JANUARY 2021

RIE NEWS

SG GUIDE TO TECHNOLOGY, INNOVATION AND ENTERPRISE

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AGRICULTURALLY SOUND

From farm to plate, we look at some of the unique agri-tech innovations that help mitigate climate change for a greener tomorrow

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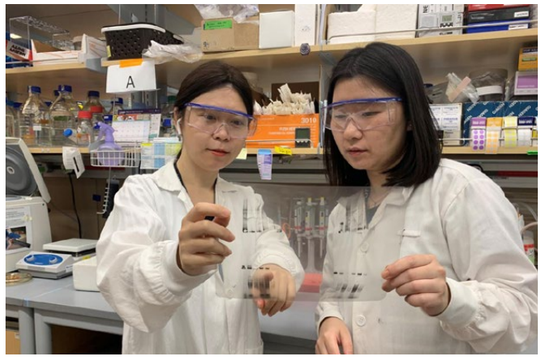
RESEARCH ROUNDUP

DETECTING ARSENIC WITH PLANT SENSORS

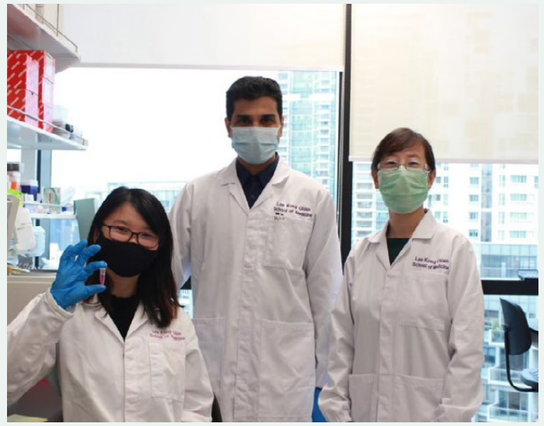
Food crops such as rice can absorb harmful arsenic from the soil, leading to contamination of food and produce consumed by humans. Scientists from the Disruptive & Sustainable Technologies for Agricultural Precision (DiSTAP) at the Singapore-MIT Alliance for Research and Technology (SMART) have come up with a new type of plant nanobionic optical sensor that can detect and monitor arsenic levels belowground in real time. The nanosensors exhibit changes in their fluorescence intensity upon detection of arsenic and are embedded in the plant tissues. This method is a significant upgrade from current methods which are time and equipment intensive. When implemented, this groundbreaking advancement could greatly improve agriculture industry, food safety and the wider environmental safety.

EDITING DNA TO PREVENT CANCER

NUS scientists have found a way to potentially suppress cancer using a process called RNA editing, which gives cells finer control over its proteins. The researchers studied the RNA encoding of a protein called COPA, which influences the development of cancers of the liver, esophagus, stomach and breast. They examined whether RNA transcribed from the COPA gene was edited in cancer tissue samples, and found that any given cell contained a mix of both edited and unedited version of COPA, with the latter more likely to become cancerous. The edited COPA was more likely to suppress a molecular signaling network which could trigger cancer cells. The team is now trying to boost the natural RNA editing mechanisms in cancer cells to tip the balance in favour of the edited COPA, suppressing the cancer.



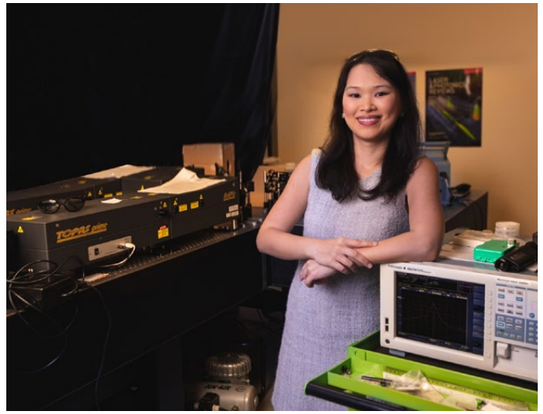
AN ORAL ALTERNATIVE FOR DIABETICS



Diabetics may one day have the option of an oral insulin medication as opposed to the traditional, more painful, jabs. Insulin therapy is a crucial part of treatment for diabetics, but oral dosage remains challenging as the insulin, being a protein, breaks down in the gastrointestinal tract before it can even reach the bloodstream to regulate blood glucose. A team comprising of scientists from NTU's School of Materials Science and Engineering and the Lee Kong Chian School of Medicine are trying to change this through a nanoparticle loaded with insulin at the core, then coated with alternating layers of insulin and chitosan, a natural sugar. Experiments showed that this coated nanoparticle remained stable as it passed through the stomach into the small intestine with minimal insulin release, before going into the bloodstream. This game changing technology has significant impact on diabetic therapeutics and should hopefully improve patient compliance.

AT THE SPEED OF LIGHT

SUTD researchers have developed a technology allowing photonic integrated circuits (PICs) to unlock their potential as high-resolution 3D photonic structures in ultra-high speed communications. Their technology – high-resolution 3D waveguides that transcend the restrictions of light confinement in a single plane – could be useful in further advancements in the photonics field, including imaging techniques and spectroscopic systems. Alongside this, the researchers also demonstrated very low loss 3D waveguide couplers, which unlike current industry standards, do not require post-processing or post-fabrication packaging.



FEATURE

CELEBRATING SCIENCE

Over 500 eminent scientists and young researchers took part in the **Global Young Scientists Summit 2021**, held virtually for the first time.

Why is it so difficult to make self-driving cars, and what are some of the conditions that would be necessary for life to exist on other planets? These were some of the exciting topics that came under the microscope at the recent Global Young Scientists Summit (GYSS) 2021, organised by the National Research Foundation, that took place from January 12 to 15.

With the GYSS 2021 held virtually for the first time in its nine-year history due to the COVID-19 pandemic, over 500 promising young researchers from hailing from 30 countries took part in online plenary lectures and panel discussions across morning and evening sessions designed to cater to participants from multiple time zones.

This year's edition of GYSS also saw a record 21 distinguished speakers on the roster, spanning luminaries from the sciences, medicine, mathematics, technology, and more, with 17 of them joining the annual event for the first time.

Professor Robert Langer, recipient of the 2008 Millennium Technology Prize and co-founder of biotechnology firm Moderna, which created one of the first major Covid-19 vaccines, was the opening plenary speaker. The visionary elaborated on his obstacle-filled journey to inventing groundbreaking drug delivery systems, urging young scientists to dream big and follow their passions.

Professor Jennifer Doudna, who made history just recently in December 2020 when she became one of the first two women to share the Nobel Prize in Chemistry for their work on the CRISPR-Cas9 gene-editing tool, explored the future of personalised medicine in a lively panel discussion with one of her mentors, Professor Thomas Cech, who won the same prize in 1989.

In other lectures and panel discussions, the eminent speakers shed light on a panoply of scientific fields, from the origins of lithium batteries to the next phase in quantum computing, as well as how boosting renewable energy is crucial to limiting climate change.

Professor Low Teck Seng, chief executive officer of the NRF, noted that the GYSS is unique among scientific conferences. "The GYSS involves speakers who are recipients of the Nobel Prize, Fields Medal, Millennium Technology Prize and Turing Award," he said. "This makes our event a truly multidisciplinary summit that covers physics, chemistry, medicine, mathematics, computer science and technology."

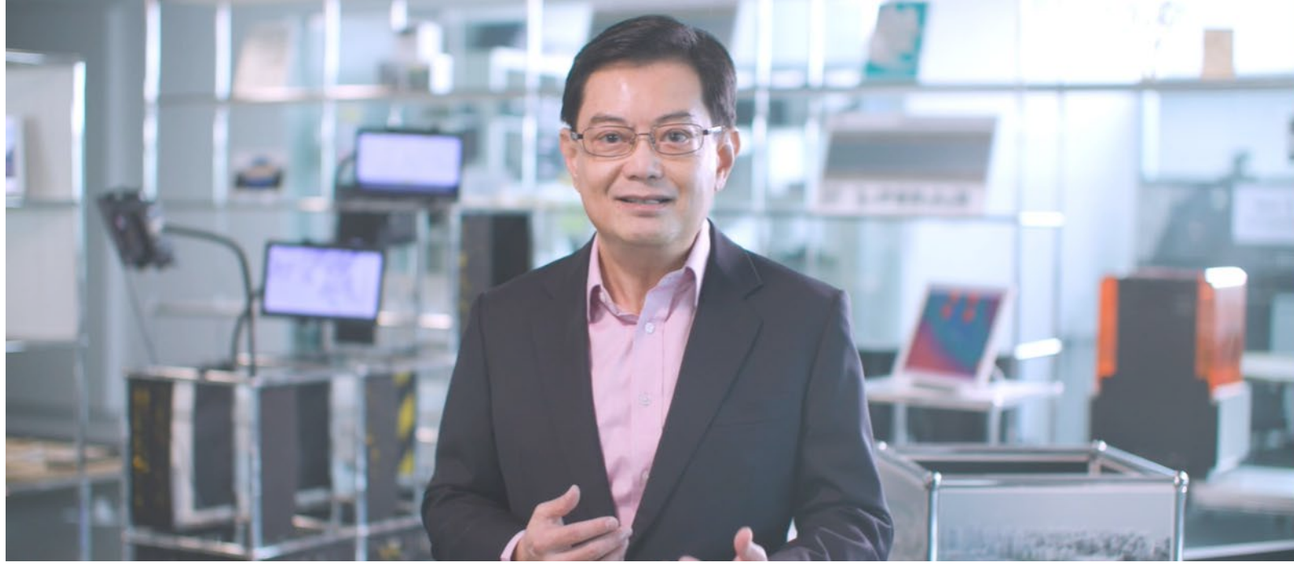
"It is very heartening to see that, year by year, our network of speakers and participants is continuing to grow, and we are a platform not only for global scientific exchanges, but for conversations on society and solutions for global challenges," he continued.

Opening the GYSS 2021, Deputy Prime Minister Heng Swee Keat, who is the Chairman of NRF, said that supporting science and scientific collaborations has become more important than ever in the wake of the Covid-19 crisis. "While each of us can pursue research excellence individually, our efforts are greatly multiplied if we work together," he said.

"By working together, we can build back better from this crisis, and create a better and brighter future for the world."

As part of its inaugural video competition, the event also saw three young scientists winning round trips to Singapore to participate in its 10th anniversary edition in 2022.

Mr Juan Cruz Landoni, a doctoral researcher and participant whose Hamilton-inspired video on



DPM Heng Swee Keat launched the GYSS 2021 and highlighted the importance of science and scientific collaborations in his opening address.

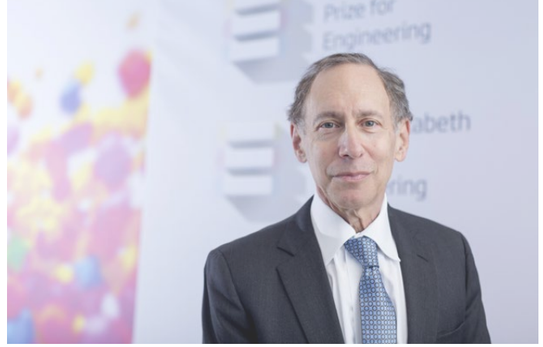
mitochondria won him one of the prizes, called the experience "truly mind-opening".

"There weren't many cliché inspirational words, but rather many of the speakers provided truly fresh and honest perspectives regarding science and beyond, underlining our responsibility as scientists in ethics, society and policy. That was the truly inspirational part," he said.

Mr Neel Kanth Kundu, who won a prize for his video on quantum communications, agreed. "Attending GYSS 2021 was a once-in-a-lifetime experience for me...it was such a nice experience to virtually meet and interact with other young scientists from all around the globe and to know about their research interests."

Mr Nakul Rampal, who also won a prize for his video on porous materials, added, "I am most excited about meeting fellow young scientists, interacting with and learning from some of the best researchers in the world, and finally, exploring – both as a scientist and as a tourist – the beautiful country of Singapore!"

> **"It's just a wonderful feeling to follow your scientific instincts and curiosity, to occasionally understand something that's never been understood, and to wonder at what nature is able to do.**
>
> Professor William Kaelin Jr, Nobel Prize in Physiology or Medicine, 2019



The power of perseverance

Many years before Professor Robert Langer became a celebrated scientist-entrepreneur with a Millennium Technology Prize and over 1,400 granted and pending patents to his name, he was a struggling young scientist.

Sharing his scientific journey with young researchers during his opening plenary lecture for the GYSS 2021, he recalled the numerous obstacles and doubts that he faced in his early years, including a dispiriting string of nine grant rejections when he wanted to further his research on controlled release drug delivery systems for large molecules, which are now ubiquitous.

“I just kept trying to work,” said Prof Langer, encouraging young scientists to persevere in the face of difficulties and challenges. “I had a very rocky road early in my career, and if I have anything to impart, it is to dream big dreams that you hope are going to have a big impact on science and medicine, and recognise that you may often have a lot of obstacles. It is really important to not give up, to keep pushing, and hopefully your big ideas and big dreams will come true.”

A spotlight on personalised medicine

The future of personalised medicine is bright with the CRISPR-Cas9 gene editing tool, said Professor Jennifer Doudna and Professor Thomas Cech, who won the Nobel Prize in Chemistry in 2020 and 1989 respectively, during a live panel discussion on the subject at GYSS 2021.

Prof Doudna shared the Nobel Prize for her work in developing the tool, while Prof Cech has used it extensively. Answering questions about its potential from young researchers globally, the speakers noted that scientists have already tapped it in studies to fight sickle cell and other blood diseases, as well as other illnesses and conditions.

The duo also addressed concerns about its use, such as the ethics of making heritable gene edits, and the possibility of unintended consequences. Prof Doudna said, “The vast majority of work is focused on treating diseases, not heritable changes, and I have been encouraged by people knowing that it is a tool not to be deployed without caution.”

Prof Cech added that he had faith in scientists’ ability to overcome technical challenges: “With a robust tool like CRISPR-Cas9, and with human ingenuity and scientific creativity, we can make medical miracles.”

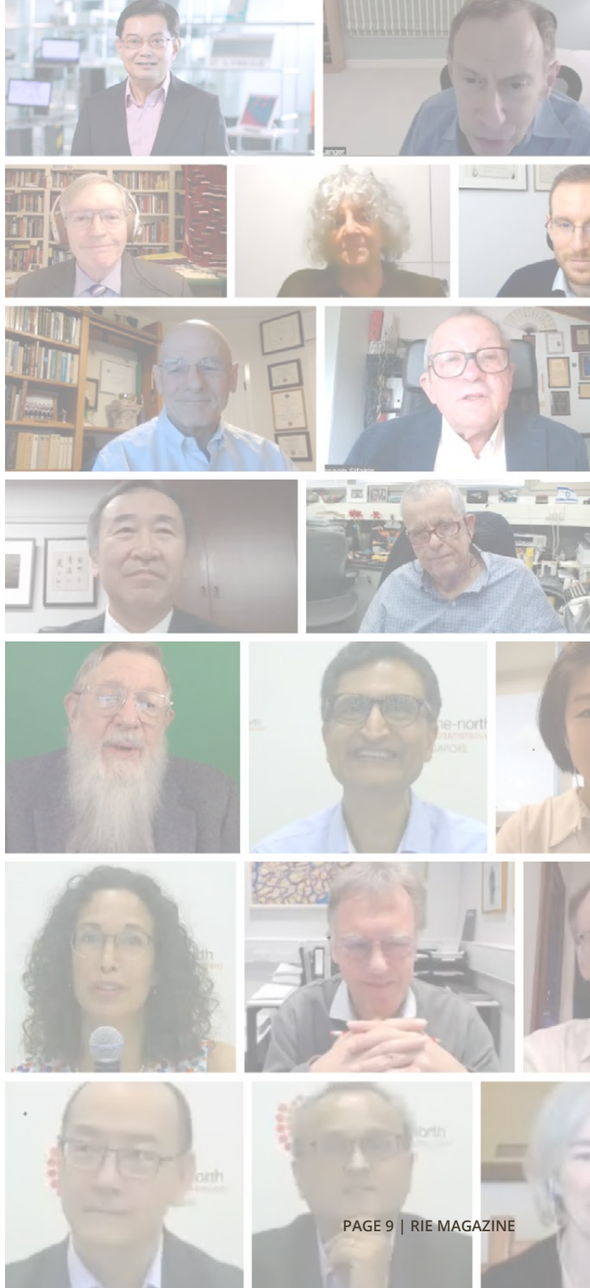
Life on other planets

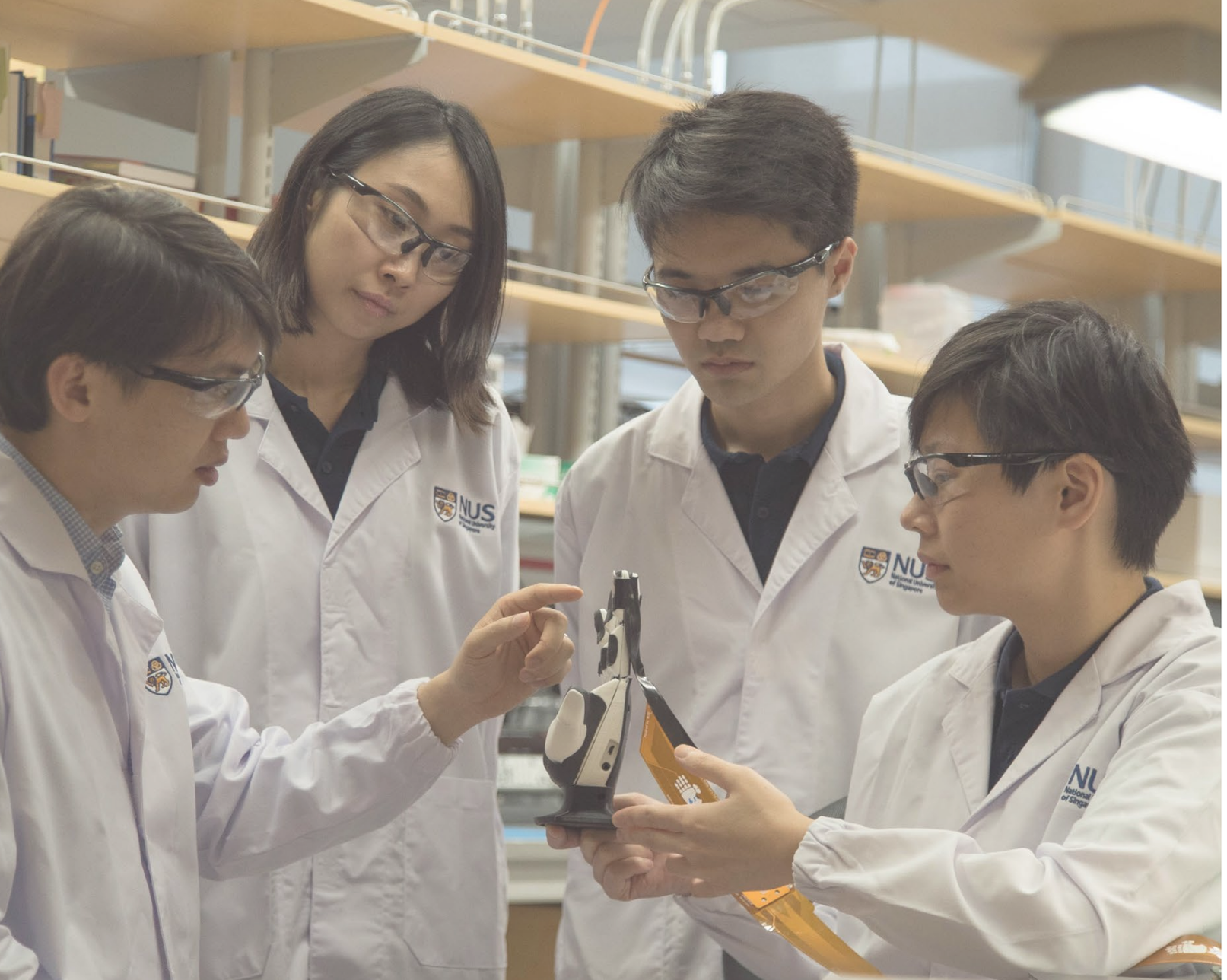
Since Professor Didier Queloz was the first to discover a planet orbiting a sun-like star outside of our solar system, also called an extrasolar planet or exoplanet, 25 years ago, scientists have uncovered more than 4,000 others, reshaping our view of the universe.

In the final plenary lecture of GYSS 2021, Prof Queloz spoke about this exoplanet revolution, noting: “We’ve had to expand our understanding of planet structures. We have the giants and the ice giants, but between the ice giants and the Earth we have a lot of diversity, from mini-Neptunes to gas dwarfs to rocky super Earths, and even a planet with a massive ocean. We have found that planetary formation is way more creative than what we imagined.”

Discussing the impact of his discovery, which won him the Nobel Prize in Physics in 2019, he added that scientists are investigating the possibility of life on other planets, identifying the universal building blocks of life but keeping in mind that life on other planets could use completely different and unexpected sets of chemistry.

He concluded: “Asking questions about life is very complex, but a very exciting challenge.”





SPECIAL

RISING STARS

In the spirit of the Global Young Scientists Summit 2021, this issue will spotlight promising young scientists who reside here in Singapore.

We speak to them about their research journeys, goals and ambitions, and what drives them to go further.

MAKING SCI-FI DREAMS A REALITY

NRF Fellow **Dr Benjamin Tee's** research sounds like a sci-fi dream come true – and in a way, it is. His research project on nature-inspired artificial intelligence has spurred the development of cutting-edge innovations, such as artificial nervous systems and self-repairing materials.

A unique research programme intersecting materials science, electronics and medicine, and bringing about positive socioeconomic impact: that was Dr Benjamin Tee's dream.

An avid sci-fi fan, he was inspired by the likes of prolific author Isaac Asimov, and the Star Wars and Star Trek movies. "This affinity for scientific possibilities led me to pursue this field," he explains, adding that his doctoral experience at Stanford University, at the heart of Silicon Valley, also influenced him.

Focusing on what he calls "physical AI" – a field which includes sensor devices, robotics, and human-machine interfaces – Dr Tee's research has also won him a slew of prestigious awards, including the NRF Fellowship, the MIT TR35 Innovators under 35 Award, and the Singapore Young Scientist Award in 2016. Today, he is a faculty member at the National University of Singapore, where he leads the Sensors. AI Systems Labs, a research programme which aims to discover and apply nanoscience to create intelligent materials, devices and systems.

The ambitious multidisciplinary programme, which Dr Tee was able to launch after receiving his Fellowship grant in 2017, has churned out a number of innovations since its inception. Within the first year of obtaining the Fellowship, his research group developed and patented an artificial nervous system that is able to transmit tactile sensory data more than 1,000 times faster than the human nervous system.

"It's also highly power-efficient as it mimics aspects of the human nervous system," notes Dr Tee.

Besides this groundbreaking innovation, the team has also developed new electronic materials that can self-repair. In addition to being fundamental in the development of successful human-machine interfaces, such devices can help to drive more sustainable use of electronic gadgets. "Imagine if your mobile devices could self-repair!" Dr Tee enthuses. "We can reduce electronic waste and help you save some money too."

In all of these, however, nature remains Dr Tee's key inspiration. "Nature is probably the world's greatest engineer," he explains. "It has developed highly complex systems that are extremely power-efficient...The human brain, for example, uses only about 10 watts of power, and yet it can perform exquisite operations such as human thought and muscular dexterity."

In order to perform these processes, nature needs sensors – for instance, humans have our five senses in order to understand our environment and learn new skills and abilities, says Dr Tee.

"In almost all science fiction scenarios, there is some form of AI assistant that can perform tasks in a human-like fashion," he says. "Yet, the ability to sense the environment at such high speeds and across so many sensors still remained an elusive goal. Hence, I decided to tackle the gap between sensory inputs and machines to realize physical embodiments of AI, such as robots and prosthetics."

"And as I love to build things and see them work, I thought – why not merge Nature's design principle with artificial electronic systems for machines?"

Bridging ideas and reality

Back in 2017, , AI had not yet become as ubiquitous as it is today. However, Dr Tee's passion for his idea led him to apply for the Fellowship, which would provide him with the necessary resources to launch his programme.

"I was very interested in continuing my work in the field of advanced sensors and soft flexible electronics," he adds. "I felt that there would be an inflection point soon, and we would witness exponential growth in how such newer forms of electronics can be applied to healthcare and robotics...I also believed that AI would become critical in the next stage of human technological growth."

As such, it came as a shot in the arm when the Fellowship panel accepted his ambitious proposal, allowing him to assemble a team of like-minded students in order to achieve his research goals.

And even as the five-year Fellowship period nears its end, Dr Tee is confident that this is just the beginning. With many of his innovations on the cusp of translation, and many more ideas in the pipeline, he's hopeful that he will be able to continue contributing to the local tech, venture, and enterprise sectors in the years to come.

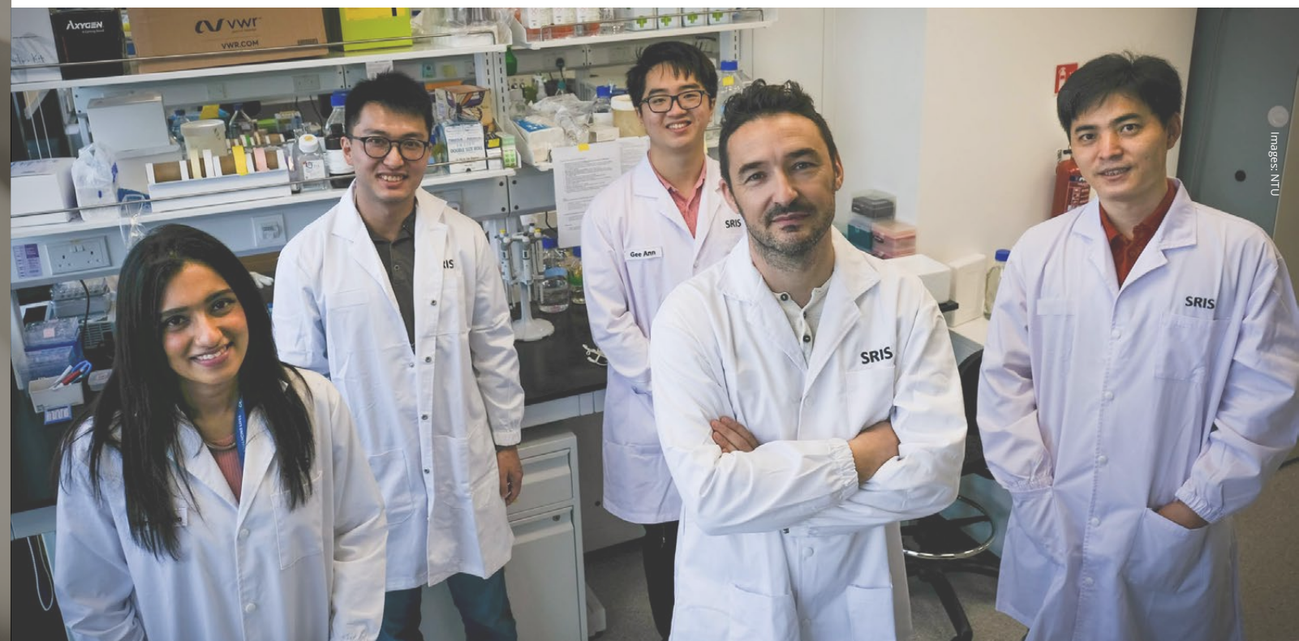
"I think what I am most proud of is my students, research, and postdoctoral staff, whom I had the privilege to train and work together with to develop many of these exciting technologies that I expect will start to see socio-economic impact in the next three to five years," he says.

"Research is a marathon, and I will continue to work hard to innovate and bring the technologies developed out of my research lab into the real world."

DECODING THE IMMUNE SYSTEM PUZZLE

The human immune system has long been a subject of intrigue for **NTU's Dr Franklin Zhong** – and today, his research is helping scientists discover new therapies and solutions.

(left to right) Dr Kim Robinson, Dr Franklin Zhong, Mr Toh Gee Ann, Prof Bruno Reversade, and Dr Sun Zijin



Images: NTU

(left to right) Ms Pritisha Rozario, Dr Franklin Zhong, Dr Kim Robinson, Mr Toh Gee Ann, and Prof Bruno Reversade

The human immune system is a complex maze of cause-and-effect – a puzzle that Dr Franklin Zhong, along with his team at the Lee Kong Chian School of Medicine, hopes to figure out.

His interest in innate immunity was sparked during his postdoctoral training at A*STAR with geneticist Dr Bruno Reversade, when he discovered a new inherited disease caused by mutations in an immune sensor gene called NLRP1. "These patients develop a peculiar skin disorder characterised by recurrent growths on their palms and soles," he explains. "Sadly, for these patients, some of these skin lesions are prone to becoming malignant."

At the time, the concept of how a defective immune system could lead to development of cancer was unknown and – to Dr Zhong – a particularly intriguing scientific question. His personal experience with childhood eczema, a condition caused by a disregulated innate immune response, pushed him to pursue this question further. "In hindsight, my first-hand experience with the health burden of immune-related diseases contributed to my interest in this area," he adds.

Cut to a few years later, and today, the 2019 National Research Foundation (NRF) Fellow leads his own lab at the Lee Kong Chian School of Medicine, focusing on the investigation of how the human innate immune system defends against pathogens – in particular disease-causing viruses – while avoiding attacking the body itself.

For instance, the lab has recently discovered – in collaboration with groups at A*STAR and National University of Singapore – that the NLRP1 protein functions as a sensor for the common cold virus, or human rhinovirus (HRV), in the lungs and bronchus. This finding was published in prestigious scientific journal Science last October.

The discovery could potentially help guide the development of better therapies against virus-triggered asthma and obstructive pulmonary disease exacerbations. While his research plans have been slowed down for now due to the pandemic, Dr Zhong hopes that with time, he will be able to share more discoveries with the scientific community, and eventually get them patented and translated into novel therapies to modulate the immune system.

He credits the lab's rapid growth to both the NRF Fellowship, which he says has provided him with the support needed to get his lab up and running quickly, as well as the support from his host institution. "I'm very lucky to have assembled a team of talented research assistants and scientists who are passionate about working on some these interesting and medically relevant problems."

And while the field of immunology has grown by leaps and bounds in the past few years, the emergence of SARS-CoV-2 in the past year has surfaced a plethora of new questions and complexities. "There is so much we do not yet understand," Dr Zhong says. "For instance, we still do not know why SARS-CoV2 is so deadly for some patients while many remain asymptomatic. Is the difference due to genetics or the environment? Why are children less susceptible to severe symptoms?"

Indeed, the pandemic has only strengthened his belief that a better understanding of the way the human immune system works is a pressing medical need, for doctors and scientists alike.

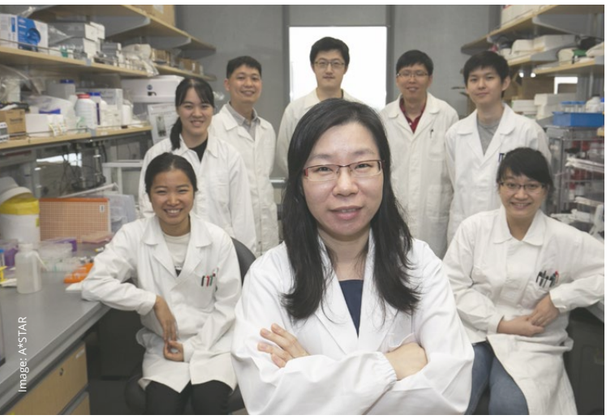
"The ongoing pandemic has exposed the many fragilities of our society, but it has also given us scientists a renewed sense of responsibility and purpose," he says.

"I hope Singapore builds on the momentum and continues to invest in fundamental research in this area; and hopefully in the near future, it will become a world leader in biotech research and innovation."

> **" The ongoing pandemic has exposed the many fragilities of our society, but it has also given us scientists a renewed sense of responsibility and purpose.**
>
> Dr Franklin Zhong, Nanyang Assistant Professor, NTU

ADVANCING DIAGNOSTICS, EMPOWERING PATIENTS

Young Scientist Award recipient **Dr Shao Huilin** is best known for her powerful COVID-19 detection kit – but the **NUS** faculty member and **A*STAR** joint investigator has much more in store for the world of diagnostics.



*Dr Shao Huilin and her research team at A*STAR*

When COVID-19 struck, biomedical engineer Dr Shao Huilin saw an opportunity to put her skills to good use.

Drawing on her expertise in non-invasive diagnostics, Dr Shao and her team worked relentlessly to develop and clinically validate a COVID-19 detection platform which can achieve the sensitivity of the gold-standard polymerase chain reaction (PCR) tests, but in as little as 30 minutes at room temperature. The test kit, which the team is now working on bringing to hospitals and clinics, is a modified version of an earlier platform developed by the team to diagnose other infectious diseases like Zika, Ebola, malaria, dengue, and hepatitis.

Her story began in Harvard University, where Dr Shao did her PhD training. During her clinical rotation, she observed that diagnostic tests in hospitals often involved invasive procedures and long, anxious waits.

"The experience left me wanting," she says. "I wanted my interdisciplinary training to make a real impact, beyond the bounds of science labs. And as a biomedical engineer, I am committed to developing new generations of diagnostic technologies that can reveal important clinical information, much earlier and safer, to empower patient care."

That experience marked the start of Dr Shao's pursuit of better, non-invasive diagnostic technologies. And it has certainly paid off – in 2019, she won the prestigious Young Scientist Award, administered by the Singapore National Academy of Science (SNAS) and supported by the Agency for Science, Technology and Research (A*STAR), which recognises innovative and productive young Singapore-based scientists.

Her COVID-19 kit is testament to that innovative spirit. Diverging from the traditional PCR kit's approach, her technology's sensing mechanism is inspired by biological cells – or "how nature has done it", as Dr Shao quips. This design allows sensitive detection of COVID-19 targets, with a performance comparable to the best PCR test kits, and yet bypasses the time-consuming steps of PCR processing, such as sample preparation, reverse transcription, and thermal cycling.

"The entire assay is completed in as little as 30 minutes at room temperature, and can be performed near patients to provide rapid and accurate results," Dr Shao explains.

The team is now collaborating with commercial partners to bring the platform to the patients. Dr Shao she has received in the past months – from members of the public expressing their interest in being part of clinical trials, to thank-you notes from patients who have benefitted from their technologies.

"These encouraging comments not only reaffirm our research goals, but also motivate my team to continue to do our very best," she says. "With this, I truly believe the diagnostics field will emerge stronger post-pandemic."

In the meantime, she is working on multiple new projects to bring forth a generation of smart diagnostic technologies for safe and informative detection of infectious diseases, neurodegenerative diseases and cancers. "These technologies not only advance the frontiers of science and engineering, but also bring important clinical benefits," says Dr Shao.

"With our clinical collaborators, we have shown that these new technologies can expand the reach of previously under-appreciated biomarkers, reveal important disease insights through a single blood test, and guide treatment decisions in real time. We are also working closely with investors and commercial partners to translate our technologies," she added.

"Together, we are pushing the boundaries of molecular diagnostics, to transform patient care with faster, more accurate and more affordable solutions."

FEATURE

AGRICULTURALLY SOUND

The **agri-food tech sector** is one of growing importance in Singapore's economy as the world looks for innovative, cost-effective and sustainable food solutions to feed its growing population.

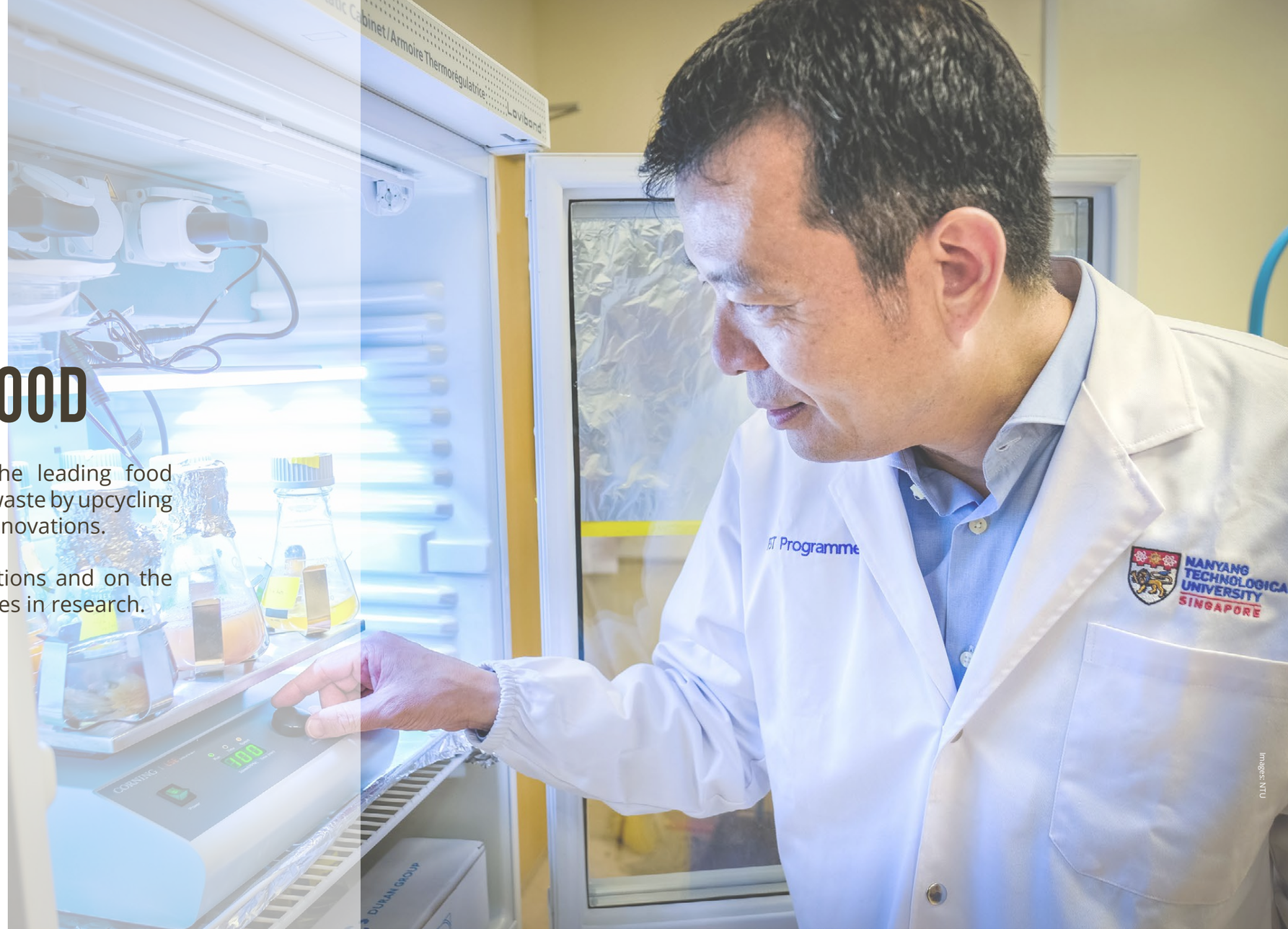
From farm to plate, we look at some of the unique local innovations that help mitigate climate change for a greener tomorrow.

FEATURE

AN APPETITE FOR FOOD

NTU's Professor William Chen, one of the leading food scientists in Singapore, strives to reduce food waste by upcycling them into reusable, sustainable food-grade innovations.

We speak to him about some of his innovations and on the importance of adopting sustainability principles in research.



Images: NTU

While other laboratories pack themselves with complexed chemicals stored in fridges, the ones you will find at Professor William Chen's lab are chock full of daily produce from the market and leftover food products. The director of Food Science and Technology (FST) at Nanyang Technological University (NTU) quips that the working environment helps to whet his researchers' appetite for science and that it comes with "fresh vibes" (pun not intended).

Prof Chen, who is also NTU's Michael Fam Chair Professor in Food Science and Technology, explains that most of the work he does involves finding ways to reduce food waste by not only turning them into reusable products, but also improving its sustainability.

He says, "Waste is unavoidable, especially when it comes to food waste which is increasingly becoming an issue in many countries, including Singapore. While reducing waste is a key effort in creating an environmentally friendly society, as scientists, we should also look at ways to turn those unwanted things into useful products and enhance them further with added benefits."

From soybean waste and prawn shells, to cling wrap

Having walked the halls of academia for over two decades, his passion for saving the environment led him from being a teacher to an inventor, and he is bringing his students along for the ride.

He highlights that food packaging is one of his research areas: "Food packaging is a consistent issue that society faces as these are always discarded after a single use. This is especially more important since the pandemic, as people started ordering takeaways while they work from home, or to overcome the lack of seating areas as food outlets are practicing social distancing measures."

He cites one of his earlier innovations which involves creating a biodegradable food wrap made of cellulose extracted from the waste soybean waste. The soybeans are first crushed to squeeze out juice that is used to make bean curd and soy milk. The residue is then fermented by microbes that consume the nutrients, leaving behind cellulose, a form of fibre.

Cellulose-based plastic wraps have been on the market for a few years, but Prof Chen says that most are made from wood or corn, cultivated for that purpose. In contrast, his wrap is made from a waste product – so it doesn't compete with edible crops for land, and is more sustainable.

"In Singapore, the amount of food waste we generate every year can fill up 15,000 Olympic-sized swimming pools," he says, adding that because soy products are so popular in Singapore, approximately 30 tons of soybean residue are produced every day.

> **"In Singapore, the amount of food waste we generate every year can fill up 15,000 Olympic-sized swimming pools.**
>
> Professor William Chen, director of Food Science and Technology, NTU

Prof Chen and his team have also improved on this technology further by enhancing it with antimicrobial properties using chitin from discarded prawn shells and fruit waste such as fruit peels and red grape pomace. "Chitin serves a wide variety of uses in the food industry, such as food thickeners and stabilisers, and as antimicrobial food packaging," says Prof Chen.

"So, we thought that if we could extract chitin from prawn shells and convert them into chitosan, we could develop a more durable cellulose film with antimicrobial and antibacterial properties."

"While this is still being further developed, imagine – biodegradable food packaging made from soybean waste with antimicrobial properties from discarded fruit and prawn shells. We can tap two waste streams and create something that could be beneficial to the food industry and beyond." Prof Chen's biodegradable packaging material could kill the proverbial two birds with one stone; since it could potentially replace plastic containers used for food takeaways, it would help Singapore reduce its reliance on single-use plastic waste.

All-natural, 100 per cent organic

While the buzzword 'organic' is often thrown about to entice consumers, Prof Chen and his team pays homage to the term. He stresses that he uses natural methods to create his innovations without the need for additional chemicals and additives.

A few years ago, he developed an organic and all-natural food stabiliser from the seeds of the durian fruit. Food stabilisers are commonly used in prepared food items to give them a uniform texture. They contain sugar-protein biopolymers, which bind ingredients that naturally tend to separate. Some examples include gelatine and gum arabic which are

Using discarded prawn shells, Prof Chen and his team discoverd a natural and sustainable way to produce chitin, an important substance in the food industry

added in soft candy and sweeteners, pectin in dairy products, and emulsifiers in lotions and cosmetics.

Dubbed the king of fruits, durian seeds (about 3-4 cm in diameter) are normally thrown away after the flesh is consumed, but using a patented technique to harvest the thick gum from the seeds, an NTU team has shown that it could be used as a natural food stabiliser, which also support probiotics.

"The majority of consumer food contains food stabilisers, which are indispensable to ensure that various ingredients that do not mix well can gel harmoniously. What we have done is to use something we often ignore when eating durians – its seeds – to produce a 100 per cent natural food stabiliser that can even keep our gut system healthy," says Prof Chen.

In another research project, using yeast, he developed a plant-based food preservative that is more effective than artificial ones. Prof Chen explains that the organic preservative comprises a naturally-occurring substance known as 'flavonoids', which is produced by plants to mitigate stress. Similar to how vaccines are manufactured using yeast, Prof Chen and his researchers found that the yeast produced flavonoids with high antimicrobial and antioxidant properties, two key traits of preservatives that inhibit bacterial growth and keep food fresher for longer. "Compared with commercial-grade artificial food preservatives on meat and fruit juice samples, our organic preservative kept its samples fresh for two days without refrigeration," says Prof Chen.

"This organic food preservative is derived from plants and produced from food grade microbes, which means that it is 100 per cent natural. It is also more effective than artificial preservatives and does not require any further processing to keep food fresh."

Industry relevance and partnerships: hallmarks of good translational research

Sharing his thoughts on what grounds his research, Prof Chen remarks that the key ingredients would be to ensure it remains relevant to industry and current needs, as well as to continue collaborating with industry partners to further develop them.

"Innovation cannot exist in a vacuum, and this also applies to good, translational research. The mortar that propels good research into great ones are those that involve an industry partner, who can advise on how to ensure the research remains practical, feasible and beneficial to society."

Prof Chen cites NTU's partnership with Fraser and Neave, Limited (F&N), which jointly launched the F&N-NTU F&B Innovation Lab in 2019 to translate food technology innovations into industry applications for fast-moving consumer goods. Spearheaded by his FST Lab at NTU, research projects at the lab range from enhancing food products and processes to developing biodegradable packaging solutions for the food and beverage industry.

Besides hard work, another piece of advice Prof Chen has for young researchers is to align their research focus towards helping society. "My research work has always been driven by the needs of society. I hope the fruits of my research inspire others to adopt the mantle of sustainability and address problems that industry and society face, so that our dreams of a greener future come closer to reality."

Typically thrown away, durian seeds see another lease of life as they are developed into an all natural food stabiliser (left to right) Research Fellow Dr Jaslyn Lee and Prof Chen

Biodegradble food-grade packaging with antimicrobial properties made from prawn shells and fruit waste (left to right) Research Officer Lee Pei Pei, Prof Chen and PhD student Tan Yun Nian

FEATURE

ABUZZ WITH INNOVATION

Founder of Polybee **Siddharth Jadhav** explains how his platoon of robot bees are taking farming to new heights of innovation.

Images: Polybee

With the nation moving towards high-tech agriculture and indoor vertical farming gaining popularity, Polybee, a Singapore-based agri-tech company, discovered a problem that the industry has now run into: pollination.

Mr Siddharth Jadhav, founder and chief executive officer of Polybee, said that while others might not think so, pollination is essential to sustain the production of daily produce, especially fruits and vegetables. He says, "Natural pollinators support many varieties of fruits and vegetables. However, they are highly vulnerable and are currently facing pressing issues such as climate change and other environmental factors."

He adds, "We must find better and sustainable ways to continue the critical pollination process that is also crucial to ensure a sustainable food production chain and enhance national food security."

Mr Siddharth also highlights the lesser-known important role of pollination in seed production. "Most of our food comes from hybrid seeds, which exhibit traits found in different varieties of the same plant species. These 'hybrid seeds' are in a US $50 billion market, which are made by manual cross-pollination processes that are not sustainable."

Mr Siddharth says that it is not feasible for natural pollination to occur in indoor environments such as vertical farming due to the lack of natural ultraviolet (UV) light – the special spectrum of light that enables natural pollinators such as bees to navigate. "The lack of UV light in indoor farms poses a significant challenge to natural pollination by bees and replicating the UV light may give rise to other unforeseen problems that need to be addressed. Moreover, bees require a wide-open space with a diversity of crops to feed on. Putting it simply, natural pollination is not sustainable within an indoor farming model."

When it comes to scalability, pollination is challenging because of the high levels of uncertainty and unpredictability, says Mr Siddarth. He stresses that this is the very first step to turn flowers into fruits and vegetables, and there is plenty of room for innovation. "Pollination is the crucial first step in growing fruits and vegetables, and optimising this with technology was one of the driving forces that motivated us to think of a solution," he adds.

Enter Polybee – artificial intelligence and robotics

Tapping deep tech such as artificial intelligence (AI) and robotics, Mr Siddarth developed small drones that can pollinate crops like strawberries, tomatoes and pepper. With the support of the National University of Singapore (NUS) and the Temasek Foundation, his idea was accelerated through the founding of Polybee in 2019 to further develop and testbed the technology with veteran industry partners.

Slightly larger than a bee, the 9cm-long miniature flying drones are agile enough to manoeuvre through confined spaces and cover a large amount of space in a timely and consistent manner.

The entire indoor space is also mapped out using cameras and is connected to an AI-powered system, which controls several drones autonomously, ensuring precision pollination within 1cm of error. Mr Siddarth and his team are able to effectively operate one drone per 10-15 square metres in a vertical farm, and 13-17 drones per hectare in a greenhouse.

Mr Siddarth says, "Pollination is a fragile process and the challenge is for the drones to be stable enough for actuation. To address this, we have developed a state-of-the-art feedback control algorithm hooked up to precision positioning systems."

Polybee has completed a trial with a major seed company in Southeast Asia, and Mr Siddharth plans to start trials in Singapore very soon. He says, "Every environment may pose different challenges and it is critical that our drone system is tested in a variety of settings so that we can fine tune and perfect the system for eventual commercial roll-out."

Tests so far have been promising. Trials with the Singapore Food Agency show that over 90 per cent of the flowers yielded fruit, which meets industry standards. He now aims to venture into more partnerships with seed and vertical farms, and hopes to develop a commercially viable product as early as the end of this year.

Mr Siddharth says that he is appreciative of the support from the 'Lean Launchpad' programme by NUS as well as the NUS Graduate Research Innovation Programme. He also says that Singapore has good support structures in place to nurture the growth of deep tech innovations at every stage.

He remarks, "I am happy to admit that Polybee is entirely a product of Singapore's excellent innovation ecosystem for deep tech startups. Be it venture support from NUS in the early days, Temasek Foundation's financial and strategic support, or even SGInnovate's talent programmes; we are immensely grateful for the help we have received at every stage."

Mr Siddharth Jadhav, founder and CEO of Polybee

FEATURE

UNEARTHING NOVEL IRRIGATION SOLUTIONS

We speak to **NTU's Professor Lam Yeng Ming** on her research that could help regenerate forests after catastrophes like wildfires.

During catastrophes like draughts and wildfires, the topsoil becomes hydrophobic (water "hating") due to the organic residues, which makes it difficult for water to penetrate the soil, hindering the growth of plant life. Avid materials scientist Professor Lam Yeng Ming, chair of the School of Materials Science and Engineering at Nanyang Technological University (NTU), discovered a way to enhance soil wettability and water retention using a nanogel that contains a unique formulation.

It was made using super absorbent materials that improve soil retention. The formulation also provides a double benefit of improving both wettability and water retention. The innovation was commercialised under the auspices of an NTU agritech spinoff, FytoSol, which Prof Lam oversees as its founder.

"The nanogel that we have developed improves the ability of water to penetrate the ground effectively and for extending water availability to plants when soil moisture is low," says Prof Lam.

She adds that the nanogel has immense potential for applications in horticulture, agriculture, golf courses and even forest regeneration. "Our innovation helps overcome the challenges of climate change and play an important role to spur plant growth from reluctant dry soils."

"We are also confident that the nanogel can help regenerate forests after wildfires, where the soil has lost its water retention abilities."

When applied to soil, Prof Lam explains that the special formulation within the nanogel acts as a mini 'water bank', drastically reducing the chances of plant dehydration and water wastage through run-offs and drainage. The formulation can store a substantial amount of water during irrigation, 'locking' the water in to minimise evaporation but releasing it in times of need. She highlights that the gel can cut water consumption for plants by at least half.

Images: fytosol

The FytoSol team: (left to right) Dr Goh Chin Foo, Ms Cynthia Chiang, Dr Nguyen Anh Chien, Dr Zhang Liling, Prof Lam Yeng Ming, Dr Chen Zhong, and Mr Chan Yok Pun

Prof Lam also emphasises that the nanogel is suitable for indoor plant keeping such as in HDB homes and allows water-guzzling plants such as Japanese roses or even food crops to be grown on HDB rooftops. "With the ability to store more water over a longer period of time, we would be able to grow a wider variety of plants especially those that require more water, which is only achieved at a complexed irrigation facility."

"This also helps reduce mosquito breeding as the soil is able to retain the water without much drainage and reduce the need for constant watering," added Prof Lam.

The nanogel was trialled with building developers and Prof Lam's team also won the Mitsui Chemicals Award at the Tech Plan Demo Day by Leave a Nest/ Tech Planter as well as the Cool Ideas Enterprise Award by the Housing and Development Board (HDB) – both in 2018. Moving forward, Prof Lam aims to continue to work with the industry and further enhance the technology.

Images: SUTD

COMMENTARY

NO FARM NO FOUL

COVID-19, with its zoonotic origins, has shone a spotlight on wild animal farming. But is it truly an outdated practice, as its critics say – or is it a risky innovation? **SUTD's Dr Lyle Fearnley** shares more.

At the end of last year, the first reports of the zoonotic virus we know now as COVID-19 emerged in Wuhan, China. Amidst a whirlpool of political and corporate turmoil, one theory in particular soon escalated to gain worldwide recognition (and outrage) – the theory that pointed to a seafood market in the city as being the cause and origin of the pandemic.

This theory became so pervasive that the virus was soon given the unfortunate moniker: the 'Wuhan virus'. A full year after this virus ravaged the globe, things have become slightly clearer. The practice of wild animal farming quickly fell victim to public offense – but it's still not apparent whether or not it truly was ever at fault.

Dr Lyle Fearnley, a cultural anthropologist who hails from the Singapore University of Technology and Design (SUTD), hopes to shed some light onto this practice. In his new book, Virulent Zones: Animal Disease and Global Health at China's Pandemic Epicentre, Dr Fearnley discusses new viruses emerging out of intensively-farmed landscapes and human-animal interactions. We speak to Dr Fearnley to find out more.

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Ever since the SARS-CoV-2 virus was identified in Wuhan, China, questions have swirled around the origin of the virus that caused a global pandemic. Based on genomic evidence, we know that it is a zoonotic virus, meaning that it 'spilled over' from animals, and that the host reservoir was probably wild bats. But how did the virus get from bats to humans?

Although investigations are ongoing, a popular theory has focused on the farming and consumption of wild animals as food – and in particular, marketplaces where live wild animals are sold. The theory posits that this practice serves as a possible 'interface' between an animal carrying the virus and the human index case. And while farming of wild animals - in species from mallard ducks to frogs to civet cats - is relatively common in China, the COVID-19 pandemic resulted in a sharp rise in criticism of wild animal foods. Today, China has prohibited the farming of most wild animal species.

Critics of wild animal farming often portray the consumption of wild animals as a traditional but outdated practice, out of step with China's modernisation drive. In fact, however, the farming of wild animals is a relatively recent strategy adopted by rural farmers, as I found out while conducting research for my book, Virulent Zones: Animal Disease and Global Health at China's Pandemic Epicentre. Conducted between 2010 and 2014, my research looked at efforts to contain the emerging avian influenza strains at their epicentre in rural China, and how scientific efforts to contain zoonotic diseases intersected with farmers' lives and livelihoods.

At the time, scientists believed new influenza viruses emerged when viruses were transmitted between wild and domestic birds. Therefore, scientists grew very concerned when they discovered that some people were farming wild swan geese (da yan), because they believed this could form a bridge between wild and domestic waterfowl and allow new viruses to emerge. When I learnt about this, I wanted to find out why these farmers had started farming wild animals, like swan geese, rather than conventional pigs or poultry.

As a cultural anthropologist, my fieldwork research is based on a methodology of participant-observation. In addition to interviews, I accompanied wild swan goose farmers as they went about their daily routines, helped them with their work, and lived alongside them on the farm. I found that farming of wild swan geese was anything but traditional. In fact, human-directed breeding and farming of swan geese only began in the 1990s in response to the tremendous expansion and intensification of poultry farming after China's market reforms in 1978.

Between 1978 and 2000, chicken production grew from less than 500 million to over 6 billion (heads slaughtered/year), with most of that growth happening in the 1990s. But the structure of production also changed markedly along with growth in output. Initially, specialised households – essentially rural family farms – raised and sold poultry, but by the 1990s these smallholders were being supplanted by agro-industrial firms known as 'dragon-heads'. As dragon-head producers scaled up production, independent smallholder farmers struggled to make a living raising conventional poultry. Many left poultry farming altogether.

Others, however, like the wild goose farmers I accompanied, sought out new opportunities in niche or unconventional products such as local poultry breeds – or, as it turns out, wild animal species. These farmers were desperate to differentiate their products from mass-market poultry in order to get better prices. On the farm, I observed that a lot of their breeding work involved maintaining the 'wildness' of the birds – such as a certain shape of beak or the ability to fly – so that the difference from conventional domestic geese would be apparent to potential consumers.

At the same time, China's economy was booming, especially in the coastal cities, and some people were getting quite rich. In the banqueting culture through which business deals were secured, carving out social distinction required serving clients dishes that would truly stand out. Since conventional meats, like chicken, had become so widespread they no longer made an impression, rare foods like wild animal meats began to be favoured. Here again, the consumer market demand for wild animal foods was not traditional, but rather a response to broader processes of agricultural modernisation.

In both cases, the turn to 'exotic' wild animals is not a continuation of longstanding tradition, but rather an effort to stand out against the very recent ubiquity of mass-produced chicken. The wild swan goose farmers saw themselves more as innovators than as traditional farmers or peasants – something that showed in their eye-catching marketing brochures, or in their continuous development of new product lines and packaging. Rather than the remaining vestige of a traditional past, wild animal farming represented one of the leading edges of the rural economy.

Although the prohibition of wild animal farming is an understandable response to the immediate concerns of the Covid-19 pandemic, it does not really address the underlying drivers of production and consumption that led the farmers I know to start breeding wild swan geese. Instead, it has pushed many wild animal farmers to economic ruin. A much more comprehensive rethinking of food systems—and their relation to the livelihoods of rural people – is needed in order to not only respond reactively to this epidemic, but also reduce the risks of future pandemics. After all, several previous zoonotic outbreaks have emerged not from wild animals, but from conventional poultry and livestock farms, including the 2009 swine flu pandemic, the highly pathogenic avian influenza, and the Nipah virus that struck nearby Malaysia in 1998.

In order to achieve this reconstruction of agri-food systems, a first step is to begin by enrolling farmers in safe farming practices rather than forcing certain farm sectors out of business – and perhaps, driving them underground, where zoonotic risks are even greater.

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