we train people to think differently." Experiments there started within days of its August 2007 opening, and ETC researchers already have a few promising drug targets.

Building Fusionopolis on a solid foundation

The Fusionopolis has been launched with similar goals: to carry out cutting-edge research, especially multi-disciplinary science, leading to commercial applications. It officially opened its doors just this month, but it will be building its interdisciplinary

Edward Holmes leads the translational and clinical research initiative in Singapore, with a strategic dual appointment at A*STAR and the Ministry of Health.

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Charles Zukoski heads the A*STAR Science and Engineering Research Council at Fusionopolis.

platform out of the institutes of A*STAR's Science and Engineering Research Council which already have a prominent international presence. SERC's institutes have 1500 researchers, 55% of which are from foreign countries like UK, Germany, China, and India—820 hold doctorates. The synergy created by housing these researchers together in the Fusionopolis will quickly make it one of the greatest centres of its kind.

The Institute of High Performance Computing (IHPC), the Institute for Infocomm Research (I²R), and part of the Data Storage Institute (DSI) have moved into Fusionopolis. In 2011, these will be joined by the remainder of DSI, the Institute of Microelectronics (IME), the Institute of Materials Research and Engineering (IMRE), and the Singapore Institute of Manufacturing Technology (SIMTech). A seventh institute, the Institute of Chemical and Engineering Sciences, will remain in its existing location that is just a 30-minute drive away from Fusionopolis.

The SERC institutes have proven themselves in various fields. In 2005, DSI won the Information Storage Industry Consortium Technical Achievement Award—the first institution outside the United States to do so—with an ultra-low flying femto slider for extremely high density magnetic data storage. The scientists describe it as "flying a jet one millimetre over the runway without touching the ground." In 2007, LO Guo-Qiang and his team at IME produced silicon nanowires in diameter of 3~4 nanometers that could scale the gate length of transistors to 2~3 nanometres. The technology, which will have applications in fields like biosensing, could enable the doubling of the density of transistors on silicon chips every two years—in accordance with "Moore's Law"—well beyond the predicted end of the law's reign around 2020. The excitement in the field landed Lo's team the coveted IEEE George E. Smith award.

Overall, in 2007 alone, SERC researchers filed 130 patents and published 1536 papers.

It is the focus on fundamental research with applications that attracts many of SERC's researchers. "It's goal-oriented fundamental research with industry as a target. It's unique," says Charles Zukoski, who has served as SERC chairman since 2004 and move to Singapore this past summer after relinquishing his vice-chancellor post at the University of Illinois.

Indeed IME, which gets 25% of its budget from industry, has 26 industrial contracts, mainly for helping Japanese or US companies develop and demonstrate their prototypes. "We develop IP and bring in new business with it," says IME executive director KWONG Dim-Lee, who moved from University of Texas at Austin three years ago.

Fusionopolis will give the talent at SERC an opportunity to explore new dimensions by linking scientists in different fields. The IME, for example, will be collaborating with I²R to design high-frequency circuits that are combined with micro-electro-mechanical systems for terahertz applications. "We have expertise in circuit design, processing, packaging and work with people focused on materials, system, and manufacturing. It will expand integration significantly," says Kwong.

The range of skills in SERC means that experimental, theoretical and computational projects can all be conducted under one roof at Fusionopolis. "If you look across the globe, there is no place that integrates so many diverse areas of physical science expertise under one roof," adds Kwong.

The hub's work-live-play-learn environment that includes pubs, cafes, a theatre and a roof-top swimming pool is aimed at encouraging scientists to get together. They also double up as testbedding sites.

Companies are already lining up for the chance to take advantage of the opportunities at Fusionopolis—but space is limited. "We have had to turn away clients," says Lim. Thirteen corporate laboratories are already in the first phase of Fusionopolis. Construction continues rapidly to meet the demand from companies.

But SERC and Fusionopolis also give opportunities to scientists whose research work may not have specific applications on the horizon. Northwestern University's Andrew Ortony has recently started a multidisciplinary project called Cognitive Computing for Social Systems at the IHPC. Ortony, famous for his work on metaphors and emotion in artificial intelligence, describes the project's goal as "trying to develop agent-based models of plausible, contextually appropriate, social interaction." He expects the research by his team to contribute to the next generation of work in social robotics. Whether or not robots look like humans, they will need social skills. "For example, they will have to recognize suffering," he says. The research will require investigation of human intentions and emotions. For the task, Ortony is pulling together an international team covering social and cognitive psychology, computational linguistics, decision theory, cognitive architectures and multi-agent systems, and social robotics.

Robots are expected to become big business, especially as ageing populations worldwide make greater demands on

Rooftop swimming pool at Fusionopolis: the complex's work-live-play-learn environment aims to encourage scientists to collaborate.

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automization, so there is a practical element to the Ortony's work. But these applications are far off—something A*STAR policymakers understood. Ortony says his main goal is "to raise consciousness, excite people." Of his team he only requires hard work and "that they think this is the coolest thing in the world."

Building bridges

Future demands of industry and society will require work at the interface of different fields. So Lim acted to maximise the opportunity of having biomedical scientists and engineers in close proximity by setting up the A*STAR Cross Council Office (CCO) last November to tear down the walls between disciplines.

"Rarely around the world do you get the scientists in biomedicine, basic human biology sciences and engineers to come together. There are cultural differences in the way they approach science and the way they want to solve problems," adds Zukoski.

CCO provides funding support for research and workshops to seed bottom-up collaborative research ideas. It will also invite research proposals for specific themes. It also organises activities that connect A*STAR's researchers with one another.

"We want to get people to really talk about how they can collaborate," says Lim.

Five groups were selected from 13 applications to receive the first round of grants, and they are already at work. GIS director Edison Liu has teamed up with Kwong of IME and SIMTech to compete for the coveted Archon X prize by developing the fastest and least expensive sequencer that is able to sequence a human genome for under US$1000. Horst Flotow is leading ETC and DSI scientists in micro-fabricating chips that can be used for imaging-based molecular diagnostics. In a collaborative project with IMCB, IMRE's Jonathan Hobley will lead a group to use optical microscopy and scanning probe microscopy to understand how axons are guided by surface properties.

"We had been discussing how we could work together in an informal way," says Hobley. "The Cross Council grant provided a way to really pursue it."

"We want to get people to really talk about how they can collaborate,"
LIM Chuan Poh

The next generation

The greatest imperative for Singapore is to keep the flow of talent coming in.

Recruitment of experienced leaders continues. Colin Blakemore, former President of the British Neuroscience Association and former chief Executive of the UK Medical Research Council, was appointed by A*STAR and Duke-NUS Graduate Medical School to be chairman of the Neuroscience Research Partnership in 2007. In the same year, renowned cell and developmental biologist, Dr Colin Stewart, moved from the NCI at Frederick, US, to join IMB as a principal investigator.

For established scientists who want to retain their post, SERC offers the Visiting Investigatorship Programme (VIP). The opportunity to run a 3-year project, like Ortony's cognitive computing program, has drawn eminent scientists from all over the globe. Since 2005, Christian Joachim has been coming to IMRE from France's Centre for Material Elaboration & Structural Studies at least three months a year to run his laboratory in atomic and molecular devices. Ortony says the chance to come and start something new is "like a rebirth."

LIM Chuan Poh, Chairman of A*STAR.

Younger scientists have also been drawn to Singapore by the A*STAR Investigatorship scheme. It targets outstanding promising talent and helps them get ahead in their career early. Thirty-three-year-old developmental biologist, Bruno Reversade, came from France to take up the appointment that comes with a US$500,000 per year grant. "It's abundant funding, and I get to start my career as a principal investigator," says Reversade, who is working on the biology of identical twinning. But he is getting the best of both worlds—independence and guidance. A week after he arrived at the IMB, he was joined by Solter, providing an experienced mentor. "It will be a great stepping stone," he says.

From last year, A*STAR is also attracting young foreign scientists to do graduate studies in Singapore with the Singapore International Graduate Award (SINGA). France's Franck Courtes, one of 20 SINGA recipients at A*STAR, says the grant was too good to turn down, especially after looking into the research of Niki Wong, the Bioprocessing Technology Institute scientist that will be his mentor. "I went back and read her articles. It was exactly what I wanted to do," says Courtes, who will study what factors make monoclonal antibodies such good producers.

A*STAR continues to cultivate the next generation of local young scientists and is on track to train 1000 PhDs by 2010. Its graduate academy offers scholarships for undergraduate, graduate, MD-PhD, and postodoctoral studies in Singapore or at any of A*STAR's overseas partners, which include Imperial College London and the University of Illinois at Urbana-Champaign. Currently 800 students have been supported, and more than 90 are back at A*STAR.

"We welcome talent at all levels," says Lim.

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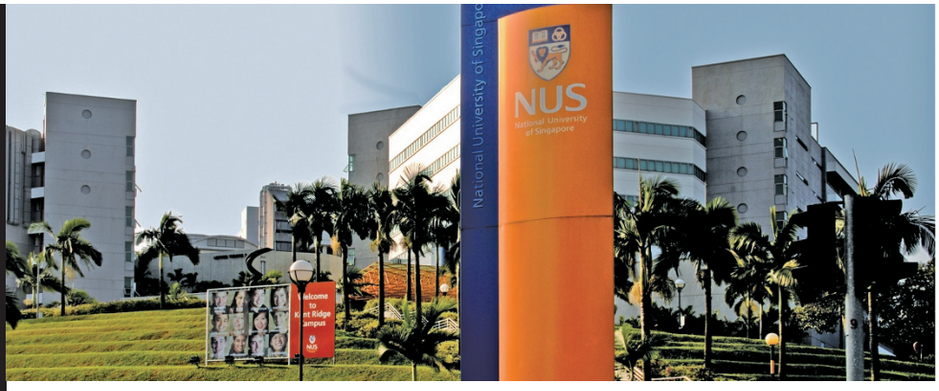


A Global University in Asia

The National University of Singapore (NUS) is poised to become a major player in science and technology. As a leading global university based in Asia, NUS offers education and research of the highest international standards, yet with unique Asian expertise and perspectives.

Over the last decade, with significant government investment and recruitment in strategic areas, NUS has strengthened its research capacity and honed its focus, resulting in exciting developments in several fields. Symbolic of this transformation are two Research Centres of Excellence specialising in quantum technologies and cancer, which were awarded to NUS in 2007 and 2008 respectively, following stringent external review.

Some of the world's top universities have welcomed NUS into the research elite through strategic partnerships. In 2005, in collaboration with Duke University, it established the Duke-NUS Graduate Medical School Singapore, which delivers a pioneering M.D. (Doctor of Medicine) programme in Singapore. Massachusetts Institute of Technology has set up its first research unit outside of Cambridge—the Singapore-MIT Alliance for Research and Technology—on the NUS campus, and is collaborating with researchers on infectious diseases and environmental modeling. The recognition of the commercial significance of NUS research has paved the way for links with multinational companies. Siemens Medical Solutions, NUS and the Agency for Science, Technology and Research (A*STAR) are jointly building a Clinical Imaging Research Centre. US industrial giant, General Electric has established a GE Water and Process Technologies Global R&D Centre at NUS.

From a teaching university to an internationally ranked research institution

"Many factors have been at work here, including a conscious decision by the university to strengthen graduate education and cross-disciplinary research, and a growth in the funding sources in Singapore," says Professor Barry Halliwell, Tan Chin Tuan Centennial Professor and NUS Deputy President (Research and Technology). NUS has successfully competed for the new funding and put in place scientific infrastructure that enables research at internationally competitive levels. It is now brimming with new talent, either cultivated at home or welcomed from abroad.

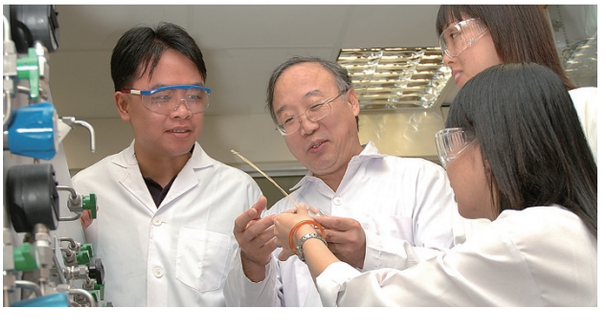
Cutting-edge research, cutting across disciplines

NUS researchers excel in a wide variety of fields and are constantly proving themselves with diverse applications. Theoretical physicist Professor Li Baowen won the 2005 National Science Award for his work on heat conduction and control of heat flow at the microscopic level. Professor Seeram Ramakrishna and his colleagues have patented a nanofibre membrane adorned with catalysts that degrade chemical warfare agents, for use in garments and face masks. Professor Thirumalai Venky Venkatesan, a pioneer in epitaxial metal oxide thin films and superconductors and one of the most highly cited physicists in the world, came from the University of Maryland last year and has already assembled a powerful team of international researchers to study nanostructured materials and devices.

NUS biologists are also producing exciting results. Professor Manjunatha Kini has established himself as one of the world's leaders in snake toxins. Professor Peter Ng's research on crustaceans has carried him to world prominence in ecology circles. Associate Professor Yu Hao's work on genetic engineering of plants produced techniques for manipulating orchids—a discovery with great potential for this commercial crop. "Especially in the last 7 or 8 years, we have made the transition to a research university," says Kini. "Now there are many strong laboratories, some of them the best in the world."

To stay at the forefront of research, NUS emphasises multidisciplinary initiatives. In the biomedical sciences, for example, the Life Sciences Institute, the National University Health System and the Centre for Translational Medicine give scientists a broad range of areas to pursue their ideas. The Centre for Optoelectronics, the Centre for Remote Imaging, Sensing and Processing, and various nanoscience initiatives offer physical scientists the same flexibility. The NUS Environmental Research Institute (NERI) likewise pulls together the university's programmes related to water, air, environmental health, and energy.

Basic research is ever relevant at NUS. The Solar Energy Research Institute of Singapore (SERIS), established with S$130 million this February, will build on NUS' strengths in areas such as novel materials, silicon thin film technology and solar-thermal energy systems, nanoscience and self-assembly of microstructures to



Researchers at NUS are given broad latitude to pursue their ideas, and they are proving themselves in a wide variety of fields – from engineering to life sciences.

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build novel solar energy applications. Professor Joachim Luther, formerly the director of the world-renowned Fraunhofer Institute for Solar Energy Systems, leads the institute. SERIS is strongly supported by the Economic Development Board (EDB).

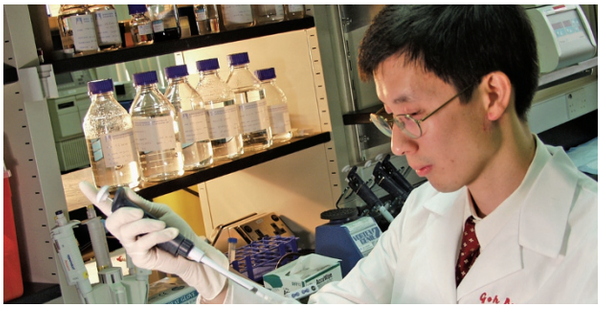
Biomedical scientists at NUS focus on health issues of special concern within Asia with the goal of bringing medical solutions to the world. Strategic initiatives at the Life Sciences Institute and the Yong Loo Lin School of Medicine include cancer, cardiovascular medicine, ageing, infectious diseases, neurobiology, and metabolic diseases. To support these priorities, NUS has developed expertise in bioengineering, bioinformatics, tissue engineering, imaging and clinical trials infrastructure, among other "platform technologies".

Barry Halliwell is now coordinating a new university-wide programme on ageing, which encompasses some 300 ageing-related projects at NUS. The initiative brings together researchers in fields ranging from molecular biology to social policy, from nursing to architectural design to environment studies. "Ageing is a serious problem facing Singapore," he says. "We are going to look at it from various angles—ageing cell, ageing body, ageing society," he adds. Other such programmes, for example on "food security", are in the works.

Centres of Excellence: Taking a leadership role

The Singapore government has dramatically increased its support for universities through competitive research programmes, especially those administered by the National Research Foundation (NRF). One of NRF's major projects was the creation of Research Centres of Excellence in Singapore, "aimed at developing a virtuous cycle of research excellence in our universities." Two of the first three are hosted at NUS.

Professor Daniel Tenen, Saw Swee Hock Centennial Professor in Medical Sciences and a Harvard Medical School expert on transcription regulation and differentiation into leukemic cells, leads the NUS Cancer Research Centre of Excellence (RCE). Many of NUS' top scientists will be involved, including Professor Yoshiaki Ito, Yong Loo Lin Professor in Medical Oncology and famous for his studies of the role of Runx 3 as a tumor suppressor of gastric cancer. Professor John Wong, a practicing medical oncologist, brings his interest in drug development and the differences between Asian and Caucasian cancers to the centre. Associate Professor Yeoh Khay Guan, a native Singaporean like Professor Wong, leads a translational clinical research project on gastric cancer—a critical health issue for Asian populations. Together the diverse mix of scientists will extend their studies "from basic cancer studies all the way to experimental therapeutics".



Strategic biomedical initiatives at NUS include cancer, neurobiology, cardiovascular medicine, ageing, infectious diseases and metabolic diseases.

While NUS has built a formidable research programme, it retains its commitment to nurturing the next generation of scientists and leaders.

NUS' other research centre of excellence—the NUS Centre for Quantum Technologies—aims to overcome the fundamental limits to information processing by harnessing the power of individual atoms, photons and other quantum phenomena to store information in new ways. The centre was launched in December 2007, but its director Lee Kong Chian Centennial Professor Artur Ekert, who holds a joint position at Oxford University, says that it already has "international visibility, a good interdisciplinary team of theorists, good experimental quantum optics and microtrap groups, and a new cold atoms group." Success builds on success. "Recruiting is getting easier and easier—the community already knows that something good is brewing up in Singapore," says Professor Ekert.

Nurturing the next generation of scientists

As seen by the presence of Tenen, Ekert, Luther and other leading scientists, NUS seeks to attract top minds from around the world to lead its scientific initiatives and to train scientists and engineers at the graduate level. Singapore offers generous grants for promising junior scientists and established scholars. For example, Professor David Virshup, director of the Cancer and Stem Cell Biology programme at the Duke-NUS Graduate Medical School, won the prestigious Singapore Translational Research Investigator Award (STaR) to expand his cancer stem cell research programme. Other recipients of STaR awards have been Professor Daniel Tenen of the NUS Cancer RCE, Professor Wong Tien Yin, who studies retinal vascular imaging, and Professor Michael Chee, who works on cognitive neuroscience at the Duke-NUS Graduate Medical School.

While NUS has built a formidable research programme, it retains its commitment to training students—though now with a mission to nuture the next generation of great scientists and leaders. The NUS Graduate School for Integrative Sciences and Engineering (NGS), established in 2003, offers scholarships and a multidisciplinary environment for top students. As Professor Virshup puts it, "One of my major goals here is to train our replacements. The acid test will be, in 15 years, where are they?"

NUS National University of Singapore

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ADVERTISEMENT FEATURE

A collegiate quantum leap: Nanyang Technological University moves forward with bold vision

The excitement of change is palpable at Nanyang Technological University (NTU).

Until recently it was known mainly for its strength in electronics and engineering. The accumulation of expertise since its establishment in 1955 has placed it in the world's top 100 universities (2008 Times Higher Education Supplement) and also led to it being the preferred partner in a host of international collaborations.

NTU is now enhancing its strengths to adapt to new challenges requiring more and new interdisciplinary research. It is also reinventing itself as a broad-spectrum, research university. "It's an engineering-based university which includes one of the best Business Schools in the region, with the addition of an art and design school, humanities, chemistry, physics and mathematics, and the range of biological sciences," says Bertil Andersson, NTU's Provost. "We are now becoming even more research-intensive and competitive, winning new sources of government support, including support for two new large-scale initiatives in earth science and water resources. These are giving momentum to the transformation."

These initiatives demonstrate NTU's continuing leadership in engineering while transforming itself into a more broad-based institution. "We're making a quantum leap both in quality of the research and in the promotion of interdisciplinary and new areas of scholarship," says Andersson. A former member of the committee that determines Nobel Prizes in Chemistry, Andersson speaks with the authority about what makes scientific breakthroughs possible.

Proven ability, new directions

As Singapore's science and technology university, NTU has a solid base upon which to build this vision. Its 28,000 students and 2,500 international faculty have accumulated an impressive list of world firsts. The School of Electrical and Electronic Engineering developed the world's smallest integrated circuit transformer for electronic devices while the School of Mechanical and Aerospace Engineering developed a wristwatch that takes its place as the world's smallest non-intrusive blood pressure measurement device. The School of Materials Science and Engineering developed the world's smallest piezoelectric heart pump. Freddy Boey, Chair of the School of Materials Science and Engineering, also developed the first biodegradable multiple drug-releasing stents that deliver drugs for vascular disorders.

Such achievements allow NTU to take advantage of new opportunities provided by a government intent on establishing a knowledge and innovation-based economy. For example, the National Research Foundation (NRF) recently began the Competitive Research Programme, a fund for "research comprising multiple related projects under a unifying theme" that will bridge gaps with industry. In the latest round of funding, NTU captured three of the four grants—with Boey receiving support to further develop his stents. The other two, each totalling S$10 million for 3–5 years, went to projects in cryptography and carbon nanotube-based printed electronics.

NTU's reputation attracts leading academics from around the world. One example is Jitendra Singh, who was appointed Dean of Nanyang Business School (NBS) in 2007. Singh came from the Wharton School, University of Pennsylvania, where he was Vice Dean of International Academic Affairs charged with shaping and implementing the global strategy of Wharton. Now, he is doing the same for NBS (which recently broke into the top 50 MBA programmes in the 2008 Financial Times rankings.)

NTU has attracted a broadening network of academic partnerships, including those with the United States Air Force Academy and Stanford University, Germany's Fraunhofer-Gesellschaft, and France's Centre National de la Recherche

NTU's research innovations includes the world's first multiple drug-eluting biodegradable stent.

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Scientifique. Its research reputation has also led to a growing list of industrial collaborations with companies such as the European Aeronautic Defence and Space Company, Siemens and Thales. In February 2008, Rolls-Royce launched a Fuel Cell Systems Process Engineering and Verification Facility at NTU.

"These collaborations continue to come because of the quality of the students and the research," says Tony Mayer, NTU's Senior Science Officer. Mayer explains how NTU capitalized on an opportunity to team up with Robert Bosch. "Bosch wanted laboratory space at NTU to work on organic photovoltaics. I offered a collaborative approach and now we have an excellent relationship with research students being jointly supervised by Bosch and NTU professors," says Mayer.

NTU has now embarked on a quest to build a world-class research-intensive environment. The School of Biological Sciences—established in 2001—has already developed strengths in structural biology, proteomics and infectious diseases research. This will be further enhanced when it opens a satellite campus to develop structural genomics as a new area of focus in Singapore.

The School of Physical and Mathematical Sciences is rapidly building expertise in synthesis & catalysis, condensed matter physics & optoelectronics, and coding theory & cryptography. The school won the highest concentration of NRF Research Fellows with scholars including Steve Zhou, a chemist in organic synthesis and asymmetric catalysis and Christos Panagopoulos, a physicist in magnetic materials and superconducting materials.

Panagopoulos moved from Cambridge, where he had been for 14 years, because of NTU's growing research profile and excellent facilities; it provides the opportunity to work with industry, and also attracts excellent research students. "It's a well planned approach. And it is very well networked," he says.

Panagopoulos sees part of his job as trying to make the School into one of the world's top in the next 10 years. "Considering how quickly NTU became a top engineering school it shouldn't take long to the do the same for science."

Scaling new heights: Two bold missions

Two new flagship projects underscore the significant role that NTU plays in fuelling Singapore's drive for research and innovation.

The Earth Observatory of Singapore, which was awarded S$150 million by the NRF and the Singapore Ministry of Education, will be dedicated to understanding the basic processes that produce natural hazards such as earthquakes, tsunamis, volcanic eruptions and climate change. Geologist Kerry Sieh left the California Institute of Technology to head the Observatory. He drew on his experience in studying Southeast Asian earthquakes and ties he had developed in Singapore to conceive the project. Sieh says the Singapore government has demonstrated great vision in supporting an establishment aimed at understanding dynamic earth processes relevant to human welfare. "Our work will help the country and the region address nature's 21st century challenges."

Sieh also experienced the benefits of being part of NTU's transformation into a more comprehensive university. During his recent trip to Sumatra, a team of faculty and students from the School of Art, Design and Media accompanied him to make a documentary. "This is one of our first interdisciplinary efforts to get science into the public eye. There are many exciting scientific stories and explorations about and in Southeast Asia. Why not work with film-makers to tell them?" says Sieh.

Kerry Sieh, Head of Earth Observatory of Singapore, surveying a newly dead coral reef on Mego Island, offshore western Sumatra, uplifted 1.5 meters during the great magnitude 8.4 earthquake of September 2007.

The Nanyang Environmental and Water Research Institute (NEWRI) is also making Singapore a global hub of environmental science and technology. The institute pulls together NTU's water and environment-related institutes under one body. "It is like an ecosystem in itself," says NEWRI director, Wun Jern Ng. NEWRI's five centres and two research groups will examine processes of desalination, reduction of energy consumption and recovery in treatment, biofilms and bioprocesses, resource reclamation, and residues and wastewater treatment. Over the next five years, NEWRI plans to produce 400 Masters and 120 PhDs, and also create technologies that can be transferred to industry. "We want to apply our research to the benefit of Singapore," says Ng.

Opportunities abound

Sieh has made a good start in recruiting top names to his observatory, including former United States Geological Survey volcanologist Chris Newhall and neotectonicist Paul Tapponnier from the Institut de Physique du Globe de Paris. But he worries about the challenge of ramping up quickly—he plans to have some 20 faculty members and 70 graduate students, and he will only take the best people.

But with new grant opportunities available at NTU and in Singapore, NTU might have an easier time recruiting talent than Sieh imagines. The Nanyang Assistant Professorship, launched in 2007 to attract the best young talent, offers generous salary and start-up grants to scholars. The scheme received more than 300 applicants for only 10 positions. The Nanyang President's Graduate Scholarship offers grants for Singaporean students to pursue PhD programmes at NTU. Furthermore, NTU also benefits from national grant programmes like the NRF Fellowship and the Singapore International Graduate Award. It now has research students from all over the world, including Middle East and Eastern Europe.

"It's easy to recruit good researchers. Singapore doesn't have a language barrier, and these really are golden opportunities in a country that is making a great leap forward in research and in a university which shares the same ambition," says Andersson.

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WIND - NO LONGER AN ALTERNATE ENERGY

Vestas is the world's largest manufacturer of wind turbines. One in three of the world's wind turbines has been installed by the company. This translates to more than 35,500 wind turbines across 62 countries. In fact, Vestas turbines generate more than 50 million MW a year, enough power to a country the size of Spain with its population of 45 million.

It is undeniable that the potential of wind energy is enormous. Not only is it an inexhaustible and non-polluting source, it also contributes to ensure energy independence and – in contrast to other forms of energy – does not draw on precious water resources

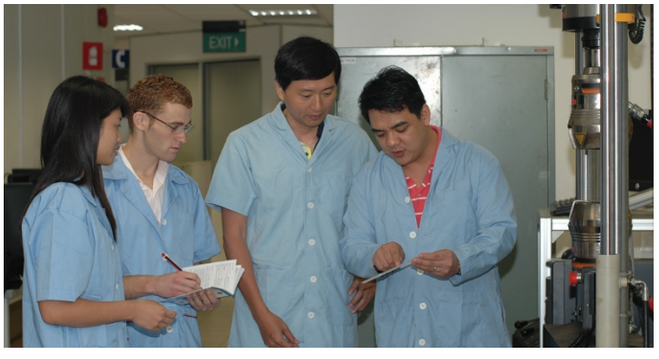
Despite this, wind energy currently makes up only one per cent of global electricity consumption. However, this figure is increasing at an exponential rate. According to the Global Wind Energy Council, the installed capacity of wind power increased by 27% just in 2007 alone. Vestas believes that by 2020, this figure could reach 10 % of global electricity consumption – even taking into account that the demand for energy is set to rise significantly over the same period.

With a 23 per cent accumulated market share in 2007, Vestas is the world leader in delivering wind energy. Significantly, the company installs one wind turbine every four hours, 24 hours a day, somewhere in the world.

WIND POWER IN ASIA

Wind is a well-established energy source in Europe and the United States, but its potential is only just being realized in the Asia-Pacific region. Vestas currently has an installed base of 5,000 wind turbines in wind farms across China, Taiwan, South Korea, Japan, India, Australia and New Zealand.

President of Vestas Technology R&D Finn Strøm Madsen believes Asia is the new hotbed for the adoption of wind technology: "Asia's electricity demand is growing rapidly and wind energy will be an important part of covering the demand. We expect high growth in Asia".



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"The message is not that wind will replace other energy resources, but that wind energy will be an important part of the energy mix going forward," stressed Madsen.

Until 2004, wind power was an insignificant form of energy in Asia. With countries like China and India accelerated economic growth, the need for energy had these countries seriously developing wind as a viable source of energy to coal and gas. And last year, China alone installed no less than 3000 MW, overtaking the traditional "big hitters" of Spain and Germany, and coming second only to the United States in newly installed capacity.

Faced with such overwhelming demand in Asia, the challenge for Vestas is to maintain a strong long-term position. To this end, Vestas relocated its Asia Pacific Business Unit Headquarters to Singapore in 2006, to further expand its existing business offices in China, India and Australia.

"Wind Energy is a global business and we need a global presence to get closer to our markets and customers in order to develop a deep understanding their needs," said Dr Ian Chatting, Vestas' Vice President Global Research. "Our business continues to grow at an incredible rate."

Today, the Vestas has expanded its Technology R&D facilities from Europe in Denmark and United Kingdom, to Asia Pacific in Singapore and India, and has recently announced a new

VESTAS TECHNOLOGY R&D IN ASIA

As wind technology was primarily developed in Northern Europe and America, Vestas understood the pressing need to attract, develop and train a competent and highly skilled talent pool for wind technology in this region.

"One of the challenges is the global war for talents," said Madsen. "The demand for people and best brains is very high."

So Vestas embarked on a mission to establish a research and development center in Asia. The company already had three regional sales and service centers, as well as manufacturing plants in India and China. Deciding where to locate this R&D hub was not a straightforward one. Vestas's plans to invest S$500 million here over the next 10 years had many countries calling.

"In the final round were also China and India, but we found that Singapore has the best match to the four criteria: access to world-class talent, IPR environment, competitive costs and ease of doing business," said Madsen. "After comprehensive due diligence in Asia and we found that Singapore best matched our drivers.

R&D TALENT POOL IN SINGAPORE

Since it started operation in mid-2007, the company's regional R&D hub has already outgrown two offices. It is now located at Fusionopolis, a newly launched 120,000 sqm science and technology test-bedding center in Singapore.

Management, Engineers and Researchers work to increase product reliability by improving on sub-system performance, evaluating new ways to maximize turbine performance efficiency, leveraging on cross-industries best practices, and by creating a vibrant environment for creativity and product innovation.

"What we have experience over the last few years that in order to make wind energy ever more cost effective we have to deal with some fundamental science in many areas such as new materials and sensor and actuator concepts, this is also a strength in Singapore," said Chatting.

The setup also works on technology research and development projects with regional and worldwide partners, universities and research institutions.

Matthew Low, Managing Director, who heads the R&D Hub attested. "By August '08, we have already established three local research collaboration agreements with Singapore varsities, namely NTU, NUS and A*Star. In addition, we have also established two regional Master collaboration agreements with Tsinghua University in Beijing, China, and the Collaborative Research Council in Advanced Composite based in Melbourne, Australia."

In the search of manpower resources to conduct research and development for the No.1 Wind Energy Company, Low has this to say, "Even though there is not much wind in Singapore, and therefore, there is no wind industry, does not mean we cannot find talents here. Since a Wind Turbine Generator is a multi-disciplined engineering machine, we need different caliber of talents from all fields of science and engineering, such as power electronics, electrical engineering, material science, structural mechanics, fluid dynamics, hydraulics, signal processing etc. to work together in a very efficient and reliable manner."

"So far, we are able to find such talents from a rich and broad engineering-based cluster in Singapore and the surrounding countries, such as semiconductor & electronics sector, industrial automation, aerospace and automotive industries," said Low.

Vestas Technology R&D Singapore will be over 100 R&D engineers in 2008, and Low is certain that the target of 150 engineers will be exceeded before end 2009, and even growing beyond 300 headcount is within expectation of the near future.

OPEN INNOVATION

Working with partners outside the company flies in the face of the conventional business innovation model where research is kept strictly in-house. Vestas promotes an "open innovation" approach that actively seeks out external partners with special expertise in a particular field.

"To reach our goals we need to reach out to the best talent that is available. Part of this is to work with the world's top universities and research institutions. Through this network, our engineers can get early and sometimes unique access to new materials, techniques and developments that would otherwise not be commercially available," explained Chatting.

"It also provides the opportunity for Vestas Engineers to develop technologies with world leading scientists and this can be a very exciting environment to be in."

Setting up operations in Singapore has also allowed Vestas easy access to a highly qualified and international workforce. Over the years, the island state has built up a robust ecosystem of enterprises of 115,000 local SMEs and 28,000 international companies. The country's open and welcoming environment attracts global talents that companies like Vestas needs.

There is no doubt that the wind power is hot. While it is not yet replacing the conventional fossil fuels in the immediate future, in today's carbon constrained economy, wind is emerging as a key player in shifting global energy supply for domestic and national power grids.

VESTAS Global University Programme

In our experience, the independent research being conducted at universities inspires and contributes significantly to the creation of innovative wind power solutions. We believe in the value of contributing to this knowledge development so we jointly can take on the challenge of setting the agenda for the next generation wind turbine solutions.

We want to attract and collaborate with the best wind power students and researchers at universities around the world. Thus, outstanding students can apply for scholarships to write their Master's thesis or PhD with Vestas, while well-established researchers can apply for sponsorship of a five-year position as a professor.

We invite you to send declarations of interest in the following technical research programmes:

- Aerodynamics
- Materials science
- Composites
- Advanced control systems
- Structural design & analysis
- Gear & drive train
- Power electronics
- Electromagnetic design
- Advanced loads modelling
- Wind power plant

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