NUS RESEARCH in brief

DECEMBER 2019 | Issue 2

NUS National University of Singapore

WORLD-LEADING MATERIALS RESEARCH

THE SCIENCE OF EDUCATION

BOOSTING AI RESEARCH

FROM THE DEPUTY PRESIDENT

I would like to take this opportunity to thank the NUS Research community for their continued effort in contributing essential knowledge across a wide range of fields. Many of these ideas and innovations promise to transform society for the better.

In 2019, we welcomed a number of distinguished faculty to NUS. Most notably, Prof Sir Konstantin Novoselov, 2010 Nobel Laureate and co-discoverer of graphene, who joined the Centre for Advanced 2D Materials. We also welcomed Prof Li Rong from the Johns Hopkins School of Medicine, where she was Bloomberg Distinguished Professor of Cell Biology. Prof Li has joined as Director of the Mechanobiology Institute.

To all of our researchers who were recognised in 2019 for their commitment and contributions – congratulations! I would particularly like to recognise Prof Markus Wenk from Yong Loo Lin School of Medicine, who received the 2019 University Recognition Award for his work in the field of lipidomics. I would also like to congratulate Asst Prof Loh Huanqian from the Centre for Quantum Technologies and the Faculty of Science, and Asst Prof Benjamin Tee from the Institute for Health Innovation and Technology (iHealthtech) and the Faculty of Engineering, for their selection by the World Economic Forum into the Class of 2019 Young Scientists, which is a community established to integrate scientific knowledge into society for the public good.

Universities have a responsibility to address global concerns, and create solutions that mitigate these issues for future generations. The impact of climate change, green energy, food security, and water conservation, are such areas where NUS will continue working to catalyse change and create solutions. These efforts will be augmented by our ongoing work to create innovative technologies for health and wellbeing, understand the dynamics of rapidly changing societies, and deploy innovative artificial intelligence systems that enhance how we live and work.

In shaping the future of NUS Research, I welcome Professor Liu Bin to the position of Vice President for Research and Technology. Prof Liu is a leader in the field of functional materials with applications in energy, environmental and biomedical research. I would also like to recognise the contributions her predecessor, Prof Philip Liu, made to the fields of oceanography and sustainable costal engineering, and wish him all the best as he returns to academic pursuits in the Faculty of Engineering.

Prof Chen Tsuhan
Deputy President for Research and Technology and Distinguished Professor

NUS RESEARCH IN NUMBERS

10300
Research publications

Our researchers collaborated with

2858
institutes and universities from

146
countries

4
Research Centres of Excellence

5
Corporate Laboratories

17
Schools and Faculties

28
Research Institutes and Centres

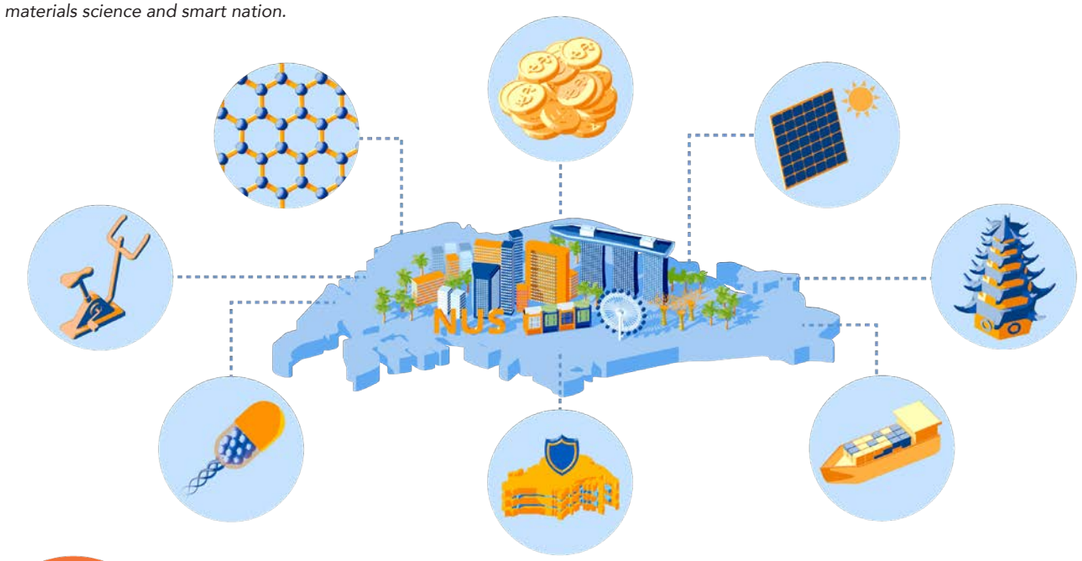
$781.6m*
Total research funds awarded by external sources

NUS Research is centred on eight integrative research clusters. These are ageing, Asian studies, biomedical science and translational medicine, finance and risk management, integrative sustainability solutions, maritime, materials science and smart nation.

$336.0m* From industry and other government sources (local and overseas)

$223.2m* Total awarded by the Ministry of Education

$222.4m* Awarded by the National Research Foundation



465
Patents filed

92
Patents issued

356
Invention disclosures

106
Technology licenses executed

Our researchers work to innovate and develop solutions that meet the present and emerging needs of Singapore, Asia, and the world.

*Based on FY 2018. All other data based on Calendar Year 2018

WORLD-LEADING MATERIALS RESEARCH AT NUS

NUS has aggregated some of the world's top materials researchers to pioneer innovative solutions to pressing global problems

About the cover:

Materials Research focuses on the discovery and creation of new materials (blue) for innovative technologies that will revolutionise the fields of healthcare (yellow), sustainability and green energy, (green) and Smart Nation (pink).

Materials research is poised to play a pivotal role in tackling some of the most pressing global challenges, from the emerging climate crisis to quantum computing.

To accelerate progress in materials research, NUS designated it a key area of focus. In turn, NUS has amassed some of the world's most prolific and prominent researchers in the field, and over the past decade, has reached the top-tier level in materials research, globally.

One of the most important advances of the 21st century in the field of materials research was the isolation of graphene — the world's first two-dimensional (2D) material. Since this breakthrough, research into 2D materials has flourished, and ground-breaking applications have emerged in areas such as photovoltaics, semiconductors, electrodes and water purification.

PROFESSOR SIR KONSTANTIN NOVOSELOV

The discovery of 2D materials is co-credited to Professor Sir Konstantin Novoselov jointly with Professor Sir Andre Geim and the pair were awarded the 2010 Nobel Prize in Physics for their achievement. Prof Novoselov is now the Tan Chin Tuan Centennial Professor at NUS Materials Science and Engineering and continues to investigate this rich research area.

At just one atom thick, 2D materials are as thin as materials can possibly be, and today, approximately 700 stable 2D materials have been predicted, with many remaining to be synthesised.

"Different 2D materials hold different properties. They can be metals, semiconductors, superconductors, ferromagnets, and more," Prof Novoselov explained.

Prof Novoselov's latest research combines 2D materials and the principles which govern living matter, to develop new functional intelligent materials with bespoke properties. These bio-inspired materials could have applications in everything from artificial neural networks to smart membranes.

PROFESSOR LIU BIN

NUS Vice President (Research and Technology), and the Head of NUS Chemical and Biomolecular Engineering, Professor Liu Bin actively pursues green energy solutions, by aiming to convert solar energy into clean and accessible energy fuels. She is seeking value-added products by developing highly efficient organic semiconductor catalysts.

Her work is instrumental in establishing innovative bio-imaging methods for biomedical applications.

"We endeavour to realise the visualisation of crucial biological processes and non-invasive treatment for some diseases using biocompatible organic materials, especially those with aggregation-induced emission (AIE) characteristics," she explained

Prof Liu has invented imaging tools which are highly sensitive, specific, photostable and biocompatible. Her inventions have been commercialised through the NUS spin-off LuminiCell, which provides real-time cell tracking with 3 times longer duration and 10 times brightness as compared to existing tools. With LuminiCell, researchers can image cell behaviour to enable new diagnostic and therapeutic capabilities for cancer, infectious disease, vascular diseases and more.

PRESIDENT'S ASSISTANT PROFESSOR BENJAMIN TEE

President's Assistant Professor Benjamin Tee from NUS Materials Science and Engineering is currently researching state-of-the-art smart electronic skin materials that can sense the environment.

Being able to sense environmental changes in pressure, temperature and humidity is a natural ability all humans have, but it is much more difficult for machines to do that today. To overcome this limitation, Asst Prof Tee is exploring and developing new flexible, stretchable materials that provide more robust sensing capabilities. These flexible 'electronic skins' can also self-heal, just like real skin. This autonomous self-repair capability provides a new way for electronic devices to withstand damage.

His research in electronic skins will also enable better prosthetic devices that are sensitive to the environment. This could reduce the phantom limb pain associated with limb loss, and the prosthetic devices would feel more natural and intelligent. "This can help patients regain normal lives and regain their mobility and confidence," Asst Prof Tee stated.

PROFESSOR
ANTONIO CASTRO NETO

A pioneer in the field of atomically thin materials is Distinguished Professor Antonio Castro Neto, Director of the NUS Centre for Advanced 2D Materials (CA2DM). CA2DM was established in 2010 for the conception, characterisation, theoretical modelling and development of transformative technologies based on 2D crystals, such as graphene.

Prof Castro Neto is an expert in all aspects of graphene and he further described the unique advantages that 2D materials offer, "They have physical and chemical properties that normal three-dimensional materials do not have – such as extreme quantum behaviour. Meaning the electrons in these materials behave like waves, not particles."

These extreme quantum behaviours could create the next generation of electronic components with revolutionary capabilities, and 2D materials like graphene are already being used in the development of quantum computers.

PROFESSOR
BARBAROS ÖZYILMAZ

Deputy Director of CA2DM and Head of NUS Materials Science and Engineering, Professor Barbaros Özyilmaz, is focussed on accelerating the widespread adoption of graphene and other 2D materials into industry.

Recently, Prof Özyilmaz discovered that 2D materials could be synthesised in such a way that they are amorphous films rather than crystals. Although crystalline 2D materials possess incredible electrical and mechanical properties, they are often costly and tricky to scale up for many industrial applications. In contrast, the amorphous 2D films discovered by Prof Özyilmaz retain some of the desirable properties of crystalline 2D materials, but are much more hardy, and cheaper to make. This breakthrough is a leap forward in making 2D materials generally viable for industrial applications.

PROFESSOR
SILVIJA GRADEČAK-GARAJ

Professor Silvija Gradečak-Garaj from NUS Materials Science and Engineering, is a pioneer in the field of green energy, and is now developing new materials for energy applications by understanding and controlling materials at the atomic scale.

Prof Gradečak-Garaj has recently developed flexible and semi-transparent solar cells that combine a range of nanoscale materials to improve the solar cell efficiency. These nanoscale materials include nanoparticles that absorb sunlight and produce electrons, nanowires that collect electrons efficiently, and graphene to conduct electricity. "These devices are flexible, so they can be used on large and curved surfaces, unlike conventional solar cells that are flat and rigid. Furthermore, as they are semi-transparent, they can be used even on windows," she said.

"Ultimately, the goal of our research is to design ways we can utilise energy more efficiently to preserve natural resources, address the challenges related to global warming, or heat island issues specific to urban environments like Singapore," she explained.

PROFESSOR
LIM CHWEE TECK

Professor Lim Chwee Teck, Director of the NUS Institute for Health Innovation & Technology (iHealthTech) and NUS Society Chair Professor at NUS Biomedical Engineering is using micro- and nanomechanical tools, to investigate why and how biomechanical changes occur in circulating cancer cells, so as to better understand their contributions towards metastasis – the main cause of death in cancer patients.

Based on his research findings, Prof Lim has developed a microfluidic cancer biochip which can detect and isolate circulating tumour cells from peripheral blood of patients (known as liquid biopsy). This technology has since been commercialised by Biolidics Limited, which obtained an FDA listing in USA and China, and is being used in over 90 locations around the world.

PROFESSOR
GUI BAZAN

Professor Gui Bazan, who will be taking up a position in NUS Chemistry and NUS Chemical and Biomolecular Engineering in January 2020, conducts innovative research in the area of living composite materials.

"Our group is pioneering living 'biocomposites' containing microorganisms and a polymeric hydrogel matrix with metallic properties," he said.

Prof Bazan's research coordinates principles from chemical synthesis, materials engineering, soft electronic matter and electromicrobiology. It lays the foundation for promoting and understanding electronic communication between synthetic elements and microbial communities. "Living microbial biocomposites provide us with a unique opportunity to harness the extraordinary diversity and adaptability of bacteria," he described.

His work may reveal how to use wastewater as a source of food for bacteria, allowing them to remove organic contaminants, while at the same time, producing electrical power for a green source of energy.

Materials research is not only one of the most rapidly evolving and fastest growing scientific disciplines, but also one which stands at the forefront of modern technology, spanning every facet of 21st century life. The team of first-rate researchers collected at NUS is revealing brand new research insights and spearheading novel applications in all aspects of this field. Ultimately, the cutting-edge materials research conducted at NUS will have far-reaching societal benefits in Singapore and globally.

PROF SIR KONSTANTIN NOVOSELOV:
PHYSICS & FINE ART

On 22 October 2004, Professor Sir Konstantin Novoselov along with other colleagues including his former PhD supervisor Professor Sir Andre Geim published one of the most revolutionary scientific papers of the 21st century.

In it, they described the isolation of the world's first two-dimensional (2D) material. This atomically thin sheet was graphene – the strongest, most stretchable, most conductive, material ever discovered – and the two colleagues later shared the 2010 Nobel Prize in Physics for their ground-breaking accomplishment.

Whilst the Nobel Prize is often seen as the crowning achievement of any scientist's career, Prof Novoselov remains grounded and modest about the award. "Of course winning a Nobel Prize is special in the career of any scientist, but honestly, I'm the same person as before," he said. "Being a prize-winner doesn't make you 100 times smarter, but people certainly listen to you for a change," he joked.

Professor Sir Konstantin Novoselov enjoys working creatively, both in material science and in abstract art forms (Photo: The University of Manchester)

This humble attitude also translates into how Prof Novoselov conducts his research and works with his students. "I tend to work in small teams," he said. "But of course, what is most important is the community. I find it much more stimulating if you collaborate. So, my task now is to create this sense of community in my lab at NUS," he noted.

Originally from Russia, but also a citizen of the United Kingdom, Prof Novoselov has a long collaborative history with the NUS Centre for Advanced 2D Materials. However, it was the new opportunities available which ultimately attracted him to make the move from Manchester University to NUS. "I wanted to take my research in a slightly new direction, and I needed a place that would offer me a good start. Singapore has an established and dynamic scientific community, with NUS offering strong collaboration opportunities from multidisciplinary backgrounds," he stated.

This new research direction will be looking deeper into cutting-edge advanced materials. "People know me as the graphene researcher, but I would like to expand further. What graphene and other 2D materials taught us is that you can create artificial materials which are designed atom by atom for specific purposes," he explained. By building from the atomic level up, these advanced materials could push the boundaries of what is possible, for example by being lighter, stronger, and more conductive than ever before.

Naturally, working with these atomically thin materials calls for a skilled and patient researcher. The intricate manipulations involved often require a steady hand – something which Prof Novoselov claims he did not always have. "I like to work with my hands, but 20 years ago as a PhD student, I saw that my professors were much more adept at handling materials than me," he said. "So, as a form of training, I bought a cutthroat razor to shave with. After much practice, my hands became steadier and I was able to perform the skillful actions required. I still shave with a cutthroat razor today," he declared.

Now, Prof Novoselov admits that he has fewer opportunities for hands-on research, as he encourages his team to perform many of the practical elements of lab work. So to continue working with his hands, and to keep his dexterity keen, he has taken to more artistic pursuits and regularly paints.

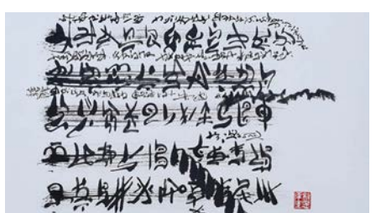
"I was lucky enough to be trained in traditional Chinese painting by a prominent Chinese artist," he said. After painting customary objects like bamboo, orchids, lotuses, and cherry blossoms, Prof Novoselov started to use the same techniques to paint other objects, and his teacher was encouraging. "He understood that it doesn't matter what you paint, it's how well you transfer the mood to the painting that's important," he explained.

Professor Sir Konstantin Novoselov often paints with a combination of graphene ink and Chinese ink to encode secret characters within his paintings. These can only be revealed with a spectrometer and such methods can be used to authenticate the work.

Now he uses Chinese brushes and techniques to paint anything that he likes – even using graphene ink in some paintings. "Graphene ink is not as black as Chinese ink; it has a silver sheen which I can use for the aesthetic quality," he added.

He continued, "But also, it's possible to paint with Chinese and graphene ink in combination so that the graphene ink cannot be seen with the naked eye. In fact, the only way to observe the brushstrokes would be with a spectrometer. In this way, I can encode secret characters and meanings in my paintings using graphene." However, unfortunately, Prof Novoselov is staying tight-lipped on where to look, and how to decipher these codes.

Since starting his positon at NUS just over a month ago, Prof Novoselov mentioned that he's already been hard at work. "This first month was very intense, with a lot of effort on settling in. However, I'm very happy that I managed to dedicate most of my time to science. I've continued some old projects, and also started some new ones too," he said. Whether scientific or artistic, Prof Novoselov's work is always interesting and innovative, and as such, his upcoming projects at NUS will certainly be ones to look out for in the future.



A combination of graphene ink and Chinese ink can encode secret characters within the paintings. These can only be revealed with a spectrometer and such methods can be used to authenticate the work (Photo: Konstantin Novoselov)

CONGRATULATIONS TO

PROFESSOR
MARKUS WENK
Yong Loo Lin School of Medicine

Professor Markus Wenk from the Yong Loo Lin School of Medicine received the University Research Recognition Award at the NUS University Awards 2019 for his ground-breaking research in the field of Lipidomics.

Lipids such as cholesterols, triglycerides, and other fats are essential dietary nutrients for humans and other animals, but they also have an involvement in many metabolic diseases like stroke, hypertension, and diabetes. As such, the field of lipidomics is the study of the networks and pathways of cellular lipids in biological systems, with the goal of completely understanding their roles. It involves the identification and quantification of thousands of cellular lipids and their interactions with other lipids, proteins, and other metabolites.

On his win, Prof Wenk stated, "Winning this award, I am extremely delighted and proud, but also grateful that I continue to have the support from NUS to conduct my research". To any young researchers who would like to be in his shoes one day, he said, "My advice would simply be: enjoy what you do, and do it well."

ASSISTANT PROFESSOR
BENJAMIN TEE
NUS iHealthtech and Faculty of Engineering

ASSISTANT PROFESSOR
LOH HUANQIAN
NUS Centre for Quantum Technologies and Faculty of Science

Assistant Professor Loh Huanqian from NUS Physics and the NUS Centre for Quantum Technologies, and Assistant Professor Benjamin Tee from NUS Materials Science and Engineering and NUS iHealthtech were among 21 young scientists from 10 countries selected by the World Economic Forum (WEF) to be in the Class of 2019 Young Scientists.

The Young Scientists community was created in 2009 to convene rising-star scientists and engage them in the work of the WEF to integrate scientific knowledge into society for the public good. The community consists of extraordinary scientists from across academic disciplines and geographies, under the age of 40.

Asst Prof Loh and Asst Prof Tee were invited to the recent WEF's Annual Meeting of the New Champions, held in Dalian, China, where they participated in discussions alongside business, political, media, academic and civil society leaders.

ASSOCIATE PROFESSOR
VINCENT TAN
Faculty of Engineering and Faculty of Science

ASSOCIATE PROFESSOR
ANDREW HUI
Yale-NUS College

ASSOCIATE PROFESSOR
YAN NING
Faculty of Engineering

The NUS Young Researcher Award 2019 was awarded to Associate Professor Andrew Hui from Yale-NUS College, Associate Professor Vincent Tan from Faculty of Engineering and Faculty of Science, and Associate Professor Yan Ning from Faculty of Engineering.

With such a range of academic backgrounds, the research interests of the award-winners vary dramatically. Assoc Prof Yan explores biomass conversion and green chemistry, Assoc Prof Hui studies early modern Europe and the Global Renaissance, and Assoc Prof Tan investigates information theory and machine learning.

NEW RESEARCH INITIATIVES

CORPORATE LABORATORIES AND INDUSTRY PARTNERS

LATEST TECHNOLOGIES TO TRANSFORM HEALTHCARE

A new consortium led by the Institute for Health Innovation and Technology (iHealthtech) at NUS was launched on 1 July 2019 to tap on the latest science and technologies originating from Singapore's research laboratories and create novel and personalised healthcare solutions. The Health Technologies Consortium (HealthTEC), was established with funding of $1.5 million over three years from the National Research Foundation (NRF).

The consortium will bring together researchers and companies in order to leverage on deep tech in areas such as bioelectronics, biomimetic materials, robotics and smart sensors, as well as big data to develop and provide health and wellness solutions. Researchers will have the opportunity to learn the pain points of product development and collaborate with companies to solve them. With access to research and technologies from Singapore's research institutions, companies could gain a competitive edge by applying the latest innovations and technologies to improve existing products and services as well as develop new products and services.

"Our ultimate aim is to capture value through faster translation of research output into benefits to patients, to society as well as the economy. So far we have excellent industrial participation, not only from multinational corporations but also local enterprises, SMEs as well as start-ups," said Professor Lim Chwee Teck, Director of iHealthtech and HealthTEC.

From left: Prof Lim Chwee Teck, Director of iHealthtech and HealthTEC; Prof Chen Tsuhan, Deputy President for Research and Technology; Prof Tan Chorh Chuan, Executive Director, Ministry of Health Office for Healthcare Transformation and Chief Health Scientist at the Ministry of Health; Mr Lim Tuang Liang, Executive Director of the Research, Innovation and Enterprise Coordination Office at NRF; and Mr George Loh, Director of Services and Digital Economy at the National Research Foundation, officially launching the consortium

NEW R&D HUB TO BOOST DIAGNOSTICS

A new partnership between NUS, Agilent Technologies and NUH to develop diagnostics tools that will not only detect existing conditions in patients but also test for biomarkers of other diseases for early prevention, was was launched by the Ministry of Health's Director of Medical Services Associate Professor Benjamin Ong on 17 August 2019.

From left: Prof Tan Eng Chye, NUS President; Assoc Prof Benjamin Ong, Ministry of Health's Director of Medical Services; Mr Mike McMullen, Agilent President & CEO; and Assoc Prof Eugene Liu, Chief Executive Officer of NUH, launching the NUS-Agilent Hub

The NUS-Agilent Hub for Translation & Capture (NUS-Agilent Hub), is a S$38 million research facility and Singapore's first integrated translational R&D hub leveraging on biochemical innovation and research data analytics to develop new methods of translating clinical research into clinical diagnostics.

The collaboration aims to be a global premier one-stop research centre for informing clinical testing through the use of emerging technologies and translational studies to provide greater insight and accuracy.

Comprising laboratories located in NUS and NUH, some 1,000 square metres of research space, NUS-Agilent Hub represents a unique and innovative approach to conducting joint research in health and medical science. Its "hub and satellite model" will allow research to be conducted centrally in Singapore – and shared globally through key partnerships and alliances supported by NUS and Agilent.

NUS researchers will develop innovative analytical tools for detection and quantification of small molecules of clinical interest using technologies from Agilent such as mass spectrometry, which can then be tested in a clinical setting at NUH. Initial research will focus on cardiovascular disease and diabetes, which accounted for 30 per cent of all deaths in Singapore in 2017, and affected 440,000 Singaporean adults in 2014 respectively.

STEPPING UP THE PUBLIC UNDERSTANDING OF RISK

Aiming to further their mission to better communicate and improve the public understanding of risk, Lloyd's Register Foundation Institute for the Public Understanding of Risk (IPUR) has established partnerships and collaborations with global analytics and advice firm Gallup and Understanding Risk (UR), a global community of over 9,000 experts and practitioners interested and active in the creation, communication and use of disaster risk information.

At the Institute's official office opening on 4 June, NUS signed a Memorandum of Understanding with Gallup, agreeing to work together to generate new research and development activities centred around the global perception, measurement and communication of risk.

NUS is the first university in Singapore and Southeast Asia to partner Gallup on the Lloyd's Register Foundation World Risk Poll, a first-of its-kind endeavour aimed to understand the attitudes of 98 per cent of the world's adult population on the most pressing risks faced and feared by individuals in their daily lives. Through this collaboration, NUS researchers will be able to access new emerging data, as well as Gallup's global archive of cross-country comparable data. The analysis from the results of this Poll could lay the groundwork to shape international policy and the implementation of relevant interventions.

IPUR's collaboration with UR – an initiative of the Global Facility for Disaster Reduction and Recovery which is part of the World Bank Group – was also announced. They will partner to organise the 10th anniversary of the UR Forum which will be held in Singapore from 18 to 22 May 2020. The forum is held every two years and offers opportunity for the members to share knowledge and experience, collaborate, and discuss innovations and best practice in risk assessment.

IPUR was set up in 2017 through a donation from the Lloyd's Register Foundation and funding from NUS to offer an Asian context in the research into the public understanding of risk and communication of risk. The Institute accomplishes its aims by conducting scientific and empirical research, and organising workshops and outreach events.

(From left:) Prof Tan Eng Chye, President of NUS; Prof Richard Clegg, Executive Director of Lloyd's Register Foundation; and Prof Koh Chan Ghee, Director of IPUR, officially launching the Institute

NUS, CISCO COLLABORATE TO BOOST DIGITAL ECONOMY

From left: Prof Chen Tsuhan, Deputy President for Research and Technology and Mr Naveen Menon, President ASEAN, Cisco signing an MOU to collaborate on innovation and research (Photo: Cisco)

NUS and Cisco will promote joint research and development activities in the areas of Data Analytics, Internet of Things (IoT), Automation, Cybersecurity, Artificial Intelligence, Machine Learning, and Software Defined Networking.

The collaboration will see the two sides identify joint research projects and sponsored chairs, as well as exchange scientific, academic and technical information. The research projects will focus on key areas and sectors such as healthcare, manufacturing, customer experience and Smart Nation. In addition, they will make use of the NUS Kent Ridge campus as a living laboratory for the co-creation, exploration and evaluation of innovative ideas, technology and scenarios in real-life use cases.

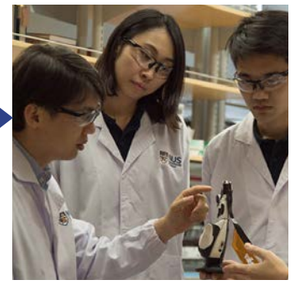
These technologies are key not just to successful digital transformation of businesses, but also to efforts of governments across the world as they look to digital adoption to improve citizen services. Singapore is among the global leaders on that front with its Smart Nation initiative focusing on the Digital Economy, Digital Government and Digital Society.

TECHNOLOGY & INNOVATION

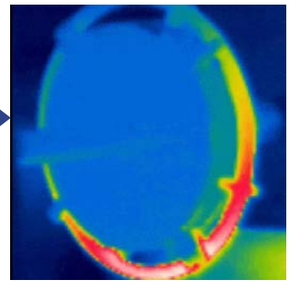
Deep-learning AI system developed by Prof Ooi Beng Chin puts Singapore on global map of big data analytics

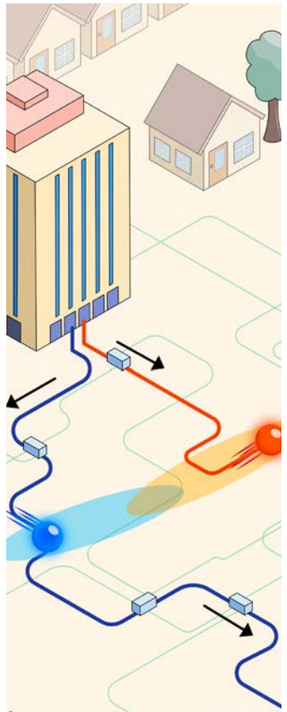
Asst Prof John Ho developed smart textiles that boost wireless connectivity 1,000 times

Asst Prof Benjamin Tee created artificial nervous system with exceptional sense of touch



Assoc Prof Qiu Cheng Wei discovered how to 'lock' heat in place



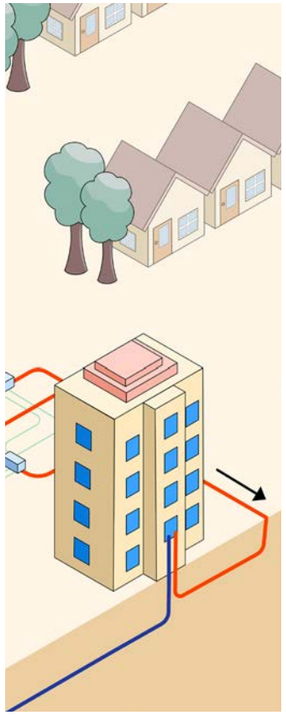


STRENGTHENING CYBER SECURITY WITH LIGHT

In a major breakthrough for data encryption and cybersecurity, researchers led by Assoc Prof Alexander Ling from the Centre for Quantum Technologies, in collaboration with the NUS-Singtel Cyber Security Research & Development Laboratory, have developed a technique that allows pairs of entangled light particles to remain synchronised as they navigate the optical fibre networks that carry data to our homes and offices.

The approach supports the deployment of quantum key distribution (QKD). In this technique, signals are sent in particles of light known as photons. It is through the detection of individual photons that encryption keys are created for secure communication. In the trials, the researchers designed a photon source that created photons at specific wavelengths. The photons, which were joined through the quantum property known as entanglement, remained synchronised as they travelled to distinct detectors via different paths, encountering different obstacles, in the system. Maintaining the synchronisation of entangled photons is crucial, as signals are identified by their arrival time at the detectors.

The success of the results, published in Applied Physics Letters, demonstrates potential applications for entangled photons, such as in synchronising clocks for time-critical operations like financial trading, and boosts expectations for QKD over commercial fibre networks.

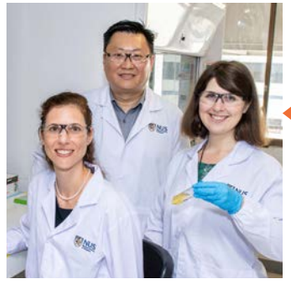


HUMANITIES & SOCIAL SCIENCES

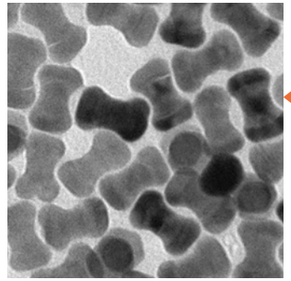
Study by Asst Prof Ng Kok Hoe finds 1,000 homeless people in Singapore

Assoc Prof Leher Singh finds English proficiency unaffected by early exposure to Hokkien

HEALTH INNOVATION

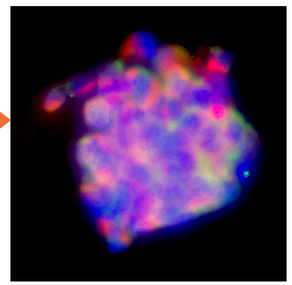


Assoc Prof Ang Wee Han collaborated with Assoc Prof Giorgia Pastorin to develop new 'Trojan horse' cancer drug



Prof Zhang Yong produced light emitting nanoparticles to control biological processes

Assoc Prof Edward Chow and Dr Toh Tan Boon targeted JAK/STAT pathway to inhibit tumour development in the liver



Assoc Prof Koh Hwee Ling uncovered anti-cancer properties of plants

GROUNDBREAKING NEW BLOOD TEST FOR ALZHEIMER'S DISEASE

Researchers from the Institute for Health Innovation and Technology (iHealthtech) and the Faculty of Engineering, developed a novel device for the early diagnosis of Alzheimer's Disease (AD) from blood samples. This work was led by Assistant Professor Shao Huilin.

The technology, which was termed Amplified Plasmonic EXosome (APEX), is designed to measure aggregates of amyloid beta (Aβ) protein– an early-stage molecular marker of AD – in the blood. The APEX system was found to be highly sensitive and accurate in its ability to diagnose AD. As the APEX system uses native blood plasma without additional sample processing, it conducts direct measurements and is very simple to use in clinical settings. The team are currently in discussions with industry partners to commercialise this technology. The device is expected to reach market within the next 5 years.

NUS ARTIFICIAL INTELLIGENCE RESEARCH GETS BOOST

A rapid advancement in AI-based technologies is changing the way we work, live and interact as communities. Industries are becoming increasingly automated, and employees are being encouraged to gain new skills so that they can work with these technologies. However, as societies look to embrace the benefits of improved AI, people remain acutely aware of the challenges posed in its deployment, in particular in the protection of data, privacy and even identity.

The development of AI technologies thus requires a holistic approach, where technological innovations are pursued with societal concerns in mind. Such work is continuing at NUS, and has been boosted with the Singapore National Research Foundation (NRF) recently awarding three researchers from NUS Computing with the NRF Fellowship for Artificial Intelligence.

One recipient, Dr Kuldeep Meel, aims to develop a mathematical framework that addresses real-world problems in AI. His work is motivated by a particular paradox of AI systems. He explained, "The paradox is this: while cutting-edge AI systems can now achieve human-level accuracy in their predictions, these same systems can easily fall prey to the simplest of adversarial attacks, unlike humans."

To solve this issue, Dr Meel and his research group will be studying AI systems in three dimensions: to design formally correct AI systems, ensure verification of AI systems and to explain decisions made by these systems. "Today's AI systems have achieved significant progress similar to those achieved by software and hardware in the past. However, that is also when incorrect behaviour of computers could lead to catastrophic impact on society. Hence, all these goals we aim to achieve can significantly impact the safe adoption of AI," Dr Meel added.

Another recipient, Dr Angela Yao, will be conducting cutting-edge research in artificial visual intelligence. Specifically, Dr Yao and her team aim to analyse and develop efficient algorithms for video analysis and explore methods for learning from large-scale video data.

"Video is the next frontier in artificial visual intelligence," said Dr Yao. "There is now an unprecedented amount of video data coming from CCTVs, internet video platforms, robotics and more. However, most computer vision algorithms treat video as a collection of image frames, and current algorithms are unable to analyse and predict all of these data. The immediate challenge is to develop new AI models that are efficient, flexible and powerful."

Dr Yao believes that results from her study will help inform the progress of many high-impact applications such as autonomous vehicles, home assistance robotics, surveillance and content-based video indexing. "In these systems, an enormous amount of video data needs to be processed. We hope to develop efficient and intelligent video understanding algorithms for these tasks."

In another project, Dr Arnab Bhattacharyya will develop efficient algorithms for causal inference. In data analytics, causal inference refers to the process of inferring the cause of an action, event or effect. Dr Bhattacharyya and his research group will study the mathematical foundations of algorithmic causal inference and apply these insights into AI and other domains such as economics and biology.

"Machine learning is routinely used not only to classify data but to also assist in policy making and policy predictions," said Dr Bhattacharyya. "This can be a dangerous task, as correlations in data do not necessarily indicate that there is causation."

To solve this problem, Dr Bhattacharyya and his team aim to find a way of incorporating causal inference to machine learning. "Causal modelling is an essential component of human intelligence – we use it routinely to make predictions about our world. Yet it is a core problem for AI systems," Dr Bhattacharyya explained. "We want to develop a framework that is able to automatically build large causal models through feature extraction, experimentation, and inference, and then apply it to problems in economics, biology, and medicine."

NUS Computing Assistant Professors Dr Bhattacharyya (left), Dr Meel (middle), and Dr Yao (right) received the NRF Fellowship for Artificial Intelligence

THE NRF FELLOWSHIP IN AI IS GIVEN TO OUTSTANDING YOUNG RESEARCHERS TO LEAD IMPACTFUL AND INDEPENDENT AI RESEARCH IN SINGAPORE. FELLOWS WILL RECEIVE A FIVE-YEAR RESEARCH GRANT OF UP TO S$3 MILLION TO FUND THEIR STUDIES. THIS FEATURE HAS BEEN ADAPTED FROM THE NUS SCHOOL OF COMPUTING NEWS.

27 NUS RESEARCHERS AMONG THE WORLD'S MOST INFLUENTIAL SCIENTIFIC MINDS

27 NUS researchers were named in the global Highly Cited Researchers 2019 list released by Clarivate Analytics. These outstanding researchers have contributed essential knowledge to the fields of Chemistry, Computer Science, Economics and Business, Engineering, Materials Science, Physics and more.

The annual Highly Cited Researchers list from the Web of Science Group identifies scientists and social scientists who have demonstrated significant influence through publication of multiple papers that are ranked in the top 1 per cent by citations for their field and year of publication.

The Highly Cited Researchers 2019 list draws on the data and analysis performed by bibliometric experts from the Institute for Scientific Information at the Web of Science Group. This year, some 6,000 unique researchers have been named Highly Cited Researchers across 21 fields of study, with over 3,500 in specific fields and close to 2,500 for cross-field performance.

PROFESSOR
JIANG DONGLIN
Dept of Chemistry, FoS

PROFESSSOR
LEE JIM YANG
Dept of ChBE, FoE

ASSOCIATE PROFESSOR
ZHAO DAN
Dept of ChBE, FoE

PROFESSOR
LIU BIN
Dept of ChBE, FoE

PROFESSOR
LIM CHWEE TECK
NUS Institute for Health Innovation and Technology
Dept of BME
Dept of MechEng, FoE

PROFESSOR
ANG BENG WAH
NUS Energy Studies Institute
Dept of ISEM, FoE

PROFESSOR
LIU XIAOGANG
Dept of Chemistry, FoS

PROFESSOR
BARBAROS ÖZYILMAZ
Dept of Physics, FoS
Dept of MSE, FoE

DR
SU BIN
NUS Energy Studies Institute

ASSOCIATE PROFESSOR
XIE JIANPING
Dept of ChBE, FoE

PROFESSOR
STEPHEN JOHN PENNYCOOK
Dept of MSE, FoE

PROFESSOR
GE SHUZHI SAM
Dept of ECE, FoE

PROFESSOR
LOH KIAN PING
Dept of Chemistry, FoS

ASSOCIATE PROFESSOR
QIU CHENG-WEI
Dept of ECE, FoE

PROFESSOR
ARJEN HOEKSTRA†
(Adjunct Senior Research Fellow)
Institute of Water Policy, LKYSPP

ASSOCIATE PROFESSOR
ZHANG RUI
Dept of ECE, FoE

PROFESSOR
SEERAM RAMAKRISHNA
Dept of ME, FoE

ASSOCIATE PROFESSOR
GOKI EDA
Dept of Chemistry and Dept of Physics, FoS

PROFESSOR
FREDDY BOEY
NUS Deputy President (Innovation and Enterprise)
Dept of BME, FoE

PROFESSOR
GENE YEO
(Distinguished Visiting Professor)
Dept of Physiology, YLLSoM

PROFESSOR SIR
KONSTANTIN NOVOSELOV
Dept of MSE, FoE

PROFESSOR
CHEN WEI
Dept of Chemistry and Dept of Physics, FoS

ASSISTANT PROFESSOR
THOMAS YEO
Dept of ECE, FoE

PROFESSOR
ANTONIO CASTRO NETO
NUS Centre for Advanced 2D Materials
Dept of Physics, FoS
Dept of MSE, FoE

PROFESSOR
NEAL CHUNG TAI-SHUNG
Dept of ChBE, FoE

PROFESSOR
ZHANG YONG
Dept of BME, FoE

PROFESSOR
VLATKO VEDRAL
Centre for Quantum Technologies at NUS
Dept of Physics, FoS

†Passed away 18 November 2019

PSYCHOLOGICALLY WISE INTERVENTIONS FOR IMPROVING EDUCATION IN SINGAPORE

A new wave of interventions to improve education is upon us. These 'psychologically wise' interventions from social psychology have been gaining prominence across scientific communities, educators and the mass media worldwide. Unlike most traditional educational interventions, these focus on psychological factors that occur within individuals, and tend to be relatively brief in duration and conveniently scalable.

One example of such interventions is the 'growth mindset' established by Professor Carol Dweck at Stanford University. This is the belief that intelligence is malleable, and that it can be developed over time through hard work and effective strategies. Growth mindset interventions have been incredibly effective at changing beliefs and raising academic achievement; especially so in light of the brevity and cost-effectiveness of these interventions. Today, governments, private organisations and even parents want to know how to cultivate a growth mindset.

What characterises these psychologically wise interventions is their high degree of precision in identifying and addressing the psychological roots of problems – even problems as large as racial achievement gaps in education. Take, for example, the "social belonging" intervention led by Professor Gregory Walton at Stanford University that was published in the leading journal Science. An hour-long intervention session at the beginning of university, which addressed disadvantaged minority students' doubts about fitting into university, put these students on more positive academic trajectories throughout their undergraduate careers, relative to peers who did not receive the intervention. This intervention, albeit brief, essentially halved the achievement gap between these disadvantaged minority students and their more advantaged peer groups by the end of college, three years later.

What these interventions effectively change is to turn maladaptive thoughts into more adaptive ones. Put yourself in the shoes of a young student. Imagine that you receive an essay back from your teacher and your paper is covered in red markings. What would you think and how would you feel? Some students tend to think, "I'm a lousy writer. My teacher must think I'm really bad," or, "That teacher just doesn't like me." In other words, they see their teacher's feedback as criticisms about their ability or indications that the teacher does not think they are good. Not surprisingly, these students do not tend to feel motivated to invest time and effort into getting better. This type of thinking is not uncommon among students, even though, when offering feedback, their teachers have their best interests at heart, and want them to improve.

Imagine instead that you see a handwritten message from your teacher clipped to the top of your red-inked essay, which reads: "I'm giving you these comments because I have high standards and I know that you can meet them." Now, what would your reaction be? Many students who received this 'wise feedback' intervention, developed by Professor Geoffrey Cohen at Stanford University, interpreted their teachers' feedback in a more positive light – they saw the feedback as an affirmation (rather than a criticism). These students were, in turn, more likely to revise their essays incorporating their teacher's feedback, and to submit final essays of a higher quality.

By changing students' subjective interpretations in more adaptive ways, psychologically wise interventions enable them to respond to the challenges of learning in more effective ways – including greater persistence, investing in building better relationships with their teachers and peers, and using better learning strategies. In turn, these effective behaviours can often lead to deeper learning, greater confidence, better relationships, and higher performance in school – putting students on more positive academic trajectories in the long run.

When people first hear about these interventions, they may think, "These must be magic," or, "This is all just common sense." Psychologically wise interventions are neither. Instead, they are immensely precise techniques that identify and alter the root of the psychology of students, which otherwise poses a barrier to their learning and performance.

Social psychologists specifically target the psychological issues that students face – such as how they interpret critical feedback from teachers, or how they make sense of a bad grade on an exam – and then design precise interventions to address these issues. Like medicine, social psychologists apply the same scientific rigour to developing interventions. They start with a deep theoretical understanding of the psychological root of the problem, refine and pilot test intervention designs, and test the efficacy of the interventions on people using gold standard double-blind, randomised, controlled trials. This creates an evidence-based understanding of the psychological problem at hand, and how and why an intervention works (or does not). This is crucial, as it is impossible to know what interventions are truly effective without scientific testing.

For us in Singapore, we should consider, what would it mean to adopt this scientific approach as a society. The most important ingredients are (a) an open mindset towards experimenting on different learning approaches and pedagogies, and (b) strong support of this research from the ministry, schools, teachers and parents.

I believe that Singapore is ready for the application of psychological science to improve education. At NUS, I lead a team of passionate psychologists who believe that improving learning can be done in a scientifically rigorous and psychologically precise manner. With support from NUS leadership and the National Research Foundation, we look forward to the many exciting things that we can accomplish in the years ahead.

About the author

Dr Patricia Chen is an Assistant Professor in the Department of Psychology, NUS Faculty of Arts and Social Sciences. She is also Deputy Director at the NUS Institute for Application of Learning Science and Educational Technology (ALSET). She is a recipient of the 2019 National Research Foundation Fellowship.

SECURING OURSELVES THROUGH QUANTUM CRYPTOGRAPHY

Today, we use the internet for almost everything, from shopping and bill payments, to banking and entertainment. In doing so, we place our trust in cryptosystems that protect our private information and identities. However, the emergence of quantum computing is threatening all of that. No longer a theoretical dream, quantum computers have undergone rapid development in recent years, and if built with enough memory, can break even the most sophisticated cryptographic systems. Put simply, the advent of quantum computers will break nearly every cryptosystem in use today, rendering most of the digital services completely insecure.

To that end, the feasibility of migrating critical information to quantum-secure infrastructure is being explored. Currently, the best candidates are platforms using quantum cryptography, which are based on the established laws of quantum theory, one of the most successful physical theories to date. Quantum cryptography is in principle unbreakable and is widely regarded as the top solution for long-term information security. In fact, many countries have already started multi-million-dollar research programs to develop the next-generation quantum cryptosystems, with the intent to deploy them by the next decade. One notable example is the European Quantum Flagship initiative, which, with over EUR1 billion in funding, aims to commercialise quantum cryptography across Europe.

To achieve long-term information security, quantum cryptography employs a technique called quantum key distribution (QKD). This enables the secure exchange of secret keys in an untrusted network, e.g. the Internet. In practice, the secret key is transmitted using a sequence of carefully prepared single-photon signals, which can only be retrieved if the receiver uses the same coding scheme as the sender. The basic idea is that if an attacker tries to learn the secret key, the process of monitoring will invariably disturb the quantum signals. This quantum effect allows the authenticated users to verify if someone else has monitored the quantum channel. If the noise is sufficiently low, then the secret key can be used for encryption, otherwise the protocol is aborted, and the users restart the process.

However, while quantum cryptography is a relatively mature quantum technology, it still faces some fundamental issues. In particular, there is still a considerable gap between the mathematical models used in the theory and the actual quantum devices employed in practice. From the standpoint of information security, such a gap can be very dangerous, for it is highly vulnerable to deliberate hacking attacks or information leakages.

As such, efforts are currently underway at NUS Electrical & Computer Engineering (ECE), and the Centre for Quantum Technologies (CQT), seeking to establish quantum protocols that are secure even when the underlying quantum devices are unreliable.

The goal of such efforts, in essence, is to determine whether it is possible to achieve practical quantum cryptography with as little assumptions as possible about the quantum devices. If successful, this would significantly close the gap between the theory and practice of quantum cryptography, thereby making it more viable for practical use.

To this end, my group at ECE and CQT focuses on two interrelated multidisciplinary programmes that use quantum correlations to self-test quantum devices. The basic idea is to employ statistical correlations to distinguish good quantum devices from the malfunctioning ones.

Leveraging on this idea, we consider approaches to understand how one can mathematically prove the security of quantum cryptography with only partially characterised quantum networks. A practically interesting approach is to consider quantum signals with bounded energy constraints, but with no assumptions made about the quantum receivers.

To determine if the network is indeed quantum in nature, we have designed statistical tests that only quantum devices which are functioning close to their original design intent can pass. Importantly, in this approach, no device modelling is required in the security analysis. From the perspective of information security, this new framework could provide information security against side-channel attacks and unreliable devices, as evidenced in one of our recent findings.

We also take an experimental approach, which aims to develop new photonic devices that can make quantum cryptography faster and cheaper. One of our objectives here is to design and produce a micro-chip self-testing quantum random number generation device whose randomness is guaranteed by quantum correlations. We envisage that such a device could be installed in smart mobile devices and wireless sensor networks to strengthen their information security.

All in all, our ultimate goal is to make quantum cryptography more practical and cost-effective.

Of course, we are not alone in our efforts to establish a reliable infrastructure for quantum cryptography and communication. Although the quantum computers available today lack the ability to hack our most secure systems, it is only a matter of time before they are able to do so. With the theory already so well advanced, it is somewhat naïve to believe that the technology is not already reaching such capabilities. In a sense, a technological arms race for quantum computers is under way. As quantum computers become more powerful, so too will the systems that defend against their malicious use, and protect the private information of governments and industries alike. For individuals, this will mean continuing to live 'online', without fear that one's identity or private information could be compromised.

About the author

Dr Lim Ci Wen Charles is an Assistant Professor at NUS Electrical and Computer Engineering, and the Centre for Quantum Technologies, a Research Centre of Excellence hosted at NUS. He is a 2019 National Research Foundation Fellowship recipient, and was awarded a 2019 Quantum Engineering Programme (QEP) grant with which he will continue his work on quantum cryptography and communication, and in particular, its role in smart mobile devices.

Office of the Deputy President (Research & Technology)

nus.edu.sg/research