

LOOKING 50 YEARS BACK, AND 100 YEARS INTO THE FUTURE

Singapore's short political history, and dramatic scientific progress

This year, as Singapore hosts various events to mark its Golden Jubilee – the 50th year since becoming an independent state – it has a lot more to celebrate than its rapid social and economic development. Science has also been booming.

OVER THE PAST 15 years, Singapore has been striving to remake itself as a centre of scientific and technological innovation. Massive investment has created formidable infrastructure, a powerful army of researchers who are actively engaging with the forefront of global science, and burgeoning technology-based industries.

This attempt to recast itself as a major scientific player, seemingly overnight, through large-scale investment has made some colleagues abroad envious of Singapore. Some are also skeptical: scientific development requires culture and history — can you really ‘buy’ science? No one now doubts that Singapore’s investment has attracted top global talent that is generating groundbreaking research. The jury is still out as to whether

it has created a self-sustaining scientific culture, but there is no question that many of the requisite pieces have fallen into place.

Singapore’s investment in science and technology has soared more than tenfold over the past 25 years. The S\$16.1 billion science and technology budget for 2011–2015 was 20% higher than that for the previous five-year period. Whereas other countries reduced budgets following the economic crisis, Singapore continued to invest.

That investment has created an embarrassment of riches in funding schemes, which attract scientists in Singapore and entice those overseas to take advantage.

Incentives at all levels

Fellowships offered by the Singapore National Research Foundation provide S\$3 million over five years for young overseas

researchers who are ready to engage in independent work in Singapore. The A*STAR Investigatorship similarly aims to cultivate young genetics and molecular biology researchers from Singapore or abroad by offering generous S\$6 million grants for six-year terms, in addition to salary. The Ministry of Education also provides funding ranging from S\$5 million to S\$25 million over five years for high-impact multidisciplinary research at domestic universities.

To ensure their own students get plenty of international exposure, Singapore pays the way for many of its best to travel abroad, mostly to top universities in Europe and the United States, for their undergraduate and graduate education. These A*STAR scholarships have already funded some 1,400

Singaporean students, and many have brought that experience back to broaden Singapore’s vision.

As in other countries, researchers in Singapore are increasingly being asked to think about relevant applications. The Competitive Research Programme funds multidisciplinary teams to conduct high-impact research relevant to Singapore, awarding 64 projects focused on fields that include environment and water, digital media, satellites and space research, and biomedicine. For more established researchers who are looking to explore the commercial potential of their discoveries, the Singapore National Research Foundation offers S\$250,000 renewable Proof-of-Concept Grants.

The Campus for Research Excellence and Technological Enterprise programme injects an international twist by supporting collaborations with overseas universities that encourage entrepreneurship and technology transfer in areas of universal practical importance: human systems, energy systems, environmental systems and urban systems. Ongoing projects include the Singapore–MIT Alliance for Research and Technology — the first Massachusetts Institute of Technology research centre outside of Cambridge — and the Singapore–ETH Centre Future Cities Laboratory with the Swiss Federal Institute of Technology.



SINGAPORE TOURISM BOARD

Going to market

Those looking for help in taking their ideas to the market can also turn to SPRING Singapore, which funds businesses just getting off the ground. The major universities also have funding and grant programmes to encourage entrepreneurship. For example, NTUitive, an innovation and enterprise company of Nanyang Technological University (NTU), manages the University's intellectual property, is a start-up incubator and helps commercialize research.

A*STAR is particularly intent on building ties with industry. It pulled in S\$551 million in investment from industry for 2,247 projects in FY2014. It also now has 40 joint laboratories with both large and small industries, ranging from Rolls-Royce to L'Oreal, though mostly concentrated in the areas of electronics and telecommunications. The universities are also attracting powerful industrial partners. Keppel Corporation recently established a S\$75 million laboratory at the National University of Singapore (NUS) to research oil and gas exploration in deep sea and arctic regions. And this year, a further S\$1.3 million was poured into BMW Group-NTU Joint Future Mobility Research Lab for electromobility research, in addition to initial joint lab funding of S\$5.5 million.

Government investment has created state-of-the-art facilities. This October, the second phase of Fusionopolis opened its doors, offering new wet and dry laboratories as well as vibration-sensitive test-bedding facilities. This will pull together some of Singapore's most internationally prominent institutes: the Institute of Microelectronics, the Institute of Materials Research and Engineering, the Data Storage Institute and the Singapore Institute of Manufacturing Technology. Meanwhile, Biopolis, launched just over a decade ago, continues to grow, having just completed the fifth phase of its futuristic construction. Researchers there have contributed to various critical medical advances, such as the FluSurver influenza surveillance network and a vaccine for H1N1 bird flu.

Regional matters

Many scientists are encouraged to work on matters of regional importance. NUS's Biomedical Sciences Cluster, for example, focuses on Asian diseases. The university also takes advantage of its location with the St. John's Island Marine Station, a platform for marine biodiversity research.

Water remains an issue of critical importance for Singapore. NUS's Neal Chung continues to pioneer various membrane and filtration technologies that can root out viruses from the water supply as well as charged ions and toxic metals such as arsenic from industrial waste. NTU's Singapore Centre for Environmental Life Sciences Engineering has been given S\$120 million to push the

forefront of microbial biofilms to enable sustainable use of water, including a S\$6.5 million biofilm imaging facility to observe bacterial interaction. And the Nanyang Environment and Water Research Institute finds ever more effective ways to treat wastewater.

Singapore's wider concern for the environment is manifested in a variety of initiatives. NUS's sustainability cluster introduces 'smart sound materials', 'smart cool materials' and 'smart carbon materials' (to aid carbon sequestration and pollutant removal) that target solutions for highly urban Asian environments. Through its EcoCampus initiative, NTU aims to be one of the world's greenest campuses by reducing energy usage, water consumption and waste intensity by 35% from 2011 levels before 2020. The Energy Research Institute @ NTU studies renewable energy and is one of the pillars of the university's research efforts; its investigations include fuel cells, wind and tidal turbines, and photovoltaics. To get around problems of integrating new energy technologies into the existing grid — one of the key problems facing renewable energy development — NTU and government agencies poured S\$8 million into a hybrid microgrid testbed, called the Renewable Energy Integration Demonstrator Singapore.

Basic research also thrives. This year, NTU opened a S\$9 million phenome centre to study how environmental factors and diseases impact human health. The Earth Observatory of Singapore, which has received over S\$150 million in government

grants, is a regional hub for research in earthquakes, tsunamis, volcanoes and climate change.

Many basic discoveries quickly lead to applications. Researchers from A*STAR's Institute of Molecular and Cell Biology recently reported the elephant shark genome. The project led them to a family of genes that help explain why elephant sharks, like other cartilaginous fish, do not replace cartilage with bone and also opened paths to understand the molecular pathways involved in osteoporosis and other bone-related diseases. Researchers at the A*STAR Institute of Bioengineering and Nanotechnology have developed a hydrogel that effectively controls the release of drugs in the body. For hepatitis C patients dependent on uncomfortable shots of pegylated interferon, this could reduce the number of shots from one per week to one every two months. At the more recondite end, scientists at NUS' Centre for Quantum Technologies are at the forefront of efforts to understand how a phenomenon called quantum entanglement can be used in cryptography. And NUS mathematicians are studying the algebraic topology of braids, which has potential applications in air traffic control and robotic motion.

For a small island state, the breadth of research is startling. Despite being a country with a short history, Singapore is likely to succeed in its leapfrogging ambition in science, just as it did in manufacturing and economic growth, if the rapid pace of scientific development to date is anything to go by.



SINGAPORE TOURISM BOARD



THE NATIONAL UNIVERSITY OF SINGAPORE (NUS)

A leading research-intensive university, centred in Asia

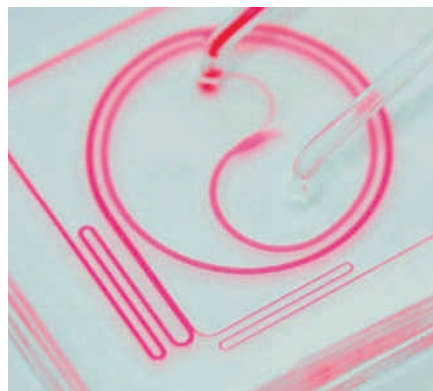
The National University of Singapore (NUS) traces its origins to a modest medical college founded in 1905 with just 23 students. Today, NUS is the largest and most comprehensive university in the island nation, with 38,000 students and about 5,700 faculty and research staff from more than 100 countries.

NUS hosts three of Singapore's national Research Centres of Excellence (RCEs), which specialize in quantum technologies, cancer and mechanobiology. It is also a partner in a fourth RCE, which builds on the university's strengths in environmental life sciences and engineering.

Within NUS, 16 schools and faculties, as well as 26 university-level research institutes and centres, focus on solving the critical issues that confront our world. In 2014 alone, NUS researchers were collectively awarded more than S\$740 million (~US\$527 million) in external research grants.

Internationally recognized & industry ready
NUS has produced internationally recognized, high-impact, cutting-edge research, and is consistently ranked among the top universities both in Asia and around the world.

NUS researchers produced more than 8,200 internationally peer-reviewed journal articles in 2014 and filed 531 patent applications and 344 invention disclosures over the same period. As reported in June 2015



The Spiral Microfluidics chip is the basis for the ClearCell FX1 System for CTC (Circulating Tumor Cells) enrichment.

by the Nature Index, which tracks the institutional affiliations of high-quality scientific articles and is widely regarded as a global indicator of important research, NUS was ranked 42nd in the world for overall scientific research, 28th for chemistry research and 27th for physical sciences research. This is a remarkable achievement for a university from a relatively young and small country, like Singapore.

At NUS, researchers also develop practical applications that benefit society. A number of promising new technologies have been successfully commercialized by NUS start-ups, as well as multinational corporations.

Clearbridge Biomedics is an example of a successful NUS biotech spin-off, which has raised close to S\$20 million (~US\$14 million)

for their products, CTChip® and ClearCell® FX system, that were developed by the Department of Biomedical Engineering and are undergoing clinical validation in the US, Europe and Asia. Endofotonics, a medtech company also began as an NUS spin-off, and is commercializing the In-Vivo Molecular Diagnostic (IMDX) system that was jointly developed by the Department of Biomedical Engineering and the Yong Loo Lin School of Medicine.

tenCube, a mobile security company with its roots in NUS, developed WaveSense, software that can remotely lock and remove the memory of a phone, as well as back up and restore phone data. tenCube was acquired by the global security software company McAfee for reportedly more than S\$12 million (~US\$9 million) in 2010. Another success story from the infocomms field is KAI Square. KAI Square was founded by two students from NUS' School of Computing and has transformed the way companies handle large amounts of video data by providing them with an efficient means of analysis.

NUS faculty provide consultancies to and hold advisory positions in over 2,000 numerous private companies and over 150 public sector agencies. Several leading companies have established research labs at and partnerships with NUS, including Agilent Technologies, GE Water, Carl Zeiss and, most recently, the Singapore-grown multinational company, Keppel Corporation.



The Keppel-NUS Corporate Laboratory draws on NUS' expertise within the Faculty of Engineering and the Tropical Marine Science Institute to develop new capabilities and innovative technology solutions to maintain Singapore's position as a global leader in the offshore and marine industry. The research thrusts of this Corporate Laboratory include enhancing productivity and safety in shipyards through automation; technologies for oil and gas exploration in ultra-deep and Arctic environments; as well as the environmentally safe and responsible pursuit of mineral resources from ocean beds. The total investment in the Keppel-NUS Corporate Lab is S\$75 million (~US\$53 million), jointly contributed by Keppel, NUS and the National Research Foundation of Singapore.

Interdisciplinary research with an Asian perspective

NUS actively encourages and supports multidisciplinary research in the belief that

such approaches provide the best hope for making significant breakthroughs in complex global challenges.

To facilitate these interdisciplinary collaborations, NUS has established Integrative Research Clusters in eight key areas: integrated sustainability solutions for energy, water and the environment; active ageing; biomedical sciences and translational medicine; global Asian studies; finance and risk management; materials science; maritime and offshore; and security.

The clusters maintain a strong Asian perspective in developing research strategies and innovative solutions. For example, the biomedical sciences and translational medicine cluster aims to be the go-to site in Asia for the development and validation of new diagnostics/drugs/devices for so-called Asian diseases. These refer to diseases that are either more common in Asian countries/ethnic groups, such as gastric and liver cancer; or in which the symptoms, disease process and outcomes are

markedly different in Asian patients compared to the rest of the world, such as breast cancer, lung cancer, and diabetes.

Partnering with the best of East and West

NUS advances its research through strategic alliances with leading institutions from all around the world. The Duke-NUS Graduate Medical School Singapore partnership, now in its second decade, has produced cutting-edge clinically-oriented biomedical research.

CNRS (Centre National de la Recherche Scientifique), the largest public research organization in France and the largest basic science agency in Europe, has set up three joint laboratories with NUS in the areas of quantum technologies, biomechanics, and infocommunication technology. NUS has established a major research partnership with Cambridge University and Nanyang Technological University that aims to reduce the carbon emission footprint of the petrochemical plants and electrical networks on Singapore's Jurong Island.

NUS' Interactive & Digital Media Institute has set up a number of joint research centres with leading Asian universities, including Japan's Keio University; Zhejiang University, China; the Indian Institute of Technology Bombay, India; and Tsinghua University, China.

Through transformative education and innovative research, NUS brings to bear a distinctively Asian leadership perspective on global challenges, providing real-world solutions to emerging problems and catalysing change for the better.



The In-Vivo Molecular Diagnostic system is currently the only system able to diagnose pre-cancerous tissue in real-time during gastrointestinal tract endoscopy.

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NANYANG TECHNOLOGICAL UNIVERSITY, SINGAPORE

The young research powerhouse

Nanyang Technological University (NTU Singapore), a key pillar of Singapore's research and development activities, stands among established heavyweights in world university rankings. With its strategic global partnerships and top talent recruitment programmes, NTU has made impressive progress as a young, research-intensive university.

Achieving unprecedented success within a short time, NTU has quickly earned a global reputation for academic and research excellence. Home to top talents and innovative ideas, NTU is courted by leading universities and big industry players for partnerships, and has produced research breakthroughs that have had global impact.

Overall, NTU has risen to be ranked 13th in the world this year, continuing its meteoric rise up global university league tables. In the Nature Index 2015 Global, it is placed 40th globally and 8th in Asia, with its young chemistry department outperforming some of the stalwarts of science and attaining a ranking of 9th in the world. NTU leads the top Asian universities in normalized citations, according to the international databases Web of Science (Thomson Reuters) and Scopus (Elsevier). This is all the more remarkable considering NTU only began ramping up its research activities a decade ago.

Bertil Andersson, chairman of the Nobel Committee for Chemistry in 1997 and a renowned biochemist, has been the president of NTU since 2011. "We focus on fundamentals to create a world-class environment

for learning, teaching and research. And the major reason for our rapid growth is that we have been very successful in attracting the best talents — world-renowned scientists, promising young researchers and the brightest students," he says.

With strengths in engineering, science, business, education, humanities, arts and social sciences, NTU delivers a holistic education to a cosmopolitan mix of undergraduate and postgraduate students from about 100 nationalities. It also has a joint medical school with Imperial College London, which has a research strategy that draws on the strengths of its parent universities.

Interdisciplinary in focus, NTU's high-impact research includes areas of global concern, such as sustainability, healthcare, new media and future learning. It is home to two national research centres of excellence, the Singapore Centre for Environmental Life Sciences Engineering (SCELSE) and Earth Observatory of Singapore (EOS), tackling important questions in environment and medicine.

NTU is also home to world-class institutes. The National Institute of Education is the training centre for all teachers in Singapore, which has one of the most successful education systems in the world. The S Rajaratnam School of International Studies was ranked among the world's top 30 university-affiliated think tanks in 2013. Other key institutes are



**NTU President
Bertil Andersson.**

the Nanyang Environment & Water Research Institute, Energy Research Institute @ NTU, and Institute on Asian Consumer Insight, all with a focus on applied research.

Life sciences, healthcare and social sciences

NTU addresses healthcare issues through a collaborative effort to develop better medical treatments and diagnostics. The medical school is

joined in this interdisciplinary effort by NTU's School of Biological Sciences, SCELSE and the NTU Institute of Structural Biology, headed by top structural biologist Daniela Rhodes. Rhodes is distinguished for her research on the structure of chromosomes and has moved to NTU Singapore from the world-renowned MRC Laboratory of Molecular Biology in Cambridge, UK. She is currently uncovering the molecular basis of ageing and cancer through a US\$17 million competitive research grant from the Singapore government.

Among several leading researchers and clinicians at NTU's medical school is geneticist Philip Ingham, internationally recognized for elucidating the signalling pathways underlying human development and cancer. He drives the school's integrated research strategy, which covers infection and immunity, metabolic disorders, neuroscience and mental health, and dermatology and skin biology, which will translate into healthier and longer lives.



Providing a different dimension to health-care issues is SCELSE, which tackles environmental and public health concerns and is a global centre for genomics with world authorities in the fields. Its founding director, microbiologist Staffan Kjelleberg, who was instrumental in coming up with new ways to combat the virulence of bacterial biofilms, is leading the effort to study these complex communities of bacteria and other microorganisms found all around us.

Among other notable scientists at SCELSE is geneticist Stephan Schuster formerly of Penn State University, whose achievement in deciphering the genome of the woolly mammoth was recognized as one of the "Top 10 Scientific Discoveries" of 2008 by *TIME* magazine and earned him a spot in *TIME*'s list of the "100 Most Influential People" the following year. His more recent research leading to the discovery of an ancient human lineage could help us understand the evolution of the human genome to better treat certain genetic diseases and illnesses. From a sociological perspective, leading migration specialist Zhou Min is shedding new light on international migration and immigrant integration.

At the forefront of sustainability research

A world leader in sustainability research, including water and energy research, NTU has won significant research funding in this area and has attracted some of the world's most respected names in science to take on the challenge of creating a greener world.

"NTU has some of the brightest minds at the forefront of sustainability and through their efforts, the university is developing new interdisciplinary knowledge and solutions to some of the most critical issues facing the planet," says Freddy Boey, a serial inventor who has a sterling record of translating

his biomedical inventions into commercial applications globally.

Although safe from seismic activity, Singapore is in a region of seismic hotspots and is an ideal base from which to address the threat of natural hazards threatening Southeast Asia. "Nowhere between Taiwan and Australia is there such a well-funded Earth science department," says world-renowned geologist Kerry Sieh, who left his endowed chair position at the California Institute of Technology to head NTU's Earth Observatory of Singapore, which has conducted breakthrough studies on the interrelated challenges of climate, governance and natural hazards.

Continuing the global quest for sustainability is a powerful partnership between NTU and the Smithsonian Institution to understand tropical ecology. NTU is now the Asian scientific hub of the Smithsonian Institution's Forest Global Earth Observatories (ForestGEO) programme.

Paying heed to sustainability practices, NTU itself aims to become one of the world's most sustainable and energy-efficient campuses by 2020. Through its EcoCampus initiative, the university intends to cut its energy and waste consumption by more than one-third. This involves test-bedding and implementing the latest sustainable technologies across NTU.

Engineering and natural sciences

Contributing to NTU's sterling performance across a number of disciplines are some promising younger scientists in science and engineering. Among them is Zhang Hua who was named one of the world's top 17 most significant scientists in Thomson Reuters' *The World's Most Influential Scientific Minds 2014*. His work in two-dimensional materials is promising for biosensing, clean energy and water treatment.

His colleague, Zhang Baile, attracted global attention with his 'invisibility cloak' research. Delving into the area of optical cloaking and light manipulation techniques, he was named one of the top 35 young innovators in the world by *MIT Technology Review* in 2012.

Echoing a commonly held view on campus, Christos Panagopoulos, who won the European Young Investigator Award in 2006 and continued his research career at NTU, says: "I had a choice between top-10 schools in the UK, Europe and USA, but I realized the potential at NTU."

These young research stars were attracted by schemes like NTU's Nanyang Assistant Professorship scheme and the prestigious National Research Foundation Fellowship that offer research funding and access to the best facilities at NTU.

In good company

You can judge a university's quality by the company it keeps, and NTU has been working closely with the biggest industry players in making its research relevant to society. On the campus are more than 20 laboratories and centres that have been jointly set up with large multinational corporations, a number who have made their maiden foray into an Asian campus.

In the last eight years, NTU has struck a record number of tie-ups with big players such as Rolls-Royce, BMW Group, Lockheed Martin, Johnson Matthey, Siemens, THALES, ST Engineering and Bosch.



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AGENCY FOR SCIENCE, TECHNOLOGY AND RESEARCH (A*STAR)

Asia's global hub for innovation

Singapore's Agency for Science, Technology and Research (A*STAR) has led the country's reinvention as an innovation powerhouse by bridging the gap between academia and industry and driving mission-oriented research and development that advances scientific discovery and technological innovation. The agency's latest five-year plan aims to strengthen Singapore's position as Asia's innovation capital.

"Singapore's economy has evolved considerably over the past few decades — moving from an industrial focus to being increasingly driven by knowledge and innovation," notes A*STAR Chairman Lim Chuan Poh. "This strategic shift will enable us to overcome our limitations and resource constraints."

Singapore has now established a vibrant research and development (R&D) ecosystem involving the public and private sectors, with A*STAR playing a pivotal role in both conducting R&D and maintaining a long-term strategic view.

"We work closely with industry to meet their needs and challenges over the near to medium term," says Lim. "But at the same time, we look ahead to invest in research that will position Singapore well for future growth sectors."

Over the past five years, A*STAR has undertaken more than 7,500 industry projects, which have generated over S\$1.1 billion in investments. This success capitalizes on a global shift in R&D towards Asia, and an increasing appreciation of the inherent value

of opening up previously secretive in-house innovation to a mix of academic, clinical and public agency partners.

"This type of open innovation thrives in an environment in which partnerships and collaborations are not only facilitated, but are also designed into the physical environment to encourage 'collisions' between scientists and innovators from different organizations," says Lim. "This is what A*STAR has created with the Biopolis and Fusionopolis campuses in Singapore's one-north innovation precinct."

Fusionopolis is Singapore's hub for interactive media, physical sciences, engineering and technology, while Biopolis houses capabilities in biomedical sciences from both corporate R&D labs and A*STAR institutes. In 2015, the second stage of the Fusionopolis campus, called Fusionopolis Two, brings some of A*STAR's key science and engineering research institutes into this innovation nexus. Now, all of A*STAR's science, engineering and biomedical sciences resources and personnel are located in a one-mile radius, concentrating top R&D talent from the public and private sectors and state-of-the-art facilities.

A*STAR has strategically developed a broad spectrum of capabilities that encompasses 18 research institutes and centres with comprehensive coverage across the biomedical sciences, physical sciences and engineering. This multidisciplinary strength not only creates a multitude of opportunities for interdisciplinary collaboration and innovation, but also catalyses the formation

of new proficiencies in growth areas such as advanced manufacturing and engineering, urban systems and smart cities.

"A*STAR has generally had a steady build up to reach its current capabilities, but there have been some breakthrough moments as well," says A*STAR Chief Scientist Sir David Lane. "For example, the original plan for Biopolis was that it would become a major attraction for private industry as well as public investment. This was helped significantly by A*STAR forging a major partnership with Procter and Gamble with a large presence in Biopolis, and by Chugai Pharmaceutical establishing a major antibody engineering subsidiary at the same site."

Innovating new frontiers in biomedicine

"A*STAR has a mission to make a difference," says Jackie Ying, executive director of the A*STAR Institute of Bioengineering and Nanotechnology (IBN). "In the biomedical field, we focus on solving clinically important problems in a way that facilitates translation and commercialization, and we collaborate internally and externally to access a full suite of capabilities and expertise. Biomedical technologies often take many years to develop — to achieve that research breakthrough. One of the things that A*STAR does particularly well is foster perseverance and commit to long development pathways."

This approach to targeted and clinically translatable research has attracted the interest of many global industry partners. The IBN's *in vitro* toxicology platform is a prominent example. "We have developed a



unique technology that uses microfluidics and microcell culturing to efficiently test for drug toxicity using human primary cells,” says Ying. “This technology is very effective and versatile. It is also cheaper and more representative of human cell response than animal studies.

In addition, the IBN is developing new devices for rapid, low-cost detection of problematic diseases, including influenza and dengue. “We are developing a technology that allows us to detect dengue from saliva samples with high sensitivity,” says Ying. “Dengue is a major problem for Singapore and Asia, and so this type of innovation has the potential to make a major impact on healthcare outcomes.”

The maturation of Singapore’s integrated R&D ecosystem and open innovation environment makes Singapore, and A*STAR as its flagship research organization, a particularly attractive proposition for many of these companies. More than 30 of the world’s leading biomedical sciences companies, including GlaxoSmithKline, Novartis and Takeda, are already leveraging the unique capabilities Singapore offers as a base for innovation.

“Singapore also offers a unique competitive advantage in its biomedical regulatory environment,” says Tadataka Yamada, Venture partner at Frazier Healthcare and a long-serving member of the A*STAR Board of Directors. “This country is very much at the forefront of regulatory science globally, particularly for drug discovery and development. It’s part of the extraordinary research and development ecosystem that has been established here in Singapore.”

Integration: the future of microelectronics

As the physical size limit for transistors is fast approaching, the semiconductor industry is

set for a change in focus. “We see Moore’s Law for semiconductors coming to an end,” says Dim-Lee Kwong, executive director of the A*STAR Institute of Microelectronics (IME). “The industry has realized that it no longer makes economic sense to push transistor scaling. The next frontier will be system scaling, integrating many different technologies using advanced packaging schemes. There will be many, many innovations in this area of heterogeneous integration.”

Although the possibilities around heterogeneous system integration are far broader than computing alone, the complexity and cost of R&D in a field that crosses so many disciplines makes it very hard for all but the top global players to invest in development, making it a perfect candidate for open innovation. “That’s where A*STAR comes in,” continues Kwong. “We establish integrative partnerships where we work together with a private company to develop a roadmap for R&D. The industry is used to relying on these roadmaps for semiconductor development, but no roadmaps exist for system scaling. This necessitates a lot of ‘pathfinding’, which is very costly and difficult without the right partnership.”

Five years ago, the IME latched onto this looming paradigm shift in the semiconductor industry and strategically positioned itself with focused funding to be ready when industry came knocking. This year, the IME moves to Fusionopolis Two, along with more than ten joint labs with industry partners in advanced packaging, including one of the giants in the field, Applied Materials. “We have been working very hard over the past decade to build strong partnerships with industry leaders,” says Kwong. “We want to be known as a partner who can deliver R&D faster, earlier and more cost effectively.

Industry is waiting for these innovations, and A*STAR is leading the world in many critical areas.”

Feeding the innovation engine

Cultivating the research and engineering talent needed to drive innovation is vital, and it is an area where A*STAR has made major investments over the past decade. To date, about 1,400 scholarships and fellowships have been awarded by A*STAR, and close to 500 scholarship recipients have now completed their degrees and are actively contributing to A*STAR and various sectors of the R&D ecosystem.

A*STAR’s long-term focus on developing a robust and comprehensive R&D platform has not only provided the backbone for Singapore’s innovation revolution, it has also given companies access to a world-leading R&D ecosystem to help drive their own prosperity. “Companies choose to locate their R&D activities where they can find the most compelling value propositions,” says Lim. “Singapore’s unique location provides access to multi-ethnic populations and cohorts that are representative of Asia. This, together with a strong intellectual property protection regime, excellent business and research infrastructure, sustained government commitment to research and innovation, and an open talent strategy, make A*STAR and Singapore a very attractive hub for hosting R&D activities.”



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NATIONAL NEUROSCIENCE INSTITUTE (NNI)

Enhancing neuroscience care

The National Neuroscience Institute is Singapore's national and regional specialist centre for the management and treatment of neurological disorders, as well as for education and research in the field.

The National Neuroscience Institute (NNI), Singapore, is a key academic medical centre that pursues research innovations to transform patient care and a member of the Singapore Health Services (SingHealth) Group, the country's largest integrated healthcare delivery network. A centre of excellence, NNI comprises specialist doctors, nurses and supporting health professionals. Established over two campuses, Tan Tock Seng Hospital and Singapore General Hospital, NNI also provides speciality services to other hospitals and treats more neurology patients than any other centre in Singapore.

A leader in neuroscience research

A regional neuroscience research leader, NNI has strong multidisciplinary research programmes in stroke, Parkinson's disease and movement disorders, Alzheimer's disease and dementia, and neuro-oncology. Since opening in 1999, the institute has been proactive in clinical and basic science research. Its dedicated Clinical Trials Research Unit is highly experienced in conducting industry-supported clinical trials and its research structure combines clinical and basic researchers in major diseases. "This strategy allows a common vocabulary to be established, which facilitates cross-fertilization of ideas between

clinicians and basic scientists, who tend to speak different languages," says Tan Eng King, the institute's director of research.

A significant milestone is the accreditation of the institute's Parkinson Disease and Movement Disorders Centre by the National Parkinson Foundation (USA) as a leading Centre of Excellence for Parkinson's disease in Asia, an accolade it has retained since 2006. Tan, who is also the centre's co-director, leads many of the national efforts in integrating clinical and research programmes and fostering closer collaborative ties regionally and with the USA and Europe. Another important milestone is the development by the dementia team of the Visual Cognitive Assessment Tool, which will allow the early detection of cognitive impairments. It is designed for multilingual populations, since it does not require translation or adaptation.

National Neuroscience Research Institute Singapore

In March 2014, NNI, in partnership with Duke-NUS Graduate Medical School, established the National Neuroscience Research Institute Singapore (NNRIS), which is the largest neuroscience body in Singapore incorporating more than 200 neurologists, neuroscientists and researchers from both institutions. NNRIS represents "Singapore's first concerted step to tackle neurological problems and to look for practical solutions for our patients in the face of our ageing population and the rising incidence of neurological diseases," says Lee Wei Ling, senior advisor and former director of NNI.

More recently, NNI signed a Memorandum of Understanding with the National University of Singapore to establish a working relationship for joint research programmes and cross-institutional collaborations in neurobiology and ageing. The initiative will collaborate on research programmes to improve the diagnosis and prevention of age-related neurological diseases using cutting-edge neurotechnology. "A virtual reality surgery platform will be developed to enhance surgical precision and visualization for neurosurgeons in the operating theatre. This will help improve patient safety and care outcomes," says neurosurgeon Ng Wai Hoe, the current medical director of NNI.

NNI works very closely with other neuroscience bodies in Singapore. "These partnerships are important for establishing a national resource for neuroscience that will help maximize research productivity and minimize duplication of efforts in a small country, which does not have the benefit of a huge neuroscience base," remarks Lim Kah Leong, assistant director of NNI Research. "It also represents a concerted effort by the neuroscience community here to provide a common platform for talent recruitment," he adds.



**National
Neuroscience Institute**
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SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN (SUTD)

A better world by design

Established in collaboration with the Massachusetts Institute of Technology, the Singapore University of Technology and Design nurtures technically grounded leaders and innovators who can serve the architectural, information systems, design and engineering needs of society. As a research-intensive university, it brings together the best minds to solve tomorrow's problems.

The Singapore University of Technology and Design (SUTD) is Singapore's fourth public university and among the first universities in the world to incorporate the art and science of design and technology into a multidisciplinary curriculum. Established in collaboration with the Massachusetts Institute of Technology (MIT) in the United States, Zhejiang University in China and Singapore Management University, SUTD is distinguished by its unique East and West academic programmes that incorporate elements of technology, entrepreneurship, management and design thinking.

To provide students with a strong technical grounding, the university offers a common curriculum for the first three terms of undergraduate study, called Freshmore. Students then select one of four majors, called Pillars, which correspond to a degree: Architecture and Sustainable Design, Engineering Product Development, Engineering Systems and Design, and Information Systems Technology and Design.

Every subject at SUTD incorporates an element of design within a curriculum that encompasses all forms of technology design

imaginable, including process design, architectural design, product design, software design and systems design. Students learn to define problems holistically and to develop creative solutions from a total design perspective. They experience the full value chain, from conception of a product or service through to development, prototyping, manufacturing, operation and maintenance.

SUTD also offers graduate and doctorate programmes. Students enrolled in the two-year, full-time MIT-SUTD Dual Masters' Programme spend their first year completing coursework at MIT and their second year conducting research at SUTD. They receive two master's degrees — one from MIT and another from SUTD. The SUTD PhD Programme offers a three- to five-year residency period, comprising research, coursework, potential industry internships and overseas research exchanges.

Industrious graduates

In August 2015, SUTD marked a significant milestone with the graduation of its first



SUTD's campus is designed and purpose built to support multidisciplinary learning and to encourage interaction.

batch of undergraduate students. More than two-thirds of its undergraduates had either secured jobs prior to graduation or were pursuing graduate studies. The majority of them found employment in Singapore's key industries and emerging business sectors, with the three most popular areas being engineering, banking and finance, and defence.

Among these students, one in four received return offers from the host company where they completed a mandatory 16-week internship. More than 400 organizations have committed to hosting SUTD students through the internship programme, offering them hands-on exposure to a real working environment.

Another group from the first batch of graduates has chosen the unconventional path of entrepreneurship, opting to spin off companies from their final-year capstone projects. Almost 90 per cent of the students who majored in Architecture and Sustainable Design decided to pursue a Master of Architecture at SUTD.

Given the global demand for innovative and sustainable products, systems and services, the technical grounding and design thinking that SUTD students receive will prepare them to contribute to areas critical to the world's social and economic development.



SINGAPORE UNIVERSITY OF
TECHNOLOGY AND DESIGN

Established in collaboration with MIT

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