Agency for Science, Technology and Research
SINGAPORE

APR 2019 - MAR 2020

ANNUAL REPORT

CREATING GROWTH,
ENHANCING LIVES

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OUR MISSION ▸

The Agency for Science, Technology and Research (A*STAR) drives mission-oriented research that advances scientific discovery and technological innovation. We play a key role in nurturing and developing talent and leaders for our research institutes, the wider research community, and industry.

Our research creates economic growth and jobs for Singapore. As a Science and Technology Organisation, we bridge the gap between academia and industry in terms of research and development. In these endeavours, we seek to integrate the relevant capabilities of our research institutes and collaborate with the wider research community as well as other public sector agencies towards meaningful and impactful outcomes.

Together with the other public sector entities, we develop industry sectors by: integrating our capabilities to create impact with multi-national corporations and globally competitive companies; partnering local enterprises for productivity and gearing them for growth; and nurturing R&D-driven start-ups by seeding for surprises and shaping for success.

Our research, in addition, also contributes to societal benefits such as improving outcomes in healthcare, urban living, and sustainability. These serve to enhance lives in Singapore and beyond.

OUR VISION ▸

A global leader in science, technology and open innovation.

A*STAR is a catalyst, enabler and convenor of significant research initiatives among the research community in Singapore and beyond. Through open innovation, we collaborate with our partners in both the public and private sectors, and bring science and technology to benefit the economy and society.

ABOUT A*STAR

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MESSAGE FROM THE CHAIRMAN AND CEO

The COVID-19 pandemic has greatly disrupted the global economy and people's lives.

Singapore was able to respond decisively to the pandemic. Our R&D ecosystem has built deep capabilities in infectious diseases and antibody research, as well as artificial intelligence. A*STAR was also able to contribute its expertise in diagnostics, modelling and simulation, material science, and precision engineering. With our strong capabilities in intellectual property licensing and productisation built over the years, A*STAR was able to help our local companies develop new products and processes to combat this new coronavirus.

Our scientists have also made important contributions to unravel the mysteries of the SARS-CoV-2 virus that causes COVID-19, advancing community-based research globally. Collectively, our long-term R&D investment and capabilities have proven to be invaluable during these unprecedented times and helped A*STAR to respond rapidly in the war against the novel coronavirus. Along the way, we have enabled technology transfer to our local biotech and medtech companies, and allowed them to secure new export opportunities.

In this year's annual report, we dedicate a special section to the teams who have been working alongside public agencies and industry to combat the pandemic and help Singapore recover.

With travel restrictions and other safety measures in place to curb the spread of the coronavirus, businesses must now adapt to the new rules of the game. A*STAR is committed to helping local enterprises survive, and even thrive, during these difficult times by embracing innovation.

Looking beyond these challenging times, we must be ready to capture new opportunities borne out of this crisis.

Minister for Trade and Industry Chan Chun Sing said at the Quarterly Economic Survey (QES) 2Q 2020 press conference in August: "We are not returning to a pre-COVID world. We must chart a new path now".

In this report, beyond COVID-19, we showcase the impact of our industry partnerships through features of local start-ups and SMEs which have reinvented themselves, and pivoted into new markets and new products to create good jobs. Our collaborations with the large local enterprises are adding value to Singapore's economy. In RIE 2020, A*STAR undertook about 2,000 projects with local enterprises, and assisted over 420 companies with their operation and technology roadmapping.

Equally important, A*STAR supports the mission of the public sector across a broad range of areas, including healthcare, food security, as well as smart cities and sustainability. Our goal is to improve life and living for Singapore and Singaporeans through our science.

A*STAR's multi-pronged talent strategy builds a pipeline of skilled talent pool to drive innovation and contribute to the country's societal and economic needs. To date, we have nurtured a pipeline of 1,650 scholars who are actively contributing to the Research, Innovation & Enterprise (RIE) ecosystem in Singapore. A number of them have become entrepreneurs, setting up their own start-ups following a successful research career at A*STAR. Others continue to drive innovation in the laboratories, and are recognised by the global research community for their efforts.

The days ahead will see Singapore experience one of its most difficult periods ever. A*STAR stands ready to support the nation in developing innovative solutions to secure better health, societal and economic outcomes, and to contribute to the furtherance of science. Together with our collaborators and public sector partners, we will forge ahead with fortitude and resilience as Team Singapore.

Ms Chan Lai Fung
Chairman

Mr Frederick Chew
Chief Executive Officer

BOARD MEMBERS

(as at 31 March 2020)

1 Ms Chan Lai Fung
Chairman
A*STAR

2 Mr Frederick Chew
Chief Executive Officer
A*STAR

3 Professor Barry Halliwell
Chair
Biomedical Research Advisory Council
A*STAR

Senior Advisor
Academic Appointments and Research Excellence, Office of the Senior Deputy President and Provost

Tan Chin Tuan Centennial Professor
National University of Singapore

4 Professor Sir John O'Reilly
Chair
Science and Engineering Research Advisory Council
A*STAR

Chairman
NICC (Standards) Ltd

5 Professor Isaac Ben-Israel
Chairman
Israel Space Agency

6 Professor Stefan Catsicas
Science and Technology Strategy Advisor
Nestlé S.A

7 Professor William Chin
Executive Vice President
Clinical and Translational Science
Frequency Therapeutics

8 Professor Chong Tow Chong
President and Acting Provost
Singapore University of Technology and Design

9 Mr Chng Kai Fong
Managing Director
Economic Development Board

10 Mr Anton S. Huber
Former Chief Executive Officer
Digital Factory Division, Siemens AG

11 Dr Benjamin Koh Khay Wee
Deputy Secretary (Development)
Ministry of Health

12 Professor Lily Kong
President and Lee Kong Chian Chair Professor of Social Sciences
Singapore Management University

13 Dr Josephine Kwa
Director
Barghest Building Performance

14 Mr Quek Gim Pew
Chief Defence Scientist
Ministry of Defence

15 Mr Ravinder Singh
President
ST Engineering Electronics Ltd

16 Professor Subra Suresh
President
Nanyang Technological University Singapore

17 Professor Sir Keith O'Nions
Chair
University of Nottingham, UK

Chair
British Geological Survey, UK

18 Mr Arunjai Mittal
Independent Director

19 Dr Omkaram Nalamasu
Senior Vice President and Chief Technology Officer
Applied Materials

President
Applied Ventures LLC

20 Professor Tan Eng Chye
President
National University of Singapore

21 Mr Yee Ping Yi
Deputy Secretary (Planning)
Ministry of Finance

SENIOR MANAGEMENT

(as at 31 March 2020)

1 Mr Frederick Chew
Chief Executive Officer
A*STAR

2 Professor Barry Halliwell
Chair
Biomedical Research Advisory Council
A*STAR

Senior Advisor to the President,
NUS

Tan Chin Tuan Centennial
Professor

3 Professor Sir John O'Reilly
Chair
Science and Engineering Advisory Council
A*STAR

Chairman
NICC (Standards) Ltd

4 Mr Suresh Sachi
Deputy Chief Executive (Corporate)
General Counsel
A*STAR

5 Professor Andy Hor
Deputy Chief Executive (Research)
A*STAR

6 Professor Sir David Lane
Chief Scientist
A*STAR

7 Professor Ong Yew Soon
Chief Artificial Intelligence Scientist
A*STAR

President's Chair Professor of Computer
Science, NTU

8 Dr Peter Nagler
Chief Innovation Officer
A*STAR

Executive Director
Institute of Chemical & Engineering Sciences
(ICES)

9 Professor Ng Huck Hui
Assistant Chief Executive
Biomedical Research Council
A*STAR

10 Professor Tan Sze Wee
Assistant Chief Executive
Science and Engineering Research Council
A*STAR

11 Mr Philip Lim
Chief Executive Officer
Accelerate Technologies Pte Ltd

12 Professor Lisa F.P. Ng
Executive Director
A*STAR Graduate Academy (A*GA)

Senior Principal Investigator
Singapore Immunology Network (SIgN)

ORGANISATION CHART

(as at 31 March 2020)

Chairman
Ms Chan Lai Fung
and
Board of Directors

Internal Audit
Director
Ms Karen Chia

Chief Executive Officer
Mr Frederick Chew

- **Chair, Science and Engineering Advisory Council**
  Prof Sir John O'Reilly
- **Chair, Biomedical Research Advisory Council**
  Prof Barry Halliwell
- **Chief Scientist**
  Prof Sir David Lane
- **Chief AI Scientist**
  Prof Ong Yew Soon
- **Chief Innovation Officer**
  Dr Peter Nagler

Corporate
Deputy Chief Executive
Mr Suresh Sachi

Research
Deputy Chief Executive
Prof Andy Hor

CORPORATE COMMUNICATIONS
Group Director
Ms Angelina Fernandez

HUMAN RESOURCE
Group Director
Mr Timothy Sebastian

FINANCE
Group Director
Ms Goh Mien Zo

INFORMATION TECHNOLOGY SHARED SERVICES
Chief Information Officer
Dr John Kan

CHIEF INFORMATION SECURITY OFFICE
Chief Information Security Officer
Mr Tay Kheng Tiong

DIGITAL TRANSFORMATION & INNOVATION OFFICE
Director
Mr Chew Chun-Chau

PLANNING AND POLICY DIVISION
Director
Mr Tan Haryanto Kurniawan

ENTERPRISE RISK MANAGEMENT OFFICE
Chief Risk Officer
Mr Phillip Lim

LEGAL
General Counsel
Mr Suresh Sachi

ADMINISTRATION
Director
Ms Kerin Lim

INFRASTRUCTURE PLANNING & FACILITIES MANAGEMENT
Director
Ms Neo Hwee Peng

A*CCELERATE TECHNOLOGIES PTE LTD
Chairman
Mr Frederick Chew
Chief Executive Officer
Mr Philip Lim

INDUSTRY DEVELOPMENT GROUP
Group Director
Mr Liau Eng Soon

BIOMEDICAL RESEARCH COUNCIL
Assistant Chief Executive
Prof Ng Huck Hui
Executive Director
Dr Danny Soon

SCIENCE & ENGINEERING RESEARCH COUNCIL
Assistant Chief Executive
Prof Tan Sze Wee
Executive Director
Dr Hazel Khoo
Executive Director
(Research)
Prof Reginald Tan

RESEARCH OFFICE
Deputy Director
(Office of Research Ethics & Compliance)
Dr Foo Ngee Chih
Deputy Director
(Research Excellence & Strategy Office)
Dr Zong Yun

A*STAR GRADUATE ACADEMY
Executive Director
Prof Lisa Ng
Deputy Executive Director
(Scholarship Administration)
Ms Ang Ee Luang

SUBSIDIARY COMPANY

Name of subsidiary company

Accelerate Technologies Pte Ltd (A*ccelerate)

% of shareholdings in company

100%

A*ccelerate is the commercialisation arm of the Agency for Science, Technology and Research (A*STAR), supporting it in transforming the economy by driving innovation and commercialising its research outcomes.

A*ccelerate aims to be the one-stop open innovation partner of choice to grow businesses in Singapore and beyond through accelerating the translation of inventions and intellectual capital into marketable products, processes and services.

A*ccelerate's IP, technology transfer and commercialisation professionals harness new technologies, increase the value of intellectual property and incubate cutting-edge business ventures to create commercial impact.

Together with industry leaders, mentors, catalysts and the A*STAR research community, A*ccelerate works to build a cohesive ecosystem for Innovation and Enterprise.

For more information, please visit https://www.accelerate.tech/

OUR COMMUNITY
(as at 31 March 2020)

The A*STAR community spans across a broad range of research areas from the biomedical sciences to the physical sciences and engineering. The community of scientists and researchers, technical and non-technical staff, and industry development and commercialisation staff was more than 5,300 strong as at 31 March 2020.

Biomedical Research Institutes

Bioinformatics Institute (BII)
Bioprocessing Technology Institute (BTI)
Genome Institute of Singapore (GIS)
Institute of Bioengineering and Nanotechnology (IBN)
Institute of Medical Biology (IMB)
Institute of Molecular and Cell Biology (IMCB)
Singapore Bioimaging Consortium (SBIC)
Singapore Institute for Clinical Sciences (SICS)
Singapore Immunology Network (SIgN)
Skin Research Institute of Singapore (SRIS)

Science and Engineering Research Institutes

Advanced Remanufacturing and Technology Centre (ARTC)
Institute of Chemical and Engineering Sciences (ICES)
Institute of High Performance Computing (IHPC)
Institute for Infocomm Research (I^2R)
Institute of Materials Research and Engineering (IMRE)
Institute of Microelectronics (IME)
National Metrology Centre (NMC)
Singapore Institute of Manufacturing Technology (SIMTech)

National Platforms

*These are facilities hosted and managed by A*STAR but funded nationally by multiple public stakeholders and serve specific national capabilities.*

Diagnostics Development Hub (DxD)
Experimental Drug Development Centre (EDDC)
National Robotics Research and Development Programme Office
National Supercomputing Centre (NSCC)
Singapore Biodesign (SB)
Technology Centre for Offshore and Marine, Singapore Ltd (TCOMS)

SPECIAL FEATURE

SUPPORTING SINGAPORE'S FIGHT AGAINST COVID-19

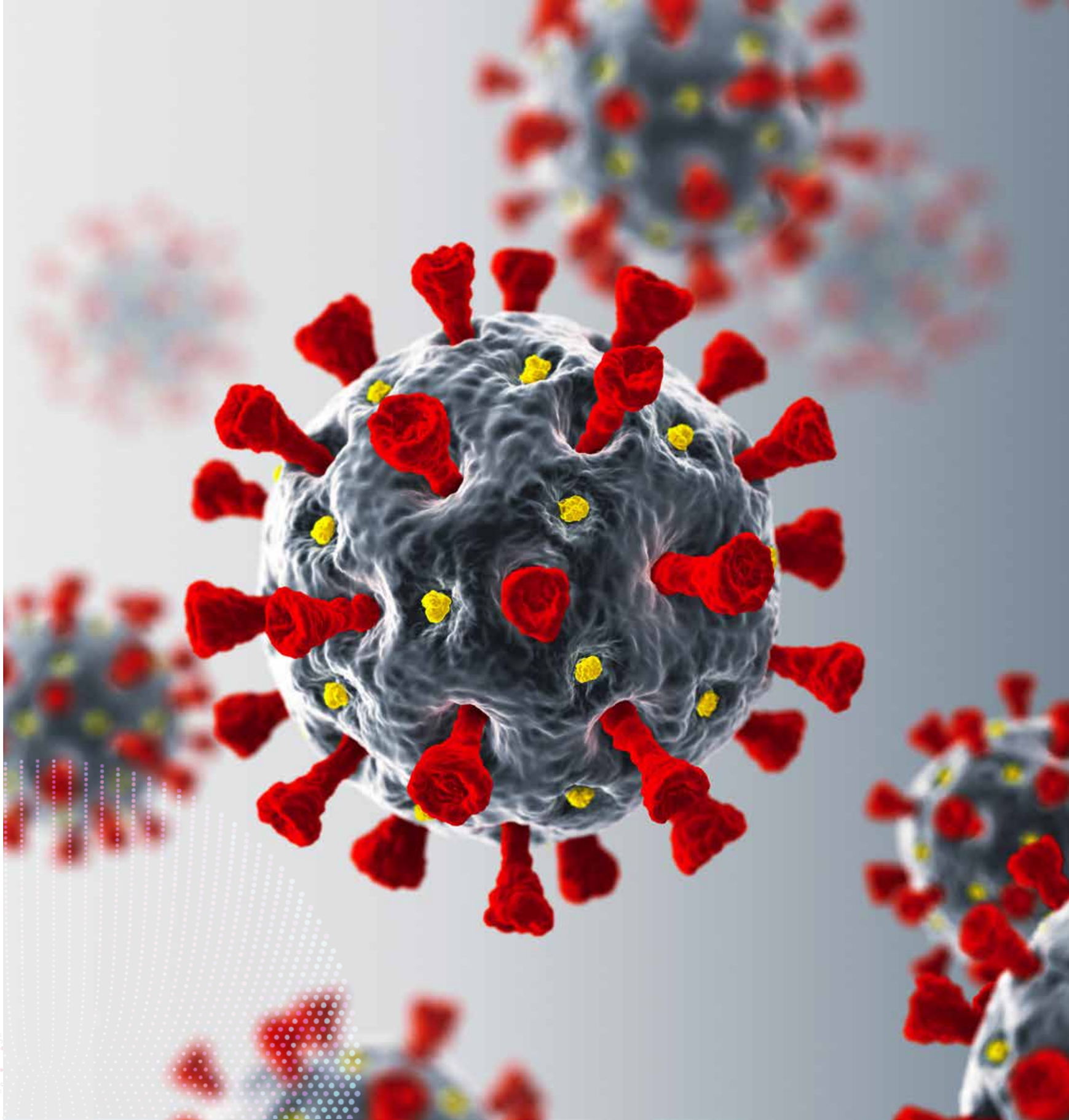
11 Diagnostic Kits and Complementary Systems

14 Antibody Discovery and Therapeutics

15 Bioinformatics and Modelling Studies

16 Protective Face Masks

17 Analytics and Detection



Singapore has responded quickly and decisively to the COVID-19 pandemic. The synergistic relationships and open exchange of information between infectious disease scientists and the clinical community that were cultivated since the SARS outbreak in 2003, were critical. The strong links that the top scientific talent in Singapore have with renowned international organisations also place Singapore in an optimal position to fight the novel coronavirus. Here are the key achievements, so far.

READ more about A*STAR's R&D contributions to Singapore's fight against COVID-19.

Coronavirus: Front-line Fighters

S'pore labs join global race to learn about virus

Having made a diagnostic test kit, scientists here now hope to develop a possible cure

Professor Lisa Ng was part of a team at A*Star that developed a kit which could test for the Sars virus in patient blood samples in 2003. ST PHOTO: KELVIN CHNG

Audrey Tan
Science Correspondent

How does the fight against the spread of a disease begin, if the virus causing it is something that no one has seen or heard of before?

As with most mysteries, it starts with first seeking answers to the most basic of questions: What is it? How does it spread? How severe is the infection it causes?

Enter the scientists, the detectives of the microbe world.

Working in laboratories, away from the glare of the public spotlight, scientists are in a race against time to answer these questions – answers that others could build upon to save lives, improve patient care and boost public health through developing diagnostic test kits, drugs and even a vaccine.

As the Health Ministry's chief health scientist, Professor Tan Chorh Chuan, told the media last week: "To fight a war, you must know your enemy."

The mystery virus first surfaced in Wuhan, China, late last December, with those infected exhibiting pneumonia-like symptoms. Since then, the virus – now identified as Sars-CoV-2 (the disease itself is Covid-19) – has spread around the globe, including in Singapore.

Many unknowns remain about it, although scientists around the world were handed an important clue when Chinese scientists first uploaded the genome of the coronavirus on a public database last month.

It allowed scientists to determine that it was related to the one that caused the severe acute respiratory syndrome (Sars) in 2003.

The availability of the genome was also a good starting point for scientists in Singapore, paving the way for the development of a diagnostic test kit, enabling clinicians to quickly screen for patients infected with the coronavirus, with high accuracy.

Developed by experts from the Agency for Science, Technology and Research (A*Star) and Tan Tock Seng Hospital, the kit has been rolled out at a number of public hospitals here and also delivered to China.

A diagnostic test "flags" parts of the viral genome unique to Sars-CoV-2 in a patient sample.

Care is taken to ensure the genetic sequence flagged is the more stable part that is less prone to mutation. But this does not rule out mutation occurring, which viruses are prone to doing.

If it does, the test has to be modified quickly.

Says Dr Masafumi Inoue, co-developer of the diagnostic test kit, who is also head of the diagnostics group in the translational sciences division at A*Star's Experimental Drug Development Centre: "This is why we have to work closely with the A*Star researchers at the Bioinformatics Institute who study the genome of the virus.

"The latest analyses show that the virus has not mutated in our targeted region of its genome."

With Singapore already having the capability to quickly screen patients for the virus, the next step is to find out how they can be treated.

This is what Professor Lisa Ng, senior principal investigator at A*Star's Singapore Immunology Network, aims to find out.

She studies how the virus works, and how the human body reacts to it, by analysing samples from patients in Singapore, and by working closely with clinicians and healthcare workers who interact directly with patients.

"In the presence of a virus, the immune system will mount a protective response. By studying these mechanisms, it could pave the way for the development of therapies and even a possible vaccine," says Prof Ng.

Since the Sars outbreak, the research community has become more organised over the past 17 years, notes Prof Tan, and advancements in technology have also yielded new capabilities, such as rapid whole genome sequencing.

He adds: "R&D is integral to preparedness and effective response."

audreyt@sph.com.sg

NO MUTATION SO FAR

The latest analyses show that the virus has not mutated in our targeted region of its genome.

DR MASAFUMI INOUE, head of the diagnostics group in the translational sciences division at A*Star's Experimental Drug Development Centre, on how the diagnostic test would have to be modified quickly if mutation occurs.

Search for cure like finding needle in a haystack: Investigator

Professor Lisa Ng, 46, is part of a team searching for a cure for Covid-19 – the "mystery" disease with pneumonia-like symptoms originating from Wuhan, China, that only recently got a name.

It is a noble task, but one that can feel like searching for a needle in a haystack, says Prof Ng, senior principal investigator with the Agency for Science, Technology and Research's (A*Star) Singapore Immunology Network.

Before a cure or vaccine can be developed for Covid-19, which has infected more than 67,000 people worldwide, scientists must first understand how the human body responds to the virus infection.

This is necessary in order to develop immune-based therapies that can stimulate the body's natural protective response against the virus, which provides a longer-term protection for the patient than drugs.

But studying how the body responds to the virus is a long process. The first step entails the search for immune system indicators – such as protein levels and the presence of antibodies – in samples taken from patients who have recovered.

As there can be thousands of such indicators present in a human body at any given time, it can be challenging to identify the specific elements of the immune system mounting the defence against the virus causing Covid-19, says Prof Ng.

The immune system comprises many different elements which all work together to rid the body of bacteria, parasites and viruses.

An important component of this system is antibodies, which are found in the blood. They detect the presence of a virus and latch on to the infected cell, flagging it so other elements of the immune system can kick in to destroy it.

When faced with a new or previously unidentified threat, the body will typically manufacture new antibodies to get rid of it.

"So, when it comes to searching for clues to how a person's immune system mounts a defence against this specific virus, which is so new, it sometimes feels like we are going in blind," Prof Ng tells Insight.

"But we are guided by certain basic understanding of biology, immunology and patient physiology," says the viral immunologist, who studies how humans respond to other vector-borne diseases such as chikungunya and Zika.

Though she had always been interested in the study of diseases in humans, Prof Ng says it was her experience during the severe acute respiratory syndrome (Sars) outbreak that changed her perception of the role of scientists in such outbreaks.

She was part of a team at A*Star that developed a kit which could test for the Sars virus in patient blood samples back in 2003.

At that time, the most common way to test for the presence of viruses that cause respiratory diseases in patients was to first collect nasal samples from them.

But Prof Ng had learnt that this method could expose healthcare workers to infection risk. In the early days of Sars, clinical sample collection equipment for infectious pathogens was not as sophisticated as it currently is.

The development of a diagnostic test that could detect the presence of the virus in blood samples – which have lower levels of the virus than nasal samples – was a breakthrough that also gave healthcare workers some peace of mind.

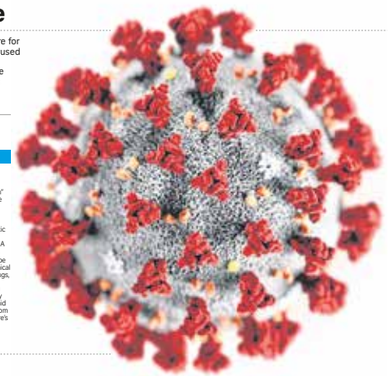
Prof Ng says: "That experience taught me that being a scientist is not just about hiding in the lab, looking at cells and then just about publishing papers about it.

"It's also about how we can help to improve and save lives."

Audrey Tan

Racing towards a cure

Scientists around the world are looking to develop a cure for Covid-19, the disease with pneumonia-like symptoms caused by a novel coronavirus originating from Wuhan, China. **Audrey Tan** speaks to Singapore scientists to learn more about therapeutics – the branch of medicine that looks at treatment methods used to alleviate or prevent a particular disease.



To tackle the current outbreak, scientists are looking to develop three broad categories of therapeutics.

TREATMENT

1 Antiviral drugs

How they work:

- These drugs work by preventing the development of the virus inside the human body.
- Just like a guided missile, these drugs target viruses at different stages of their life cycles in order to disable and block their development.
- By doing so, these drugs ultimately reduce the number of virus particles in the body, and prevent them from spreading.
- She was part of a team at A*Star that developed a kit which could test for the Sars virus in patient blood samples back in 2003.
- This could help shorten the length of symptoms and give the body's immune system time to fight off existing virus particles in the body.

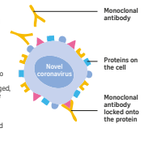
Current status:

- Most antiviral drugs are specific to one or, at most, a handful of similar viruses. A few are "broad-spectrum" and are able to target a wide range of viruses.
- As the novel coronavirus at the centre of the current outbreak comprises a single strand of genetic material known as RNA, antiviral drugs that work against similar RNA viruses are currently being tested.
- Singapore, for example, will likely be participating in a multi-country clinical trial testing a variety of antiviral drugs, including the combination pill lopinavir/ritonavir, which is used to treat the human immunodeficiency virus, which is also an RNA virus, said Associate Professor Hsu Li Yang from the National University of Singapore's Saw Swee Hock School of Public Health and programme leader for infectious diseases.

2 Monoclonal antibody therapy

How they work:

- Monoclonal antibody therapy essentially works by flagging the presence of the virus in the body, so that the immune system can work to get rid of it.
- The immune system comprises many different elements which all work together to rid the body of bacteria or viruses. An important component of this system is antibodies, which are found in the blood.
- When antibodies detect the presence of a virus, they latch on to the infected cell. By doing so, the presence of the problem cell is flagged, and other elements of the immune system can kick in to destroy it.
- In such therapy, laboratory-produced antibodies, known as monoclonal antibodies, are injected into the patient's bloodstream.
- They serve as substitute antibodies that mimic the immune system's attack on infected cells.



Current status:

- Monoclonal antibody therapy is a more specific type of treatment compared with antiviral medications.
- This is because scientists need to find out how exactly antibodies in an infected patient latch on to the virus cells. This latching on is usually done via a lock-and-key approach – the antibodies usually have to take on a certain "shape" before they can bind with the virus.
- As the virus is so new, research is still under way to understand this mechanism, before monoclonal antibodies can be generated in a laboratory, said Professor Lisa Ng, senior principal investigator from the Agency for Science, Technology and Research's Singapore Immunology Network.

PREVENTIVE

3 Vaccines

How they work:

- Vaccines are a preventive strategy that could inoculate the vast majority of the population before they get infected.
- There are two main types of vaccines – live vaccines and inactivated vaccines.
- Both types essentially involve injecting a tiny amount of a less- or non-infectious strain of the virus into the patient, to kick-start the body's protective response to it.
- That way, if the patient later gets infected by the virus, he would already have sufficient levels of antibodies in his blood to get rid of the virus before symptoms develop.

Current status:

- Scientists are now trying to understand more about the virus and how the human immune system responds to it. Such information will help in the development of a vaccine.

Sources: LISA NG, HSU LI YANG, CANCER RESEARCH UK
PHOTO: EPA-EFE SUNDAY TIMES GRAPHICS

The 'sixth sense' and long nights behind virus test kit

As merrymakers ushered in the dawn of the Year of the Rat with spirits, infectious diseases experts in Singapore were on high alert. Their radars, honed by experience, had picked up on a series of pneumonia-like cases in Wuhan, China.

By the time the Chinese authorities alerted the World Health Organisation on Jan 31 that they had an outbreak of an unknown virus on their hands, scientists here were waiting to spring into action.

On Jan 2, Dr Masafumi Inoue, a scientist at the Agency for Science, Technology and Research (A*Star), sent a text to Dr Timothy Barkham, who works at Tan Tock Seng Hospital (TTSH), saying: "How are you, Tim, how's your holiday?"

It was not a run-of-the-mill greeting from a friend.

The two infectious diseases experts first met during the severe acute respiratory syndrome (Sars) outbreak in 2003, and over the past 17 years, have collaborated on the development of diagnostic kits for other disease outbreaks, such as the swine and avian influenzas.

In his message, Dr Inoue attached a link to a news report about the pneumonia outbreak in China.

Dr Barkham replied: "Lots of noise, but no diagnostic details. Happy New Year."

The conversation ended with the pair agreeing to meet soon.

Dr Barkham, 55, a senior consultant medical microbiologist at TTSH's department of laboratory medicine, tells Insight: "We are constantly on the lookout for possible new infectious diseases. And we get reports of possible outbreaks all the time. Often, they turn out to be isolated cases, but we are always waiting to see what's next."

No one knew what this virus was, how it related to other known viruses, or where it had come from.

With no reported cases in Singapore, there were no patient samples to work with.

But Dr Inoue had a "sixth sense" it would be significant. "Based on what I observed of past events, such as the 2009 swine flu and the 2016 Zika outbreak, I had a hunch," says the head of the diagnostics group in the translational sciences division of A*Star's Experimental Drug Development Centre.

On Jan 12, the full genome of the Sars-CoV-2 virus, which causes the disease now known as Covid-19, was uploaded onto a public database.

A virus' unique genome serves as a "fingerprint" to distinguish it from other viruses.

Once the genome was made available, scientists could determine that the coronavirus was related to the virus that caused the 2003 Sars outbreak which killed almost 800 people.

Scientists from A*Star and TTSH, including Dr Inoue and Dr Barkham, were now able to develop a diagnostic test kit to help clinicians at public hospitals diagnose infections with high accuracy.

Tests for 10,000 patients have also been delivered to China, as part of Singapore's efforts to help tackle the international outbreak.

To develop the diagnostic test, Dr Inoue's team first compared the genome of the new virus with that of related viruses, such as Sars, and identified parts of the genetic code that were unique to Sars-CoV-2.

The test flags these unique areas in a process known as polymerase chain reaction (PCR).

The diagnostic test kits were developed and rolled out in less than a month – a record, considering that a similar one for Sars took months – but its speed belied the effort that went into it.

Both men and their teams had many sleepless nights and countless discussions over text messages, e-mail and the occasional beer, to troubleshoot problems, fine-tune the product and overcome challenges such as disruptions in the supply of chemicals needed.

A day after Singapore diagnosed its first coronavirus patient on Jan 23 – a 66 year-old man from Wuhan who had stayed at a hotel on Sentosa – Dr Inoue and Dr Barkham met to discuss the development of the diagnostic kit at – of all places – Sentosa, where a food festival was taking place.

Asked if they had been afraid of getting infected, Dr Inoue says: "No. That's one important thing to note – that the risk of infection is very low in an open space."

Dr Barkham says the close synergy between the hospitals and research scientists was crucial in the development of the diagnostic test, and is the result of a close partnership that began in 2003.

He said: "At the hospitals, our aim is to deliver a service to patients. What may work well in a lab setting may not be that practical in the hospital. So we have to constantly give each other feedback on how to improve the diagnostic test so it will benefit patients."

This includes, among other things, being able to try out the diagnostic tests on real human samples, which could have other molecules or compounds that could disrupt the test, giving it false positive or negative readings, he says.

Also, for the readings from the PCR machine to be accurately used by clinicians in diagnosis, both teams worked to optimise them, carrying out the test at different temperatures to see which temperature registered the clearest reading.

Though there can be differences in expectations between scientists who develop the tests and those who implement them, both want the same thing: for the science to benefit the public.

Talks are now ongoing to scale up production of the diagnostic kits for distribution to other hospitals here, says A*Star.

Dr Inoue says it is important for Singapore to develop and manufacture its own diagnostic test kit in a disease outbreak. "We have the technology. And if we develop one ourselves, we won't be put in a situation where we have to rely on others to help control the outbreak."

Audrey Tan

Dr Timothy Barkham from Tan Tock Seng Hospital and Dr Masafumi Inoue from the Agency for Science, Technology and Research worked with other scientists to develop a test kit to diagnose infections with high accuracy. ST PHOTO: JASON QUAH

The measures taken here are based on experience and data from previous viral outbreaks which have been effective, says Professor Tan Chorh Chuan, chief health scientist at the Ministry of Health. ST PHOTO: KELVIN CHNG

More prepared, less fearful now than during Sars

Joyce Teo
Senior Health Correspondent

The chief health scientist at the Ministry of Health (MOH), Professor Tan Chorh Chuan, sheds light on the measures Singapore has in place to fight the coronavirus outbreak.

***Q** There are fears that the coronavirus is airborne. Is this the case?*

A We really need to look for more data. Infections that spread mainly by airborne transmission tend to be more infectious than what we see now – it would be conditions like chicken pox.

We reference how coronaviruses tend to be spread, and it's usually through droplets and hand contact.

In Wuhan, there are many reasons it spread so quickly. The whole city was isolated and conditions are very different, so it may not be representative of where we are at in Singapore.

***Q** What are the changes you have made to your lifestyle now that there is local transmission?*

A I continue to do what I normally would do, except I am much more careful about keeping my hands clean. It'll actually be hard to live normally if we went way beyond that, because we will always be in situations where we come into contact with people.

There's uncertainty with a new virus when it first appears. There is what we already know from other types of similar viruses and there's a period when concerns are raised, fears go up. We need to try to understand these issues and how best to address them.

It's part of confronting a new virus that we have not encountered before and learning as quickly as you can about it.

In the meantime, the practices that we are putting in place are based on experience and on data from previous types of viral outbreaks which are similar and which have been effective in those circumstances.

***Q** As MOH's director of medical service from 2000 to 2004, you were responsible for leading the public health response to the 2003 Sars epidemic. What's the key difference now?*

A People are more confident and less fearful. During Sars, many people and healthcare professionals were very fearful. I was very fearful because we had never experienced an outbreak like it before and our systems were not as prepared.

Today, for instance, there is proper use of PPE (personal protection equipment), measures to separate potentially infected patients from those who are not, working in split teams.

When Sars first started, we didn't have enough protective equipment so I had to ration the supplies. Now, we are well prepared in that regard.

Research has also improved globally and in Singapore – we can sequence much faster and develop diagnostic kits much faster. All this speeds up our understanding of this virus at a much faster rate.

During Sars, we had to manage the first five weeks without a diagnostic kit. Can you imagine trying to control an outbreak without a diagnostic kit?

***Q** What did we learn from the Sars epidemic when it comes to handling infected patients?*

A I remember, early on in the Sars epidemic, there were groups that recommended that wearing one set of masks was not good enough, you have to wear two sets.

But when we managed all the patients within Tan Tock Seng Hospital and all the health professionals were properly trained and used protective equipment, we saw that no other healthcare workers were infected.

So, you definitely didn't need to wear two or three masks. In fact, what we are using now for PPE is sufficient to protect health professionals.

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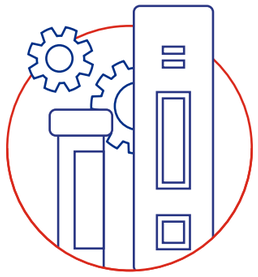


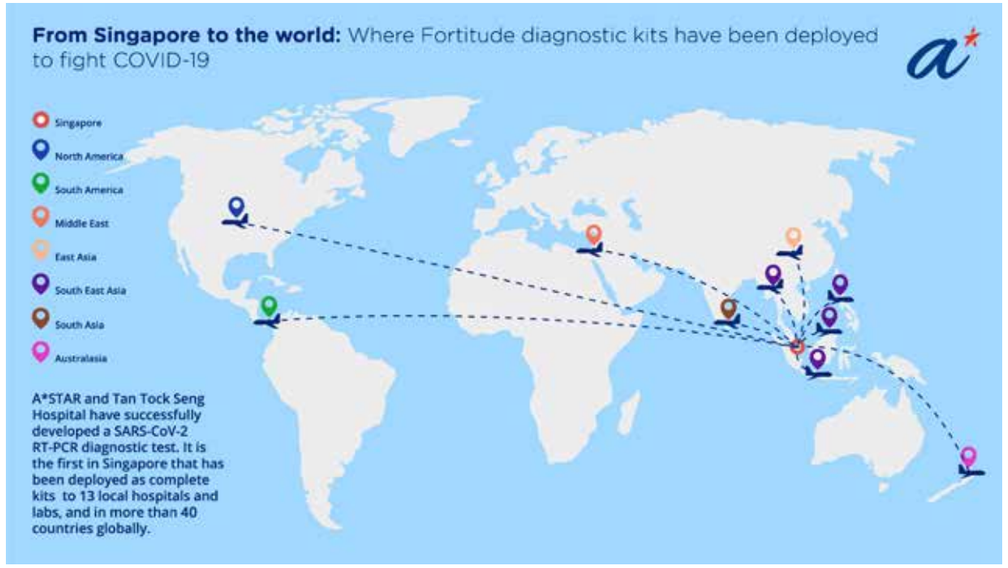
DIAGNOSTIC KITS AND COMPLEMENTARY SYSTEMS

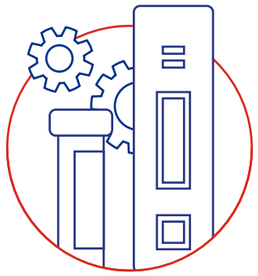
Enabling fast, accurate and safe testing of the coronavirus to help curb the spread of the pandemic in Singapore and globally

The Fortitude Kit is the first "ready-made" hospital lab diagnostic test kit that received the Singapore Health Sciences Authority's (HSA) Provisional Authorisation for clinical use. Co-developed by A*STAR's Experimental Drug Development Centre (EDDC), Bioinformatics Institute (BII) and the Department of Laboratory Medicine at Tan Tock Seng Hospital (TTSH), the diagnostic test kit detects the presence of the novel coronavirus (SARS-CoV-2) with high accuracy.

Thanks to close collaboration between scientists and the public health community, the Fortitude Kit diagnostic was developed and deployed in Singapore hospitals within a month. A*STAR worked with the National Public Health Laboratory at the National Centre for Infectious Diseases (NCID), Singapore, on the appropriate manufacturing standards of the tests. The Diagnostics Development (DxD) Hub, a national initiative led by A*STAR, further supported the development and production of these tests. A*STAR has since transferred the technology know-how to biotechs, including local company MiRXES, to scale-up, and manufacture the kits to fulfil local and international demand.

*Team members from left to right: Dr Sebastian Maurer-Stroh, Deputy Executive Director (Research), Bioinformatics Institute, A*STAR; Dr Masafumi Inoue, Group Leader, Diagnostics Group, Translational Sciences, Experimental Drug Development Centre, A*STAR; Dr Sidney Yee, CEO, Diagnostics Development Hub; Associate Professor Dr Timothy Barkham, Senior Consultant Medical Microbiologist, Department of Laboratory Medicine, Tan Tock Seng Hospital*





DIAGNOSTIC KITS AND COMPLEMENTARY SYSTEMS

The RESOLUTE 2.0 Direct PCR Diagnostic Kit and complementary automated lab system, RAVE, increases COVID-19 test delivery throughput by four times, to support the national need for expanded testing capacity. A breakthrough Direct-Polymerase Chain Reaction (PCR) diagnostic test kit for COVID-19, RESOLUTE 2.0, was jointly developed by the DSO National Laboratories and A*STAR's DxD Hub. This was an outcome of a strategic partnership between DSO and A*STAR that was inked in January 2020 to strategically align the defence-civilian research agenda.

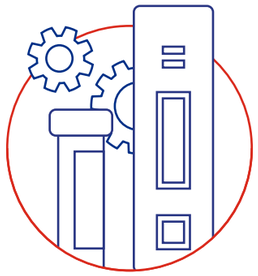
A*STAR also developed a robotics lab system, the Rapid Automated Volume Enhancer (RAVE) to complement RESOLUTE 2.0. Local small and medium-sized enterprise (SME), Sankei Eagle is a systems integrator for RAVE. Several manual processes, such as handling of test samples, capping and uncapping of test tubes, as well as pipetting and movement of liquids, are automated with custom-built robotics systems. RAVE allows for high accuracy, speed, and enhanced safety for laboratory staff. The integrated RESOLUTE 2.0 and RAVE system combines A*STAR's engineering and biomedical science capabilities. Distributed by local enterprise Advanced MedTech, RESOLUTE 2.0 and RAVE have been deployed to three local hospitals.

*The DSO National Laboratories (left) and A*STAR teams (right) involved in developing an improved COVID-19 test kit called RESOLUTE 2.0.*

Source: DSO NATIONAL LABORATORIES

Rapid Automated Volume Enhancer (RAVE) automated lab system

*The RESOLUTE 2.0 COVID-19 test kit developed by DSO National Laboratories and A*STAR can deliver test results in about 90 minutes.*



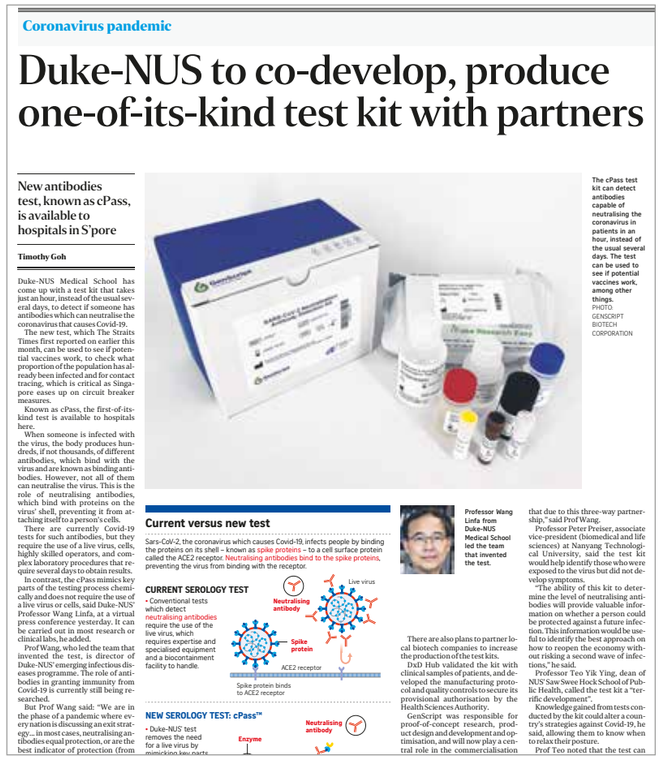
DIAGNOSTIC KITS AND COMPLEMENTARY SYSTEMS

- **Local precision medicine company Lucence developed a saliva sample collection kit that can keep the samples stable at room temperature for up to a week. The kit also inactivates SARS-CoV-2, the virus which causes COVID-19, within 45 seconds of sample collection.** The reagent fluid used in the kit was invented at A*STAR's Institute of Bioengineering and Nanotechnology (IBN). The kit's viral inactivation capabilities could mean enhanced safety and reduced risk of exposure for those involved in the collection, transport, and testing processes. This kit will be especially useful in countries where samples must be transported across long distances for testing.

The Safer-Sample kit contains a bottle of fluid that can be mixed with certain types of virus samples at the point of collection. This fluid can keep the samples stable at room temperature for up to a week, while inactivating SARS-CoV-2 within 45 seconds of sample collection.

Source: Lucence

- **A first-in-the-world "rapid smart test kit", the cPass can measure neutralising antibodies in an hour, and will be instrumental in vaccine and therapeutic development.** Duke-NUS is co-developing and manufacturing the kit with biotechnology company GenScript Biotech Corporation and A*STAR's DxD Hub. A*STAR validated the kit with clinical samples of patients, and developed the manufacturing protocol and quality controls to secure its provisional authorisation by the Health Sciences Authority. The test kit is available to hospitals in Singapore and globally.



Coronavirus pandemic

Duke-NUS to co-develop, produce one-of-its-kind test kit with partners

New antibodies test, known as cPass, is available to hospitals in S'pore

Timothy Goh

Duke-NUS Medical School has come up with a test kit that takes just an hour, instead of the usual several days, to detect if someone has antibodies which can neutralise the coronavirus that causes Covid-19.

The new test, which The Straits Times first reported on earlier this month, can be used to see if potential vaccines work, to check what proportion of the population has already been infected and for contact tracing, which is critical as Singapore eases up on circuit breaker measures.

Known as cPass, the first-of-its-kind test is available to hospitals here.

When someone is infected with the virus, the body produces hundreds, if not thousands, of different antibodies, which bind with the virus and are known as binding antibodies. However, not all of them can neutralise the virus. This is the role of neutralising antibodies, which bind with proteins on the virus' shell, preventing it from attaching itself to a person's cells.

There are currently Covid-19 tests for such antibodies, but they require the use of a live virus, cells, highly skilled operators, and complex laboratory procedures that require several days to obtain results.

In contrast, the cPass mimics key parts of the testing process chemically and does not require the use of a live virus or cells, said Duke-NUS' Professor Wang Linfa, at a virtual press conference yesterday. It can be carried out in most research or clinical labs, he added.

Prof Wang, who led the team that invented the test, is director of Duke-NUS' emerging infectious diseases programme. The role of antibodies in granting immunity from Covid-19 is currently still being researched.

But Prof Wang said: "We are in the phase of a pandemic where every nation is discussing an exit strategy... in most cases, neutralising antibodies equal protection, or are the best indicator of protection (from

The cPass test kit can detect antibodies capable of neutralising the coronavirus in patients in an hour, instead of the usual several days. The test can be used to see if potential vaccines work, among other things.
PHOTO: GENSCRIPT BIOTECH CORPORATION

Current versus new test

Sars-CoV-2, the coronavirus which causes Covid-19, infects people by binding the proteins on its shell – known as spike proteins – to a cell surface protein called the ACE2 receptor. Neutralising antibodies bind to the spike proteins, preventing the virus from binding with the receptor.

CURRENT SEROLOGY TEST

• Conventional tests which detect neutralising antibodies require the use of the live virus, which requires expertise and specialised equipment and a biocontainment facility to handle.

NEW SEROLOGY TEST: cPass™

• Duke-NUS' test removes the need for a live virus by mimicking key parts

Professor Wang Linfa from Duke-NUS Medical School led the team that invented the test.

There are also plans to partner local biotech companies to increase the production of the test kits.

DxD Hub validated the kit with clinical samples of patients, and developed the manufacturing protocol and quality controls to secure its provisional authorisation by the Health Sciences Authority.

GenScript was responsible for proof-of-concept research, product design and development and optimisation, and will now play a central role in the commercialisation that due to this three-way partnership," said Prof Wang.

Professor Peter Preiser, associate vice-president (biomedical and life sciences) at Nanyang Technological University, said the test kit would help identify those who were exposed to the virus but did not develop symptoms.

"The ability of this kit to determine the level of neutralising antibodies will provide valuable information on whether a person could be protected against a future infection. This information would be useful to identify the best approach on how to reopen the economy without risking a second wave of infections," he said.

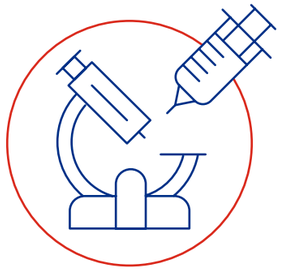
Professor Teo Yik Ying, dean of NUS' Saw Swee Hock School of Public Health, called the test kit a "terrific development".

Knowledge gained from tests conducted by the kit could alter a country's strategies against Covid-19, he said, allowing them to know when to relax their posture.

Prof Teo noted that the test can

Source: The Business Times © Singapore Press Holdings Limited. Permission required for reproduction.

- **The ASSURE test kit can accurately identify SARS-CoV-2 antibodies in 15 minutes and employs a lateral flow format, similar to those used in home pregnancy tests. The kit was co-developed by A*STAR and diagnostics company MP Biomedicals.** Serological test kits are especially important for contact tracing purposes given that there are large numbers of asymptomatic COVID-19 cases around the world. The ASSURE kit can determine if one has acquired immunity in the form of antibodies generated by the human body after exposure to the SARS-CoV-2 virus.



ANTIBODY DISCOVERY AND THERAPEUTICS

Expediting the search for treatment of COVID-19 patients

- **A*STAR scientists discovered an antibody that targets a specific part of the coronavirus, preventing it from infecting human cells.** Together with Japanese pharmaceutical company Chugai Pharmabody Research, the scientists are currently working on **optimising the therapeutic antibody for clinical use.**

Above: Dr Wang Cheng-I (right) and Ms Eve Ngoh from A*Star's Singapore Immunology Network – in a photo taken before the circuit breaker period – and their team are working with Chugai Pharmabody Research from Japan to engineer the antibody for clinical use. PHOTO: A*STAR

Left: Esco Aster's senior bioprocess scientist (vaccine development) Nandini Prabhakar beside the bioreactor that is used to culture the vaccine which the home-grown firm is working on with a US biotech company. ST PHOTO: KELVIN CHNG

A*Star researchers discover antibody that targets key part of virus

Researchers at Singapore's Agency for Science, Technology and Research (A*Star) have discovered an antibody that targets a specific part of the coronavirus, preventing it from infecting human cells, and are moving to develop it to defend against the Covid-19 disease.

Dr Wang Cheng-I, senior principal investigator at A*Star's Singapore Immunology Network, said that his team discovered the antibody in mid-March, finding it in a collection of 30 billion human antibodies made by recombinant DNA technology.

Source: The Straits Times © Singapore Press Holdings Limited. Permission required for reproduction.

- **The National Centre for Infectious Diseases (NCID) and A*STAR discovered the specific sites on the novel coronavirus that trigger the body to produce antibodies that prevent further COVID-19 infection.** These findings demonstrated that antibodies produced during infection attach to many parts of the virus, but only some antibodies are capable of eliminating the virus or offering protection against infection. The information will be used to guide development of treatments.

> *"The identification of these specific targets on the virus is a crucial advance in the development of better diagnostics and treatments for COVID-19. There is also potential to use these targets against similar coronaviruses to address other viral outbreaks."*
>
> - Professor Lisa Ng, Senior Principal Investigator at A*STAR's Singapore Immunology Network

- **The discovery of a new variant of the COVID-19 virus that causes milder infections has placed Singapore's R&D ecosystem on the map.** The findings of Singapore scientists from A*STAR's Singapore Immunology Network (SIgN), the NCID and Duke-NUS Medical School were published in The Lancet medical journal. It demonstrated that COVID-19 patients infected with this new variant of SARS-CoV-2 had better clinical outcomes. The variant, which likely came from Wuhan, China, was detected in a cluster of infections that occurred from January to March 2020. The variant has a large deletion that removes the ORF8 gene. In Singapore, the virus was transmitted from person to person across several clusters before being contained. The findings could have implications on the development of treatments and vaccines.

Professor Lisa Ng, senior principal investigator at A*Star's Singapore Immunology Network and a member of the team behind the latest discovery, which centres around a specific type of antibody that can prevent the virus from hijacking a human cell in the first place or prevent it from replicating inside a human cell. ST PHOTO: KELVIN CHNG

S'pore researchers discover antibodies that neutralise virus

Their findings could lead to better diagnostics and treatments, and guide vaccine development

Audrey Tan
Science Correspondent

The search for antibodies that can neutralise the coronavirus in a Covid-19 patient can be like looking for a needle in a haystack, but researchers in Singapore have prevailed.

They have found antibodies, a key element of the human immune system, that bind to four important sites of the coronavirus.

In binding to these sites, the antibodies prevent the virus from either hijacking a human cell, or replicating inside it.

These findings by scientists from the National Centre for Infectious Diseases (NCID) and the Agency for Science, Technology and Research (A*Star) were announced at a virtual press conference yesterday.

national scientific community with numerous unsolved questions.

But the latest discovery by the Singapore team has shed light on a key unknown: The human body's defence mechanisms against viruses.

While the findings could pave the way for better treatments and the development of a vaccine, the researchers say a lot more work is needed.

For example, one big unknown is how long the antibodies would persist in a recovered patient. The NCID will continue to monitor the antibody levels in recovered patients over two years to better determine this.

The latest discovery, published in two scientific journals – Nature Communications and EBioMedicine by The Lancet – centres around a specific type of antibody that can prevent the virus from hijacking a human cell in the first place, or prevent it from replicating inside a human cell.

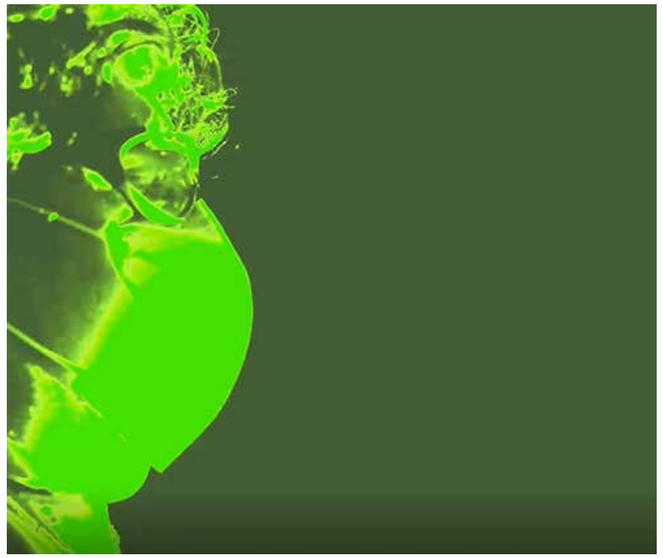
These antibodies are collectively known as neutralising antibodies, and they are but one of thousands of immune system "soldiers" that are produced by the body during

Source: The Straits Times © Singapore Press Holdings Limited. Permission required for reproduction.

BIOINFORMATICS AND MODELLING STUDIES

Tapping on modelling and simulation work to keep track of everything from the evolution of the SARS-CoV-2 virus to informing public policy on the safe re-opening of public spaces

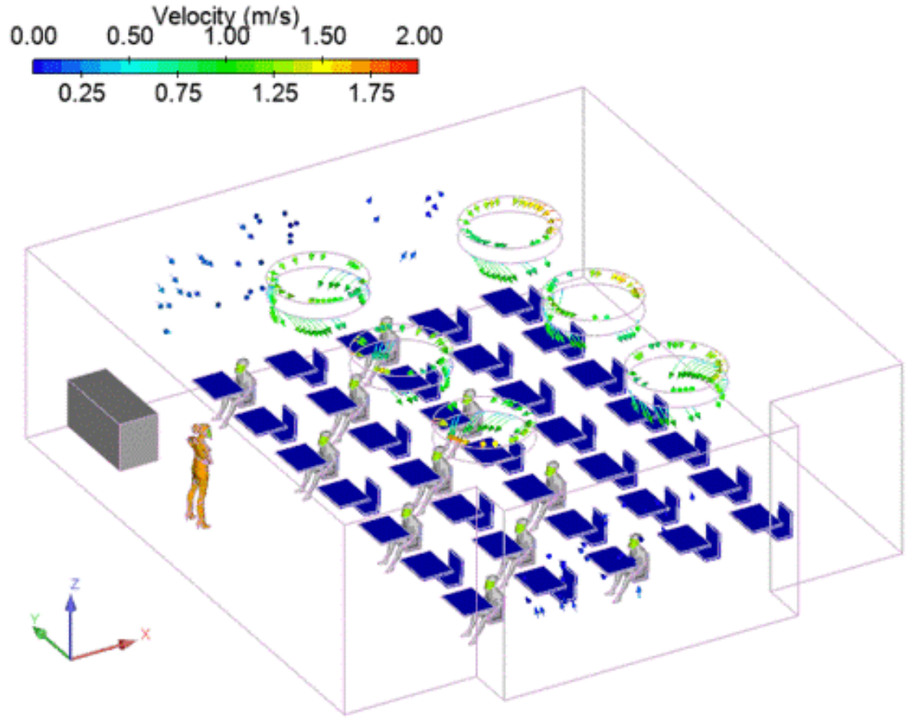
This image captured from a high-speed and high-sensitivity camera shows a subject coughing without wearing a mask.



This image shows the subject coughing while wearing a mask securely.

- **A*STAR scientists, together with SingHealth doctors from the SGH Department of Infectious Diseases, and the Department of Respiratory and Critical Care Medicine, designed an experiment to show the importance of wearing a mask in helping to prevent the spread of viruses.** Using laser sheets and high-speed cameras, as well as modelling and simulation, the experiments showed that when one wears a mask properly, it can significantly reduce the spread of droplets and aerosols ejected from the nose and mouth. The experiment serves to educate the public on the importance of wearing masks, and inform national policy.

- **Airflow Modelling in Public Spaces to Understand Droplet Transmission**
A*STAR has also embarked on a study to understand the risk of environmental transmission using airflow and droplet transport modelling supplemented with experimental droplet studies. This will enhance public health policy-making and better advise the public on safe distancing measures and guidelines.



- **A*STAR continually tracks the evolution of the virus, to inform the various COVID-19 R&D projects in Singapore as well as the global scientific community.** Dr Sebastian Maurer-Stroh, Deputy Executive Director (Research), and his team at the Bioinformatics Institute at A*STAR are part of the core scientific and curation team at the Global Initiative on Sharing All Influenza Data (GISAID). The platform promotes the international sharing of the relevant virus sequences for various applications to combat the virus. For instance, Dr Maurer-Stroh's work ensures the continual high accuracy of the Fortitude Kit in detecting the virus in COVID-19 patients.

PROTECTIVE FACE MASKS

Ensuring a secured supply of protective face masks for Singapore

As Singapore presses on in its fight against COVID-19, face masks have become an integral part of daily life to complement social distancing and personal hygiene practices. **A*STAR worked with local enterprises, including textile and apparel manufacturer Ramatex, to help them design effective masks for Singaporeans' use.** As global supply chains were disrupted by the pandemic, the key challenge in mask production has been the sourcing of raw materials. Researchers from A*STAR's Singapore Institute of Manufacturing Technology (SIMTech) and Advanced Remanufacturing and Technology Centre (ARTC) collaborated with Ramatex in the search for materials that could work as effectively, if not more so, than what was available. Tapping on the company's deep knowledge in textiles, and A*STAR's scientific know-how, the team was able to repurpose materials to design a mask that was almost as effective as medical masks, yet as comfortable and reusable as cloth masks. Special editions of these masks were also distributed to the public as part of the National Day Parade (NDP) Singapore Together Pack 2020.

The mask's ergonomic, duck beak design provides good breathability and facial coverage while reducing the components needed – such as the metal nose bridge typically found in disposable masks.

One ground-up initiative was a Do-It-Yourself (DIY) mask, the result of brainstorming between A*STAR's student researchers and scientists. **Using easily available household materials and consumables, this DIY mask could serve as an alternative to a commercial surgical mask if other options were unavailable or have been exhausted.** This was timely, as it provided a potential option to address the perceived shortage of surgical masks back in March 2020. The DIY mask was tested and evaluated at A*STAR, and also went through third party testing at TUV-SUD. Watch this video to learn how to make your own DIY mask.

Joyce Tan (pictured above) and Jason Tan, PhD students with IBN, put together the DIY mask video and taught some of the social service agencies to make these masks, to help more vulnerable members of the community learn to make them too.

The masks were distributed to each household as part of the NDP Singapore Together Pack.

ANALYTICS AND DETECTION

Supporting remote monitoring of COVID-19 patients to ease healthcare operations

Researchers and technology firms around the world, including those in Singapore, are working on wearable technology devices – to monitor and detect COVID-19, even before its symptoms surface in patients. Local medical technology start-up Respiree aims to save patient lives by predicting clinical deterioration early. An A*STAR spin-off, Respiree's core technology is a sensor platform developed at the Singapore Bioimaging Consortium (SBIC), A*STAR. The platform combines breath-cardio sensing and artificial intelligence analytics to help predict and manage early onset of clinical deteriorations, such as worsening conditions from respiratory diseases. Today, the Respiree devices are deployed on trial across segments in selected local hospitals, to support healthcare workers in caring for COVID-19 patients that often suffer from acute respiratory symptoms. Currently, Respiree and the National University Hospital (NUH), NUS Yong Loo Lin School of Medicine (NUS Medicine) are collaborating on a research study to develop predictive models using respiratory rate and breathing variability, to detect clinical deterioration in patients suffering from acute respiratory failure and pneumonia early and accurately. The aim is to deploy the use of novel respiratory biomarkers to predict worsening conditions in isolated COVID-19 patients.

Local medical technology start-up Respiree's wearable device which is used to measure vital parameters such as respiratory rate or blood oxygen levels.

Source: Respiree

A*STAR and SingHealth, with support from the Integrated Health Information Systems (IHIS), developed a "Doctor COVID" chatbot on instant messaging service Telegram, to improve communication with COVID-19 patients remotely. Patients who subscribe to the chatbot service get daily broadcast messages such as reminders and other medical information, as well as regular check-ins on their mental well-being. This effort helps to minimise transmission risk among healthcare workers. An upgraded version out later this year will incorporate conversational artificial intelligence (AI) technology, which uses machine learning and natural language processing to analyse and respond to complex questions posed by users.

'Chatbot doctor' for 3,000 patients in community care facilities

Yip Wai Yee
Tech Correspondent

His bedside manner might leave a bit to be desired, but Doctor Covid is proving quite a tonic for 3,000 patients staying in community care facilities.

The doctor is, in fact, a chatbot service on instant messaging service Telegram, but he never misses reminding those patients to record their vital signs.

The chatbot was developed by SingHealth and the Agency for Science, Technology and Research with support from the Integrated Health Information Systems to improve communication with Covid-19 patients while minimising transmission risk among healthcare workers. Patients who subscribe to the chatbot service get daily broadcast messages such as reminders and other medical information as well as regular check-ins on their mental well-being.

One week into his stay at a community care facility, for example, a patient could be prompted with questions such as "Are you scared?" and "Are you sad?"

Responses are anonymised and used to identify trends and risk indicators related to the virus, and may also be used for more long-term research purposes, among other things.

Occasionally, Doctor Covid will offer patients movie links, exercise videos and video clips featuring words of encouragement from celebrities to lift spirits.

The chatbot service is available in five languages, including Bengali. An upgraded version out later this year will incorporate conversational artificial intelligence (AI) technology, which uses machine learning and natural language processing to analyse and respond to complex questions posed by users.

Mr Franklin Tan, SingHealth's director of the office for service transformation, said yesterday that the chatbot solves two problems – patients who may face language barriers with staff, and the manpower constraints with healthcare workers having to care for many people.

"Doctor Covid leverages innovation and technology to better... care for these residents, while allowing healthcare workers to gain better insight into how each resident is doing," he added.

Community care facilities, such as those at Singapore Expo, house thousands of Covid-19 patients – most of whom are migrant workers – who are clinically well or have mild symptoms.

Doctor Covid is similar to SG-DormBot, a chatbot service available via WhatsApp that is being used at a number of foreign worker dormitories. The bot developed by the National University Health System and AI healthcare start-up Bot MD reminds users daily in their native languages to record their vital signs, and sends instant alerts to doctors whenever abnormal readings pop up.

yipwy@sph.com.sg

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People's feelings about COVID-19 around the world have shifted from fear to anger and joy as the pandemic developed, according to a study led by Nanyang Technological University (NTU) that analysed 20 million tweets on Twitter from January to April 2020. A machine-learning algorithm called CrystalFeel, developed by A*STAR was used to analyse the tweets. It is able to identify joy, sadness, fear and anger based on words or phrases. These findings can help authorities to make informed decisions to address public sentiments such as fear and anger in a timely manner.

Global sentiments on coronavirus evolved from fear to anger to joy: NTU study

DAVID SUN

When news of Covid-19 broke at the start of the year, the world was gripped by fear.

As the virus steadily spread, anger took hold, with a significant number on social media voicing xenophobic sentiment at a time when China was the epicentre of the outbreak.

A study led by Nanyang Technological University (NTU) analysing tweets found that global sentiments surrounding Covid-19 evolved rapidly.

The work is funded by the Agency for Science, Technology and Research (A*Star) and the National Research Foundation Singapore.

An algorithm called CrystalFeel, developed by A*Star, was used to identify joy, sadness, fear and anger based on words or phrases.

Researchers analysed more than 20 million tweets from January to April, posted by more than seven million users from more than 170 countries.

The study, published in May, found that fear was the dominant emotion from late January to early March.

Anger started to grow and on March 12, a day after the World Health Organisation declared the Covid-19 outbreak a pandemic, angry sentiments peaked.

Then, from late March to early April, a more joyful sentiment emerged as many countries saw national pride and community spirit, which researchers said offered a "glimmer of hope".

The lead researcher, Professor May O. Lwin, chair of the NTU Wee Kim Wee School of Communication and Information, warned that volatile emotions like fear and anger needed to be addressed by the authorities.

"If such overbearing public emotions are not addressed through clear and decisive communication by authorities, citizen groups and social media stakeholders, there is potential for the emergence of issues such as breeding mistrust in the handling of the disease, and a belief in online falsehoods that could hinder the ongoing control of the disease."

NEXT PHASE

The study is now into its next phase, as the data is split by country to derive unique variations and trends for each nation.

Preliminary findings suggest that Singaporeans are able to see the silver lining in situations, said Prof Lwin, who revealed that a more balanced sentiment was found here, compared with strong negative sentiments in other countries, "likely due to Singapore public's trust in the authorities and the healthcare system, as well as clear government communication which help raise the population's optimism and confidence in the face of crisis".

She added that aside from government intervention, it was the community that could decide whether it wanted to come together or stay isolated and angry.

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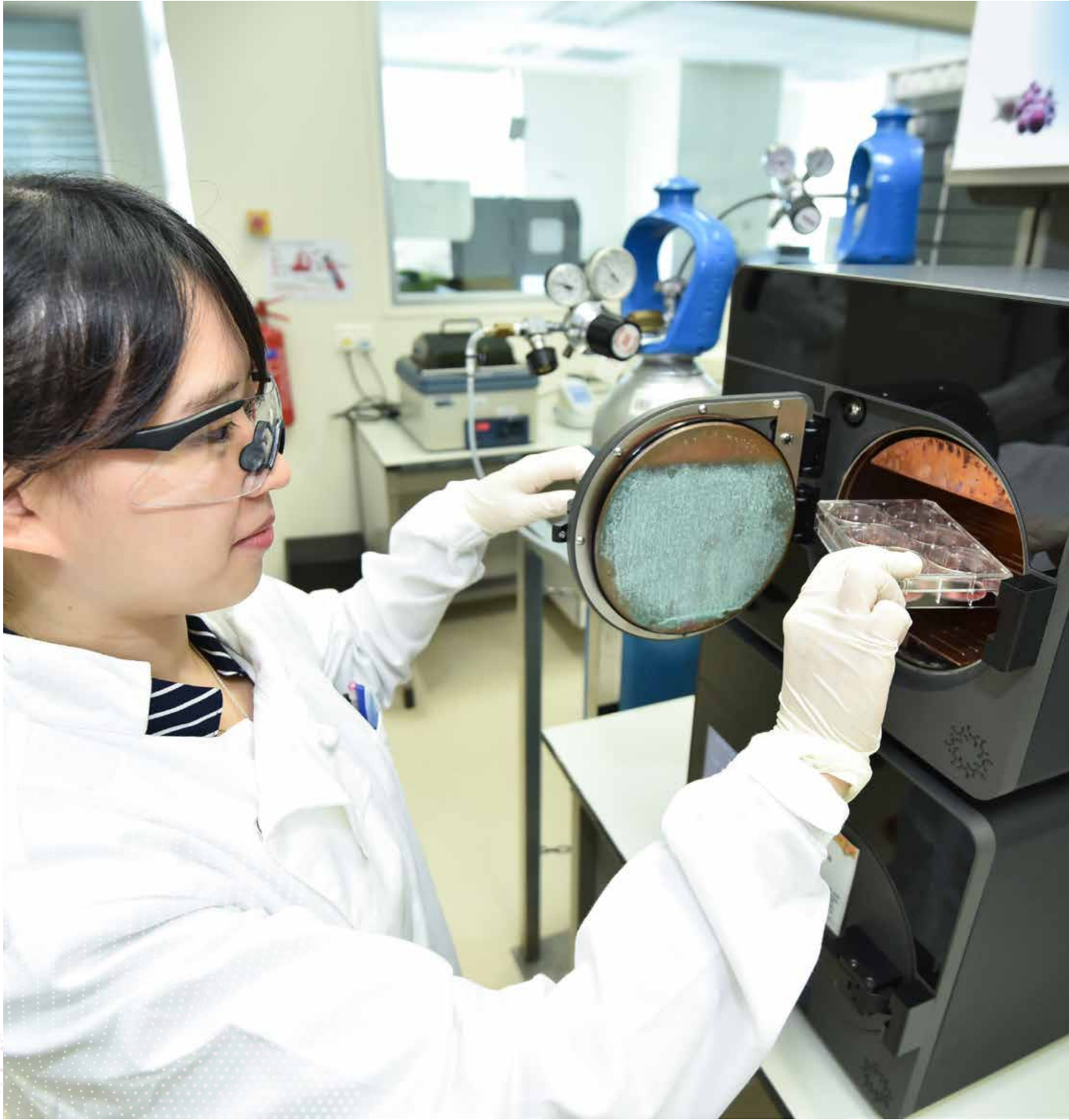


CONTRIBUTING TO BETTER HEALTH OUTCOMES FOR SINGAPOREANS

A*STAR contributes to better living, and health outcomes for Singaporeans by working closely together with the public sector and industry to develop and leverage technology. The goal is to build resilient and sustainable systems for the future, in the areas of prevention, diagnosis and treatment of diseases, as well as solutions for an ageing population.

LEARN more about the Experimental Drug Development Centre.

1. Supporting the Local Drug Development Ecosystem

*Building on capabilities honed over the years, A*STAR supports Singapore's R&D ecosystem in developing innovative medicines.*

The Experimental Drug Development Centre (EDDC), a national platform for drug discovery and development was officially launched by Mr Heng Swee Keat, Deputy Prime Minister, Coordinating Minister for Economic Policies, Minister for Finance, and Chairman of the National Research Foundation (NRF) on 26 June 2019. The centre channels high potential drug candidates toward commercial and clinical outcomes. A key milestone: EDDC has successfully moved the drug candidate ETC-159 – a novel small molecule drug candidate for colorectal cancer and other solid tumours – into Phase 1B of clinical trials.

As part of the national strategy, the **Target Translation Consortium (TTC)** was also set up in August 2019 with eight public institution members. The objective is to synergise expertise and resources to improve the rate at which public research is translated into new medicines.

The Business Times | Thursday, June 27, 2019

GOVERNMENT & ECONOMY | 17

S'pore drug development gets another shot in the arm

One goal for EDDC will be to create projects that are attractive to multinational pharmaceutical companies

By Jaira Koh
jairakoh@sph.com.sg

Singapore

A*STAR officially opened the new Experimental Drug Development Centre (EDDC) on Wednesday to take more made-in-Singapore drugs from early-stage drug discovery to clinical trials and commercialisation.

Towards this end, the statutory board also launched the Target Translation Consortium (TTC), which coordinates drug discovery efforts in academia, healthcare institutions and government agencies, and consolidated three existing A*Star grants into the Singapore Therapeutics Development Review (STDR).

In its four-storey section of Biopolis, EDDC integrates three earlier A*Star drug discovery development units, to "better harness the synergies in talent, capabilities, technology and infrastructure," said A*Star chairman Chan Lai Fung.

The TTC will complement the EDDC by facilitating discussions of promising early-stage proposals across organisational boundaries. It will also establish and share methods and criteria for evaluating projects as they move through the development process. A*Star's new grant will fund early-stage projects up to S$750,000.

Singapore has an opportunity to meet the global demand for health, "especially as growth in Asia is expected to outpace the global average," said Deputy Prime Minister Heng Swee Keat, who officiated EDDC's opening ceremony. "We are the third largest health-tech investment ecosystem in Asia, after China and India," said Mr Heng, who is also chairman of the National Research Foundation and Minister for Finance.

"Singapore's biotech companies can collectively contribute to improving the lives of patients and their families in Asia, and open up new markets for their technologies and our economy. Our three largest biotech companies were reported to have an estimated collective valuation of more than US$1 billion."

The biotech boom in Singapore is a somewhat recent one, said A*Star's biomedical research council executive director, Benjamin Seet. For the first 10 to 15 years of Biopolis' lifetime, the number of biomedical companies in Singapore actually flatlined in the low tens, said Dr Seet. But in the last five years, that number has since shot up to nearly 100 today.

"What we're seeing is that increasingly, made-in-Singapore assets – whether it's in the universities, hospitals, or A*Star – are now going to the local pipeline," he said. "Even when you look at the companies, quantitatively they are stronger companies in terms of having assets that are in later stages of development, some even as late as Phase 3 clinical trial."

In 2017, Tessa Therapeutics, a Singaporean immunotherapy firm valued at S$650 million, acquired Euchloe Bio, an A*Star spinoff. The following year, Japanese drug maker Chugai Pharmaceutical invested an additional S$282 million in its Singapore research unit.

Local biotech has even caught the eye of venture capitalists. Singapore-based Venturecraft recently made a US$40 million Series A investment to merge with another A*Star spinoff, Mirxes.

One goal for EDDC will be to create projects that are attractive to multinational pharmaceutical companies, said EDDC CEO Damian O'Connell. "We're now already in negotiations with certain world-class, top-10 multinational pharmaceutical companies where we want to co-develop their assets with us. So it's not just handing over assets, potentially, but also them bringing assets into us."

Dr Seet offered several other measures of success for EDDC, such as made-in-Singapore drugs treating patients in Asia, licencing agreements with pharmaceutical or biotech companies, or, simply, successful Singapore companies.

"At the ecosystem level, a sustainable ecosystem comprises scientists, companies, venture capital, contract research organisations, supporting each other and creating economic output from their various activity. So it's all the way from treating a patient to building an ecosystem."

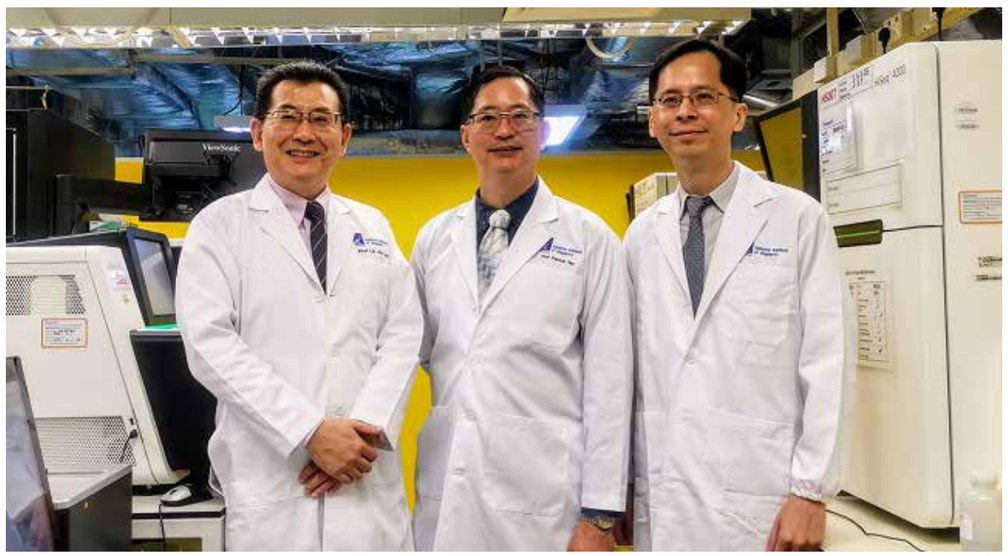
Mr Heng touring the high throughput screening laboratory at the Experimental Drug Development Centre on Wednesday.

Source: The Business Times © Singapore Press Holdings Limited. Permission required for reproduction.

2. Driving Asian Phenotype-Focused Cancer Research

*Supported by A*STAR and tapping on its multi-ethnic population, Singapore has world-class R&D capabilities in the biomedical sciences, particularly on the Asian phenotype and lifestyle.*

A*STAR's Genome Institute of Singapore (GIS) and its partners from the research and clinical communities in Singapore have completed the world's largest sequencing analysis of multi-ethnic Asian populations. This milestone study provides valuable insights on the unique diversity of largely understudied Asian populations, that could enable more accurate diagnosis of genetic diseases and chronic ailments, as well as guide prevention and targeted therapies.



Three of the authors from the study published in the journal Cell, from left: Prof Liu Jianjun (Deputy Executive Director of GIS, and Professor at Yong Loo Lin School of Medicine, NUS), Prof Patrick Tan (Executive Director of GIS, and Director of SingHealth Duke-NUS Institute of Precision Medicine), and Prof Cheng Ching-Yu (Principal Clinician Scientist at the Singapore Eye Research Institute, representing the study's participating cohorts).

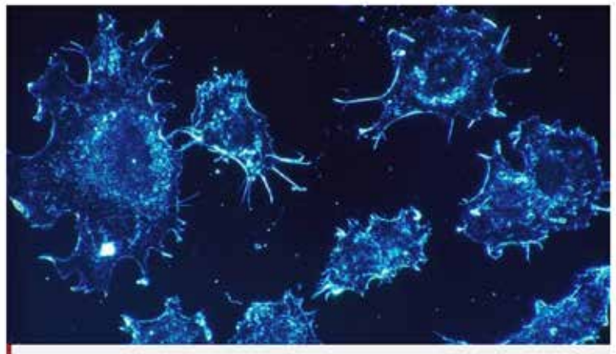
CONTRIBUTING TO BETTER HEALTH OUTCOMES FOR SINGAPOREANS

As stomach cancer is one of the most common forms of cancer amongst Asians, the Singapore Gastric Cancer Consortium, DxD Hub, NUH, and TTSH, developed GASTROClear, a device that simplifies the diagnosis of gastric cancer and allows for early intervention. Commercialised by local biotech company MiRXES, this in-vitro diagnostic medical device is the world's first non-invasive blood test for detection of gastric cancer. It works by measuring the levels of stomach cancer associated microRNA biomarkers. The product was approved as a Class C medical device by Singapore's HSA in May 2019. It is now in use at local hospitals.

Two new variants of the Epstein-Barr Virus (EBV) that can make it easier to identify individuals at high risk of developing "Cantonese cancer" were discovered by A*STAR scientists, hence allowing for early intervention. The study, published in the journal Nature Genetics in June, involved scientists from A*STAR's GIS, Sun Yat-sen University Cancer Center, Institute of Zoology of Chinese Academy of Sciences, as well as several other collaborating research institutes.

Singapore

Singapore scientists discover new viruses that help identify people at high risk of Cantonese cancer



Cancer cells. (Photo: Pixabay/skeeze)

SINGAPORE: Scientists in Singapore have discovered two new variants of the Epstein-Barr Virus (EBV) associated with cancers, in a study that can make it easier to identify individuals at high risk of developing Cantonese cancer, hence allowing

Cantonese cancer refers to nasopharyngeal carcinoma (NPC), the most common head and neck cancer in Singapore.

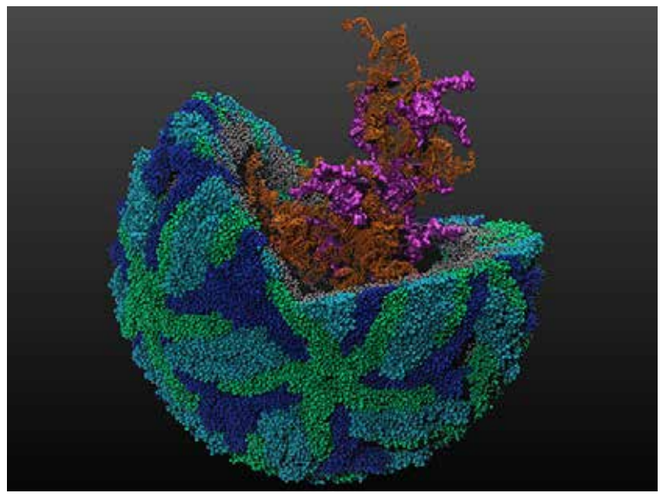
It is named so because EBV-infected individuals from the Cantonese dialect group are 20 times more at risk of developing NPC than those from other regions or populations.

Source: CNA website

3. Advancing Infectious Disease Research

*Over the years, A*STAR has built deep capabilities in infectious diseases research. Combining its capabilities in microbiology with genomics, molecular biology, immunology, bioinformatics, data analytics, and even the productisation of diagnostics, A*STAR plays a significant role in Singapore's world-class infectious diseases R&D ecosystem.*

Scientists now have a better understanding of the genetic materials and shapes of four dengue and four Zika viruses, as well as their corresponding functions. A*STAR's GIS, together with scientists from Duke-NUS Medical School and A*STAR's BII have succeeded in mapping out the structures of these viruses. Consequently, this would enable scientists to design better drugs and treatments.



Schematic representation of mature and infectious dengue virus

See the "COVID-19 Special Feature" on page 9 for more information on A*STAR's key achievements in infectious diseases.

CONTRIBUTING TO BETTER HEALTH OUTCOMES FOR SINGAPOREANS

4. Improving Health and Wellness with MedTech & Digihealth

*A*STAR has use-inspired basic science capabilities that cut across biomedical sciences, as well as science and engineering capabilities that can be applied to MedTech innovations, to prevent, diagnose and treat illnesses.*

The market for smart wearables is heating up as consumers become more health-conscious, and turn to wearable mobile devices to constantly monitor their health and fitness levels. **Local SME KaHa and A*STAR's Singapore Institute of Manufacturing Technology (SIMTech) co-developed a Smart T-shirt which can accurately measure the wearer's heart rate and ECG levels, amongst other things.**

Channel 8 Morning Express, 5 June 2019

Eko.ai is an A*STAR spin-off which uses AI-based software to enable early detection and prediction of heart disease. Their software platform offers a suite of research and productivity tools to support healthcare providers. The core technology platform was co-developed with A*STAR's research institutes and A*ccelerate. They have bagged a number of prominent awards in 2019, including the coveted Startup SG Grand Prize at Slingshot 2019 and the JLABS Award at the APACMed MedTech Forum.

Eko.ai won the Startup SG Grand Prize at Slingshot 2019 and was presented the award by SMS Koh Poh Koon (left).

Researchers at A*STAR's Institute of Material Research Engineering (IMRE), and Institute of Molecular and Cell Biology (IMCB), as well as NUH and the Singapore Eye Research Institute (SERI), have **developed a biodegradable thermogel called Vitreogel. It mimics the clear, gelatinous substance called vitreous in the eye**, and could serve as a long-term vitreous substitute in eye treatments. The team started a spin-off company called Vitreogel Innovations and is exploring the use of the gel as a sustained drug delivery platform for biologics to the posterior segment of the eye. It can also act as a scaffold to facilitate stem cell transplantation for retinal disease such as age-related macular degeneration.

Source: Vitreogel

CONTRIBUTING TO SOCIETAL OUTCOMES

A*STAR is committed to supporting the public sector and relevant industries in improving the lives of Singaporeans, especially in the areas of food security, as well as smart cities and sustainability.

READ more about A*STAR's Future of Food Initiatives.

1. Boosting the Resilience of Singapore's Food Security

*The COVID-19 pandemic has brought the importance of food security in Singapore into sharp relief. To support the national agenda of strengthening Singapore's food supply, A*STAR works closely with public R&D entities and industry partners.*

Led by the Singapore Food Agency (SFA) and A*STAR, the Singapore Food Story R&D Programme was initiated in 2019 to turn the nation's challenges in food security into economic opportunities. The aim is to build a strong foundation of food-related cross-domain R&D capabilities in local research institutions, and address emerging high-value industry needs in the areas of the agri-tech, nutrition, novel foods and food safety.

In collaboration with public agencies including SFA and the institutes of higher learning, A*STAR established the Singapore Institute of Food and Biotechnology Innovation (SIFBI) in April 2020 to bring its food science research under one roof. This includes research capabilities in areas such as nutrition, biotransformation, biotechnology, food safety, agri-food technology, and even manufacturing and engineering. The goal of this synergistic platform is to facilitate economic value capture for Singapore's food R&D ecosystem.

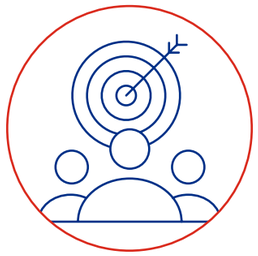
SIFBI will partner other research partners in the food ecosystem such as the NUS, NTU and SFA's National Centre for Food Science, as well as foreign universities to plug capability gaps in the local ecosystem.

> *"SIFBI will look into areas such as food, nutrition and agricultural technology and is part of Singapore's efforts to produce 30 per cent of its nutritional needs by 2030 - or what it terms its '30 by 30' target."*
>
> - Dr Koh Poh Koon, Senior Minister of State for Trade and Industry, at the Asia-Pacific Agri-Food Innovation Week 2019

*DPM Heng Swee Keat and SMS Koh Poh Koon visited A*STAR in September 2019 to gain deeper insights into our Food & Consumer R&D strategies*

SIFBI is doing its part to actively promote partnerships in the local R&D ecosystem. The aim is to accelerate innovation and the transformation of the local food industry to capture new growth opportunities in the global food market. These partnerships are essential for SIFBI to contribute to Singapore's food security goals.

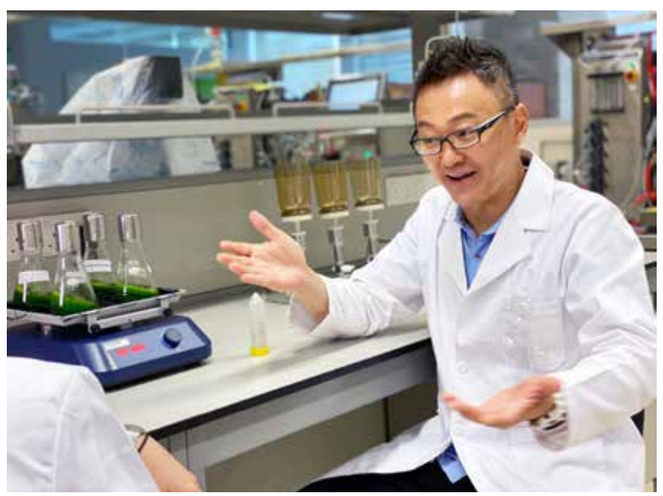
Watch: New A*STAR institute SIFBI pushes the frontiers of food innovation



CONTRIBUTING TO SOCIETAL OUTCOMES

Local start-up Archisen develops and operates systems and solutions to grow local produce in urban cities. By leveraging its expertise in crop management, engineering innovation and IoT technology, Archisen connects multiple urban farms to a centralised intelligence system, to help them stay profitable. **A*STAR provided Archisen with technological expertise that accelerated the start-up's development of their intelligent urban farm management platform, Croptron.** The start-up worked with A*STAR's BII on a yield prediction model for lettuce and kale to help prevent crop wastage, thus reducing operational costs and increase profitability.

Start-up Sophie's Kitchen's Bionutrients is developing a new sustainable alternative protein out of microalgae, which can be turned into a plant-based protein to be incorporated into consumers' everyday diet. **SIFBI and Sophie's Kitchen entered a research collaboration in August 2019 that would leverage BioTrans' know-how in fermentation, as well as bioprocess engineering and design, to develop a robust bioprocess for the production of alternative food protein using microalgae.** The partnership would enable Sophie's Kitchen to rapidly ramp up the scale of its production for commercialisation, and support Singapore's '30 by 30' goal.



Eugene Wang, Co-founder of Sophie's Kitchen's Bionutrients

Eatobe is a Singapore food biotechnology start-up which aims to address nutrient deficiencies in the population. **Eatobe's collaboration with SIFBI's Biotransformation Group has enabled it to develop proprietary enzyme cocktails that ferment whole foods to produce ingredients with higher nutrient bio-accessibility.** Eatobe produced a prototype after six months of collaboration with A*STAR, while securing grants and investments with the technology developed during the partnership.

The Eatobe R&D and Foods team in their pilot processing and test kitchen space.

Source: Eatobe

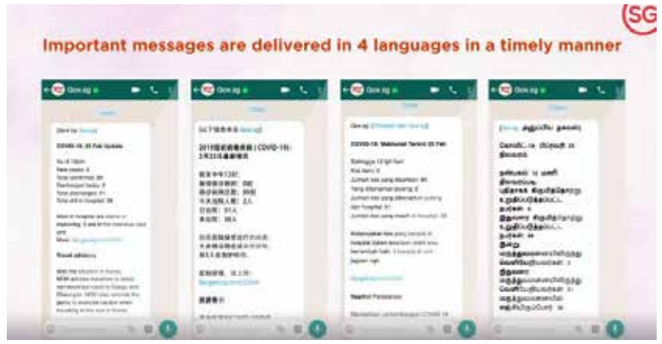
2. Building A Smart and Sustainable City

*A*STAR's capabilities range from robotics and artificial intelligence to data analytics and machine learning. Through public sector partnerships, these R&D capabilities have been developed into innovative solutions that does everything from improving public service delivery, to sustainable and more liveable spaces for Singaporeans.*

To help expedite court proceedings, the Speech Transcription System (STS) was developed by A*STAR's Institute for Infocomm Research (I²R) with the State Courts to provide real-time automatic speech transcription of English conversations presented as oral evidence and delivery in the Courts. Applying A*STAR's speech recognition technology, this STS does away with manual court reporters or transcribers. Previously, the system requires an external service provider which will take about seven days to fully transcribe all digitally recorded court proceedings.

CONTRIBUTING TO SOCIETAL OUTCOMES

SG Translate, an AI-translation engine was deployed in July 2019 to assist public communication officers in their translations of official materials. More recently, it was used to translate the COVID-19 updates on Gov.sg WhatsApp and Telegram to push out these messages quickly.



The Multi-purpose All Terrain Autonomous Robot (MATAR) is a smart security patrol robot that employs A*STAR's technologies in AI and robotics. A collaboration between A*STAR's I²R, Ministry of Home Affairs' Home Team Science and Technology Agency (HTX) and the Singapore Police Force, MATAR is equipped with sound and visual sensors with 360 video capabilities. These allow the autonomous patrol robot to detect suspicious activity on the ground. MATAR was deployed for a trial at the National Day Parade 2019.

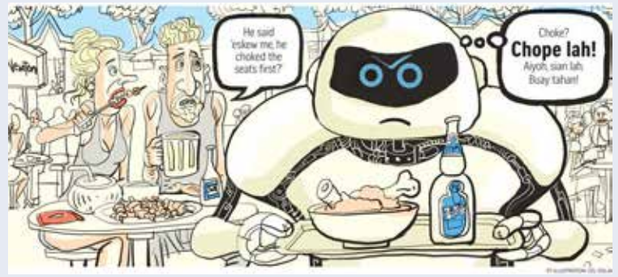
Watch the MATAR robot in action.

A*STAR collaborates with local robotics SMEs to up their game in creating innovative solutions for industry. Local start-up, SIIX-AGT specialises in multi-purpose robotics components such as base modules that can be repurposed for different market segments – much like the building blocks of service robots. By incorporating A*STAR's AI technologies into its service robots, the enterprise was able to come up with new innovative solutions to address market needs and boost productivity.

It licensed I²R's software to develop an advanced autonomous robotics base that integrates multiple sensors for indoor navigation, and to carry out multiple tasks. Powered by deep learning algorithms, the service robots are trained to avoid humans and obstacles, as well as perform tasks without human supervision. SIIX-AGT has also worked with A*STAR to prototype the earlier versions of the MATAR robots.

"Innovation is what will set you apart in a world of disruption. My vision for SIIX-AGT is to create novel robotics solutions that will transform industries and make a positive impact for society."

- Mr Ivan Khoo, the Chief Executive Officer of SIIX-AGT (right in picture)

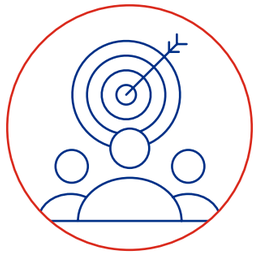


Singlish-Speaking Robots and Other Ways to Make AI Work for Singapore and Beyond
The Straits Times, 14 December 2019

Chief AI Scientist, Prof Ong Yew Soon and Assistant Chief Executive, Science and Engineering Research Council Prof Tan Sze Wee shared insights on making AI work for Singapore and beyond in this opinion editorial for The Straits Times.

Neeuro launched the brainwave-controlled game CogoLand to help complement Attention Deficit Hyperactivity Disorder treatment for children. An A*STAR spin-off, Neeuro licensed the Brain-Computer Interface (BCI) technology from A*STAR's I²R. The trial of CogoLand to complement ADHD treatment is the result of a collaboration among the Institute of Mental Health (IMH), Duke-NUS Medical School and A*STAR's I²R.

Cogoland is a game that could complement the treatment of children with ADHD.
Source: Neeuro



CONTRIBUTING TO SOCIETAL OUTCOMES

Singapore faces significant challenges related to climate-change, such as high temperatures in urbanised spots. **A team comprising of researchers from A*STAR's Institute of High Performance Computing (IHPC), I²R and HDB engineers have developed a modeller that optimises the design of urban spaces for improved liveability.** The Integrated Environmental Modeller (IEM) renders high-resolution 3D models of urban environments, and is a world-first urban-planning tool which integrates the projection of how individual environmental factors solar, wind, and noise, as well as their interrelationships, affect an urban setting. With the IEM, urban planners can visualise environmental factors on a virtual "Digital Twin" to optimise the design of urban spaces. For example, the IEM proved instrumental in the urban design plan for Tengah town. HDB's planners, architects and engineers used the IEM as one of the smart planning tools to analyse key wind channels and the solar heat gained by different urban features, such as concrete and vegetation. This will help them design open spaces as well as optimise the building layouts and orientation to promote natural ventilation within the town.

*From left: Mr Tan Sze Tiong, Director, Centre of Excellence for Environmental Sustainability Research, HDB, Dr Koh Wee Shing, Senior Scientist, A*STAR's IHPC, Dr Poh Hee Joo, Senior Scientist, A*STAR's IHPC and Mr Fachmin Folianto, Senior Research Engineer, A*STAR's I²R*

The IEM has also pushed technological boundaries in high performance supercomputing. It has created the first-ever 3D wind-flow simulation that included all buildings in Singapore at a 10-metre resolution. In 2019, the project garnered prestigious awards such as the President's Technology Award, the ASEAN Outstanding Engineering Achievement Award and the Minister for National Development's R&D Merit Award.

As Singapore gears up to become a smart nation powered by digital innovation, **A*STAR is embarking on two partnerships with large local enterprises to co-develop digital solutions for smart cities and the built environment.**

> *"Moving forward, A*STAR will enhance our support for local enterprises. For Surbana Jurong, we will do our part to support its global competitiveness in the built environment through leveraging technology. The fact that local SMEs can benefit from this new partnership is a very important outcome."*
>
> - Mr Frederick Chew, Chief Executive Officer, A*STAR

A*STAR and Surbana Jurong will jointly develop advanced digital capabilities in i) the planning of cities, residential towns and industrial parks, ii) design and simulation of buildings, and iii) services for efficient and sustainable operations and maintenance. As part of the commercialisation partnership, **Surbana Jurong is incorporating into its service offerings, technologies commercialised by A*STAR's SME and start-up licensees.** The Large Local Enterprise (LLE) will also expose local companies in its supply chain to overseas markets for new business opportunities, including the 40 countries in which the company has an existing market presence. The upcoming Surbana Jurong Campus will serve as a test-bed for new technologies in partnership with A*STAR SMEs and start-ups.

*From left: Mr Frederick Chew, CEO, A*STAR, Prof Tan Sze Wee, ACE SERC, A*STAR, Ms Chan Lai Fung, Chairman, A*STAR, Mr Liew Mun Leong, Chairman, Surbana Jurong, Mr Chong Lit Cheong, Group Chief Corporate Officer, Surbana Jurong, and Mr Wong Heang Fine, Group Chief Executive Officer, Surbana Jurong*

LEARN more about A*STAR's research on Sustainability.

CONTRIBUTING TO SOCIETAL OUTCOMES

With ST Engineering, A*STAR will focus on technology co-development, adoption and commercialisation in robotics, smart mobility, smart communications, and healthtech. A*STAR will pull technological capabilities from across its research institutes to co-develop innovative solutions with ST Engineering. The partnership will drive new business outcomes in Singapore and in overseas markets for ST Engineering and its SME partners.

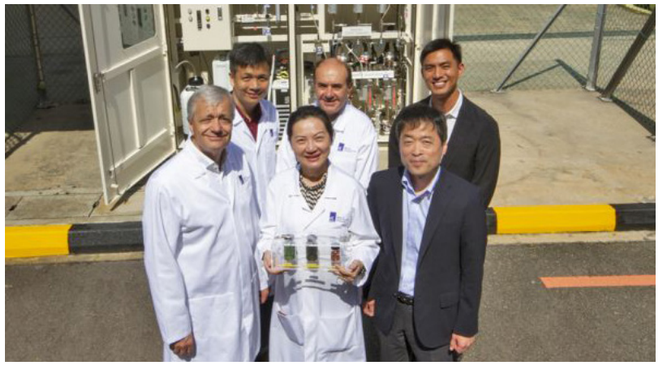
MOU signing ceremony with ST Engineering in July 2019

> *This MOU with A*STAR serves as another collaboration platform for us to work with some of the best minds in research and engineering to create differentiated, commercially viable smart city solutions that will further enhance our global competitiveness.*
>
> - Mr Vincent Chong, President & CEO of ST Engineering

Local enterprise Westcom's food waste management system is a game-changing solution that turns food waste into fertiliser within 24 hours, and generates no wastewater. **Westcom's patented microbial solution was invented after a two-year R&D process with A*STAR.** Researchers also helped Westcom set up its own in-house laboratory so that the company could scale up production of its microbial solution to serve market needs.

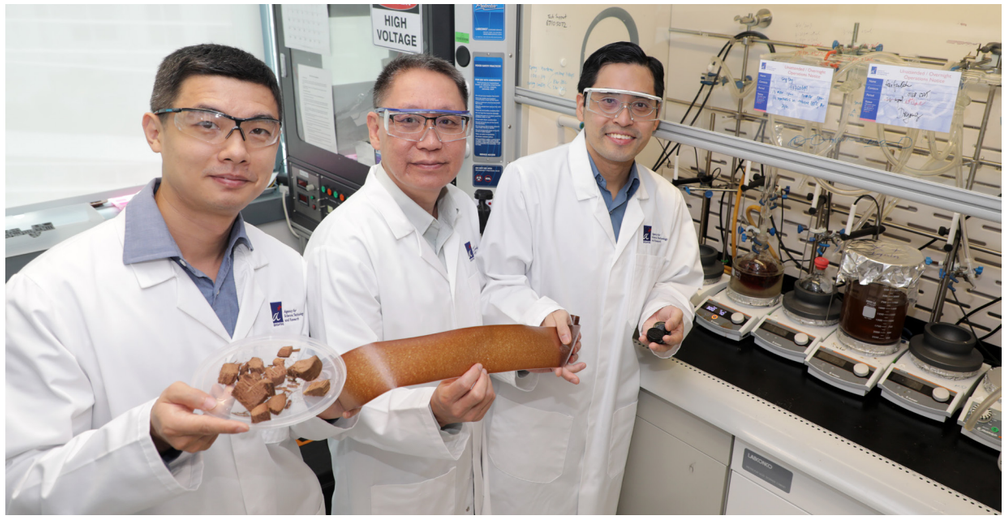
Bags of fertiliser produced by Westcom's food waste recycling machine

IHI Corporation is a Japanese multinational company (MNC) that produces heavy-industry machinery. **The company worked with A*STAR's Institute of Chemical and Engineering Sciences (ICES) to co-develop a new Methanation catalyst to help companies such as chemical production plants convert carbon dioxide emissions into methane, which could then be sold or used as an energy source to power plant operations.** The new technology aims to effectively reduce carbon footprint of these production plants, contributing to Singapore's efforts in addressing the effects of climate change.



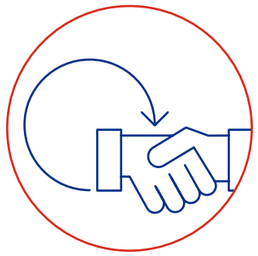
A demonstration unit of the new technology by IHI and ICES situated on Jurong Island

Researchers from IMRE have churned out biodegradable plastic made out of lignin, a waste product of processes such as paper production, and the method has proven to be cost-effective.



From left: Dr Kai Dan, Scientist, Prof Alfred Huan, Executive Director and Dr Loh Xian Jun, Senior Scientist from IMRE

Source: Lianhe Zaobao © Singapore Press Holdings Limited. Permission required for reproduction.



CONTRIBUTING TO THE TRANSFORMATION OF SINGAPORE'S ECONOMY

Open innovation adds value to the economy. A*STAR supports Singapore's world-class R&D ecosystem by bridging the gap between academia and industry, thus anchoring businesses in high-value industries here.

1. Powering High-Value Manufacturing

*A*STAR's wide-ranging capabilities in Industry 4.0 manufacturing processes give local companies a competitive edge, helping them to reinvent themselves, and pivot into new markets and new products. A*STAR also works with multinational corporation (MNC), helping to anchor their activities in Singapore to create business opportunities for local companies and jobs for Singaporeans.*

Component Technology and A*STAR have worked on several industrial projects together and to date, co-developed 27 key technologies in wire bond inspection. A partnership with A*STAR's SIMTech was crucial for a small business like Component Tech because it did not have the capabilities to develop new technology on its own. These collaborations resulted in a first-of-its-kind 3D automated wire bond inspection system, which Component Technology exhibited at the Hannover Messe trade fair in April 2019. Using algorithms and triangulation technology jointly developed with A*STAR, the machine inspects the interconnections between wires to confirm that they are up to standard. The cost savings are the key value proposition for the machine, giving the company a competitive edge. In the future, it plans to provide upgrades such as artificial intelligence capabilities so the machines can handle more complicated applications.

*Component Technology CEO and managing director Berne Chung with the first-of-its-kind 3D automated wire bond inspection system his company developed in collaboration with A*STAR*

Source: Component Technology

A*STAR's ARTC, local SMEs JM Vistec System and M8M, as well as MNC Procter and Gamble (P&G) jointly developed a new system driven by artificial intelligence to automate the process of quality inspection for P&G's luxury consumer care bottles during production.

Source: The Straits Times © Singapore Press Holdings Limited. Permission required for reproduction.

The SIMTech Innovation Factory – an initiative by A*STAR in partnership with Enterprise Singapore – is a space that supports local firms' ideation and design of unique products. Set to be operationally ready at the Jurong Innovation District (JID)'s CleanTech Park by 2021, the Innovation Factory will provide companies with design and prototyping support for products such as inspection equipment, medical technology devices and electromechanical modules. Resident design and technology experts will be on hand to guide them on their innovation journey. **The Innovation Factory supports the JID's aim to create 95,000 jobs in research and advanced manufacturing activities over the next two decades.**

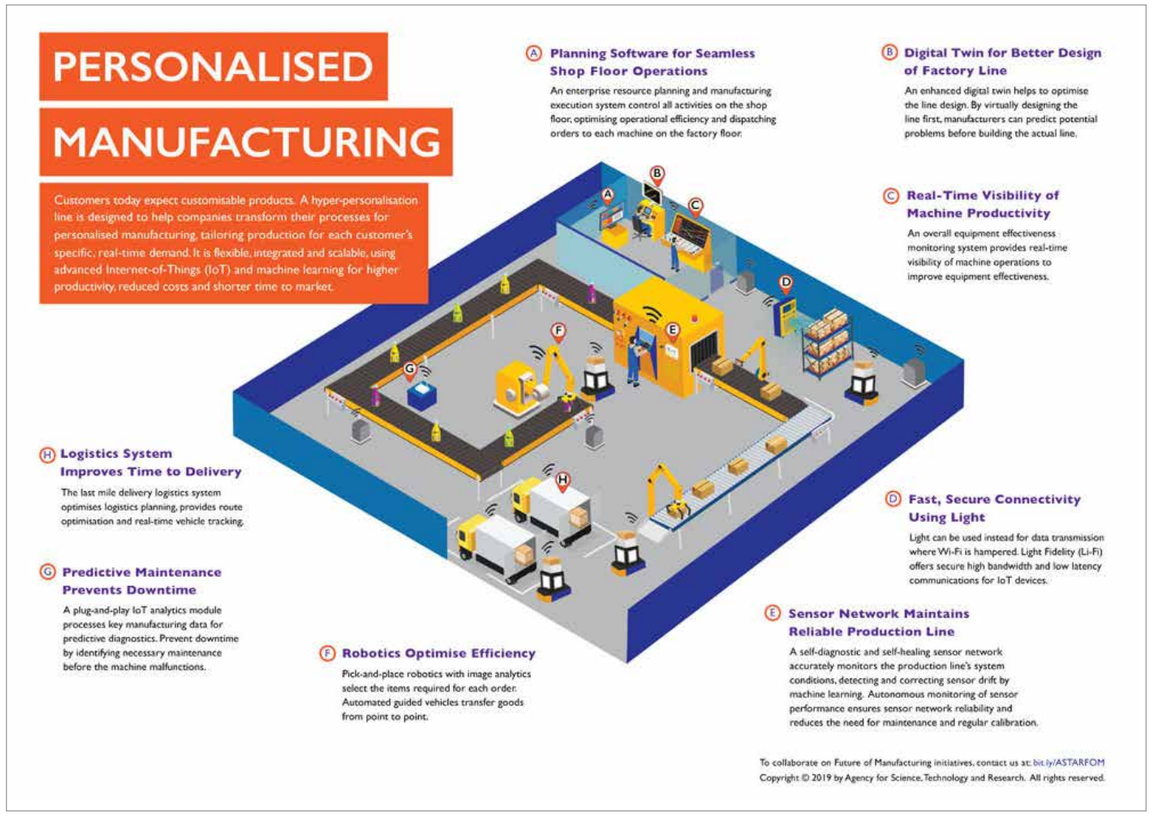
A*STAR's ARTC, Jurong Townhall Corporation (JTC) and Singtel signed a memorandum of understanding in June 2019 to develop Industry 4.0 solutions based on 5G technology. The three parties are integrating 5G technology into A*STAR's Model Factory @ ARTC in the Jurong Innovation District (JID) to drive digital transformation in the manufacturing sector. The 5G pilot network at ARTC will help accelerate the commercialisation of 5G technology and its adoption by manufacturers in Singapore.

*After developing their idea into a product concept for prototyping, companies can choose to carry out pilot manufacturing of their products at the A*STAR Model Factory located at SIMTech and the ARTC.*

CONTRIBUTING TO THE TRANSFORMATION OF SINGAPORE'S ECONOMY

At the annual Industrial Transformation Asia-Pacific (ITAP) 2019 in October, A*STAR launched a series of new Future of Manufacturing Initiatives. These include i) a hyper-personalised manufacturing platform for the fast-moving consumer goods (FMCG) sector; and ii) a learning platform that digitally connects smart factories for the sharing of Industry 4.0 best practices.

ARTC's hyper-personalised manufacturing initiative marks new frontiers for Singapore's Future of Manufacturing strategy. This move towards hyper-personalisation takes manufacturing to the next level by leveraging advanced IoT-enabled devices as well as machine learning techniques to analyse customers' real-time behavioural data. Tapping on the local R&D ecosystem, Singapore-based manufacturers are keen to deploy production know-how globally as well. In 2018, A*STAR extended its ARTC model factory to FMCG firms, complementing its work with aerospace and engineering companies. So far, A*STAR and 10 companies have collectively invested S$38 million into FMCG R&D at ARTC.

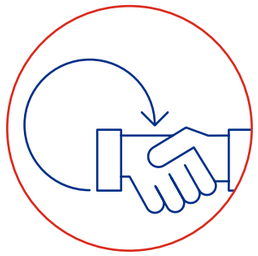


Pfizer, one of the world's largest pharmaceutical companies, established its Manufacturing Technology Development Centre (MTDC) in A*STAR's ICES in 2016. The company has extended its agreement with ICES to host MTDC till 2022, further anchoring its global R&D activity in Singapore.

In October 2019, A*STAR's SIMTech and the Singapore Precision Engineering and Technology Association (SPETA) launched a learning platform that digitally connects smart factories so local companies across industries can learn Industry 4.0 best practices. This new platform will allow companies to discover fresh approaches to digital manufacturing, and explore how these could be applied in their factories for higher productivity. Thirteen organisations across industry and institutes of higher learning have signed an MOU with SIMTech and SPETA to join this Digital Ecosystem of Model Factories Initiative.

MOU signing ceremony on the Digital Ecosystem of Model Factories in October 2019

FIND OUT more about A*STAR's Future of Manufacturing initiatives.

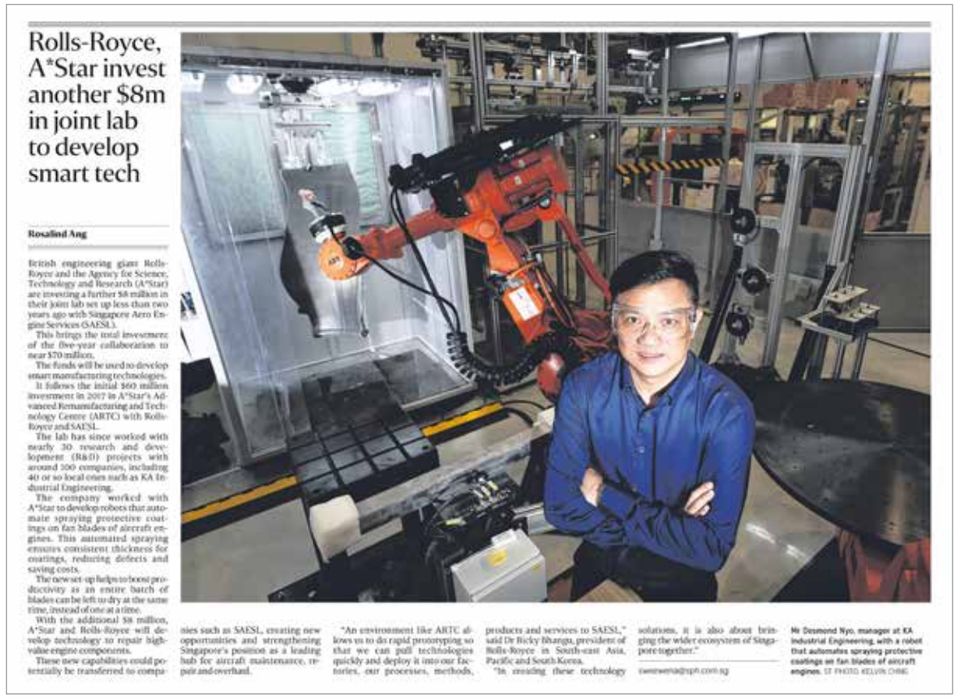


CONTRIBUTING TO THE TRANSFORMATION OF SINGAPORE'S ECONOMY

2. Enhancing Trade and Connectivity

*A*STAR supports trade and connectivity for Singapore, maintaining its competitiveness as a global air and sea transhipment hub.*

The Smart Manufacturing Joint Lab between A*STAR, Rolls-Royce and Singapore Aero Engine Services Pte Ltd (SAESL) was first established in September 2017 to accelerate the development of solutions for automatic, digital, adaptive manufacturing, and repair for the aerospace industry. Since its launch in 2017, **the joint lab has seen nearly 30 R&D projects with around 100 companies, more than 40 of which are local. For example, local SME KA Industrial Engineering, has deployed an automated boron nitride spray process developed by A*STAR for Rolls-Royce's Seletar facility.** In June 2019, A*STAR and Rolls-Royce further invested S$8 million into their joint lab with Singapore Aero Engine Services, bringing the total investment of the five-year collaboration to S$69 million.



Rolls-Royce, A*Star invest another $8m in joint lab to develop smart tech

Rosalind Ang

British engineering giant Rolls-Royce and the Agency for Science, Technology and Research (A*Star) are investing a further $8 million in their joint lab set up less than two years ago with Singapore Aero Engine Services (SAESL).

This brings the total investment of the five-year collaboration to near $70 million.

The funds will be used to develop smart manufacturing technologies.

It follows the initial $60 million investment in 2017 in A*Star's Advanced Remanufacturing and Technology Centre (ARTC) with Rolls-Royce and SAESL.

The lab has since worked with nearly 30 research and development (R&D) projects with around 100 companies, including 40 or so local ones such as KA Industrial Engineering.

The company worked with A*Star to develop robots that automate spraying protective coatings on fan blades of aircraft engines. This automated spraying ensures consistent thickness for coatings, reducing defects and saving costs.

The new set-up helps to boost productivity as an entire batch of blades can be left to dry at the same time, instead of one at a time.

With the additional $8 million, A*Star and Rolls-Royce will develop technology to repair high-value engine components.

These new capabilities could potentially be transferred to companies such as SAESL, creating new opportunities and strengthening Singapore's position as a leading hub for aircraft maintenance, repair and overhaul.

"An environment like ARTC allows us to do rapid prototyping so that we can pull technologies quickly and deploy it into our factories, our processes, methods, products and services to SAESL," said Dr Ricky Bhangu, president of Rolls-Royce in South-east Asia, Pacific and South Korea.

"In creating these technology solutions, it is also about bringing the wider ecosystem of Singapore together."

rosewena@sph.com.sg

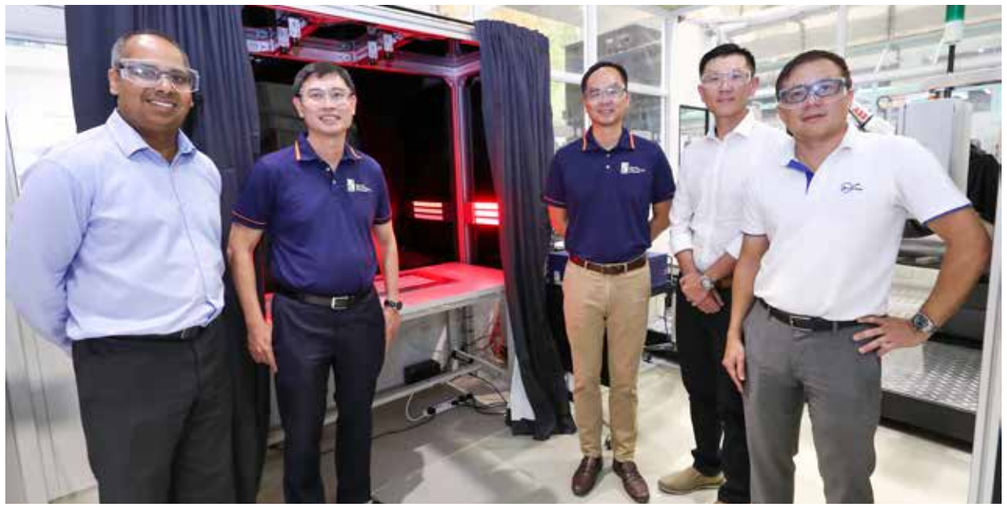
Mr Desmond Nyo, manager at KA Industrial Engineering, with a robot that automates spraying protective coatings on fan blades of aircraft engines. ST PHOTO: KELVIN CHNG

Source: The Business Times © Singapore Press Holdings Limited. Permission required for reproduction.

Another product of the Smart Manufacturing Joint Lab between A*STAR, Rolls-Royce and Singapore Aero Engine Services: **Two local enterprises and the entities have jointly developed a new technology that automates part of an inspection process in jet engine manufacturing.** System integrators Zincode Technologies and Sysmatic Global worked with Rolls-Royce and ARTC on the solution, which uses an array of cameras and specialised lighting to capture detailed images of jet engine fan blades. It has been installed in Rolls-Royce's Seletar facility for further validation.

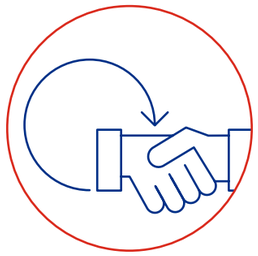
These stories highlight how **A*STAR continues to keep Singapore attractive as an R&D hub, anchoring MNCs here, and in the process, help local SMEs make headway into the aerospace industry through innovation.**

> *"We want to bring the local enterprises along; they are the receptacles for the technology that A*STAR creates so they will be the beneficiary of the business that comes as a result of it, together with Rolls-Royce."*
>
> - Prof Tan Sze Wee, Assistant Chief Executive of A*STAR's Science and Engineering Research Council



*From left to right: Dr Bicky Bhangu, President, Southeast Asia, Pacific and South Korea at Rolls-Royce, Prof Tan Sze Wee, Assistant Chief Executive, SERC, A*STAR, Dr David Low, CEO, ARTC, A*STAR, Mr Gavin New, Director, Sysmatic Global, and Mr David Tan, Director, Zincode Technologies*

Source: Straits Times © Singapore Press Holdings Limited. Permission required for reproduction.



CONTRIBUTING TO THE TRANSFORMATION OF SINGAPORE'S ECONOMY

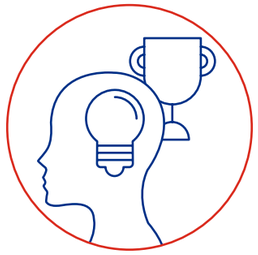
Sembcorp Marine and A*STAR inked a Master Research Collaboration Agreement (MRCA) to jointly pursue innovation in digital design and advanced manufacturing to achieve clean energy solutions. With this agreement, the partners aim to shorten the development cycle and time-to-market of new and sustainable offshore and marine innovations. Sembcorp Marine and A*STAR will also set up a joint research laboratory and workspace to facilitate the test-bedding and commercialisation of technologies.

The Centre of Excellence for Autonomous & Remotely Operated Vessels (CEAOPS) was launched in October 2019. **CEAOPS is the first research initiative to be funded under the Maritime Transformation Programme, and will be the national focal point for Maritime Autonomous Surface Ships R&D.** It will lead the way for safe and efficient operations of autonomously and remotely operated vessels, as well as vessels equipped with smart maritime systems and solutions, in complex operating environments.

CEAOPS will be housed in the Technology Centre for Offshore and Marine, Singapore (TCOMS), a joint initiative between A*STAR and NUS. Technologies developed by the R&D ecosystem in Singapore are already being deployed. For example, **Jurong Port has test-bedded a cargo forecasting prediction tool in its decision-making process for future port resources planning. This tool was co-developed by A*STAR's IHPC, Singapore Management University (SMU) and Fujitsu.** ST Engineering, IHPC and the Maritime and Port Authority of Singapore Living Lab are also working closely to develop next generation vessel traffic management systems. To help maritime SMEs embrace digitalisation, the Singapore Sea Transport Digital Plan was rolled out in 2019.

MRCA signing ceremony with Sembcorp Marine in February 2020

MOU signing ceremony during the Singapore Maritime Institute (SMI) Forum in October 2019



TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

As a vibrant Global-Asian node of technology, innovation, and enterprise, Singapore creates new products and services for the world. A strong base of researchers, innovators, and entrepreneurs is critical to achieve this. A*STAR's multi-pronged talent strategy builds a pipeline of skilled talent pool to drive innovation and meet the country's societal and economic needs.

1. Nurturing A Pipeline of Local Talent

*A*STAR scholars are actively contributing to the Research, Innovation & Enterprise (RIE) ecosystem in Singapore. Here are some success stories.*

Driving Entrepreneurship

A*STAR scholar Dr Liang Hui Guang, is CEO and co-founder of Mercurics, an AI company that allows companies to measure the personality traits of existing and potential employees that suit the organisation's needs. The A*STAR spin-off's computational modelling platform can be applied to various professional services sectors, such as human resource, retail and finance.

> *"In my PhD thesis- I wrote this in my foreword: 'I will never forget my charge to contribute – in whatever capacity my professional training allows – back to the economy of Singapore.'"*
>
> - Dr Liang Hui Guang, who scored 254 points for his PSLE and is CEO of Mercurics

Following a successful research career at I²R, A*STAR scholar **Dr Ethan Chu, founded Xjera Labs, an A*STAR spin-off focused on AI-based Video Analytics.** Xjera's AI solution helps its customers make sense of their data and videos, which can be applied to everything from the improvement of security, to general productivity. In 2019, the company won both the Emerging Enterprise Award and the Best Innovation Awards.

Winners of the Emerging Enterprise Award (from left) Mr Wong Joo Seng, co-founder and CEO of Spark System, Mr Jeremy Heng and Mr Ethan Chu, two of the three co-founders of Xjera Lab and Mr Charles Cher, Chairman of Emage Vision at the awards night on Oct 3, 2019

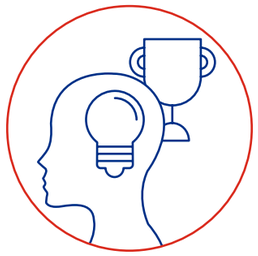
Source: ST PHOTO: ARIFFIN JAMAR

A*STAR scholar Dr Ling Ka Yi, together with Dr Sandhya Sriram co-founded Shiok Meats, a cell-based crustaceans start-ups in 2018. Born out of their desire to create an alternative to the unsustainable shrimp industry, the founders leveraged their backgrounds in biology and cell science to build Shiok Meats and craft the world's first "clean shrimp". In 2019, the enterprise raised S$6.2 million in seed funding to develop cell-based shrimps.

From left: Dr Ka Yi Ling (CTO) and Dr Sandhya Sriram (CEO), co-founders of Shiok Meats

As of April 2020, A*STAR has nurtured a pipeline of around **1,650** Singaporean PhD talent through various scholarship schemes.

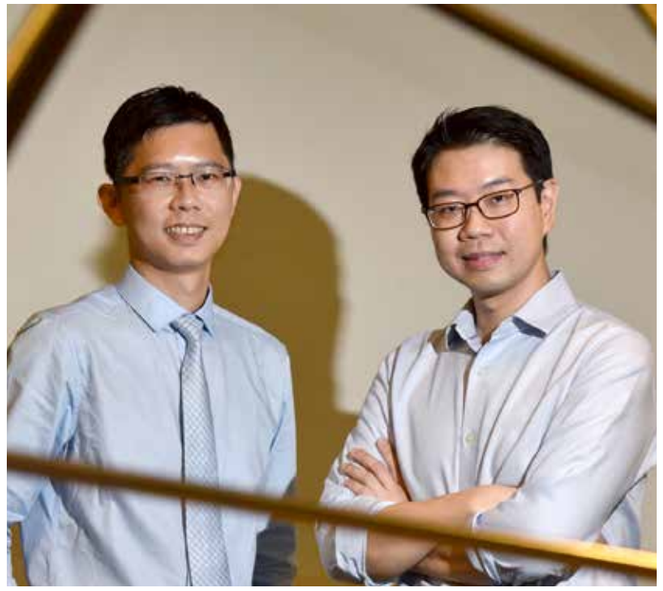
> *"The A*STAR Scholarship Award is part of our wider national strategy to allow our best to excel to their potential... Many are well regarded in their respective fields and through their work, have made a real difference to people's lives, not just in Singapore but around the world... I am happy to note that A*STAR has made significant contributions to Singapore's efforts in nurturing our talent base."*
>
> - Minister for Trade and Industry Chan Chun Sing at A*STAR's Scholarship Award Ceremony 2019



TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

Driving Innovation in the Labs

A*STAR scholar Dr Tam Wai Leong is the group leader for precision oncology at the Genome Institute of Singapore under A*STAR. He is part of the research team that collaborated with the National Cancer Centre Singapore (NCCS) in a **local study to discover that tumour growth can be slowed or prevented by "starving" cancer cells of a nutrient commonly found in meat, fish and dairy products.**



*Dr Tam Wai Leong (left), group leader for precision oncology at A*STAR's GIS, and Dr Daniel Tan, a senior consultant at the division of medical oncology at the NCCS, and a member of the research team which discovered that cancer stem cells use an amino acid called methionine as fuel and are especially dependent on it.*

Source: ST PHOTO: JASMINE CHOONG

A*STAR scholars, Asst Prof Christine Cheung from IMCB and Asst Prof Benjamin Tee from IMRE were awarded the World Economic Forum's Young Scientists of 2019, which featured 21 leading academics from 10 countries. Asst Prof Cheung's work involves using stem cell technology to study blood vessels in ways that could lead to treatments for diabetes and stroke; Asst Prof Tee's skin-like sensor systems help the brain interact with prosthetic limbs, and give robots the sense of touch, enabling them to repair themselves.

These A*STAR scholars were amongst 20 regional honourees of the **Asia-Pacific Technology Review Under 35 Award 2020,** announced in December 2019.

Dr Yvonne Gao *(pictured, left)*

Scientist, IMRE

Building modular hardware for quantum computers

Dr Ling Ka Yi

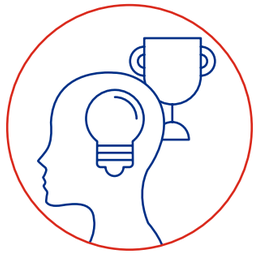
Co-founder of Shiok Meats

Bringing delicious and healthy crustacean meat to consumers by harvesting cells instead of animals

A stem cell and developmental biology senior research scientist at GIS, A*STAR scholar, **Prof Tan Meng How was one of nine scientists selected to join the prestigious European Molecular Biology Organisation (EMBO) Global Investigator Network.** In a recent joint study published in Nature, Prof Tan's team, together with NTU and Stanford University uncovered a new layer of complexity beyond the human genome. The in-depth study and new discoveries of RNA editing process provide better understanding of what makes us human.

"Tan Meng How and his colleagues' latest work greatly expands our understanding of how RNA editing contributes to the diversification of our genome – across time and age and in different tissues of the body. They have identified important findings about how RNA editing is controlled and defined new regulators of this process. This is a very important study for our understanding of the role that RNA editing plays in different contexts and will provide a foundation for future studies in this field."

- Associate Prof Carl Walkley from St Vincent's Institute and the University of Melbourne



TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

2. Fueling Innovation in Local Industry

*The Technology for Enterprise Capability Upgrading (T-Up) initiative seconds A*STAR Research Scientists & Engineers (RSEs) to local enterprises to build and upgrade their in-house R&D capabilities. Here are some exemplary A*STAR talent who have made impactful contributions to local enterprises.*

Mr Mike Wong Kim Sing, Senior Research Engineer, I²R, was seconded to local enterprise Pestech to support the development of its auto rodent surveillance system, RodentEye. The system taps on data analytics and IoT platform technologies, and reduces manpower costs by 50 per cent, while improving the effectiveness of rodent hotspots elimination by 100 per cent. **Mr Wong was pivotal in the translation of research done at A*STAR I²R into innovative solutions that gave Pestech a competitive edge.** He is also a veteran of the T-Up Scheme, having completed 10 years' worth of secondments and seen through the innovation journeys of five local SMEs.

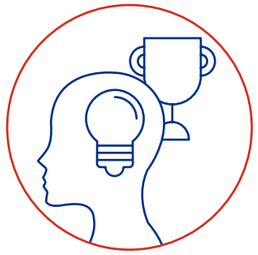
> *"A*STAR has helped Pestech to innovate its work processes, enabling us to overcome high operational costs, and provide higher-value-added service to our clients. With the training provided, our staff has also become more competent in harnessing digital technologies for greater efficiency."*
>
> - Mr Tong Kien Seng, Founder, Pestech

Winners of the T-Up Excellence Award 2019

*From left: Mr Marcus Neo Puay Keong, CEO of Omni-Plus System Pte Ltd, Dr Leong Yew Wei, IMRE, Mr Tong Kien Seng, Founder of Pestech, Mike Wong Kim Sing, I²R, Mr Chan Chun Sing, Minister for Trade and Industry, Ms Chan Lai Fung, Chairman of A*STAR, Mr Peter Ong, Chairman of Enterprise Singapore, Mr Jeffrey Lu, Co-Founder/CEO of Engine Biosciences, Dr Asha Shekaran, BTI (joined T-Up company after secondment ended)*

Dr Asha Shekaran who was from A*STAR's Bioprocessing Technology Institute (BTI) helped optimise Engine Biosciences' proprietary AI platform for faster and more effective drug discovery processes. The T-Up Project included a proof of concept screen to identify miRNAs which regulate liver cancer cell growth and drug sensitivity; and a commercial engagement of its platform technology to identify regulators of a specific biological pathway of interest. Dr Asha is currently hired by Engine Biosciences as lead scientist and platform leader.

Omni-Plus System (OPS)'s business is in providing a full solution approach to supply neat thermoplastic resins and composite materials to the electronic manufacturing industries. **Dr Leong Yew Wei was seconded to OPS for a year under the T-Up scheme where he facilitated the company's capability development roadmap.** He played an instrumental role in establishing the R&D direction of the company, enabling it to create their own proprietary product portfolio to enhance their competitiveness.

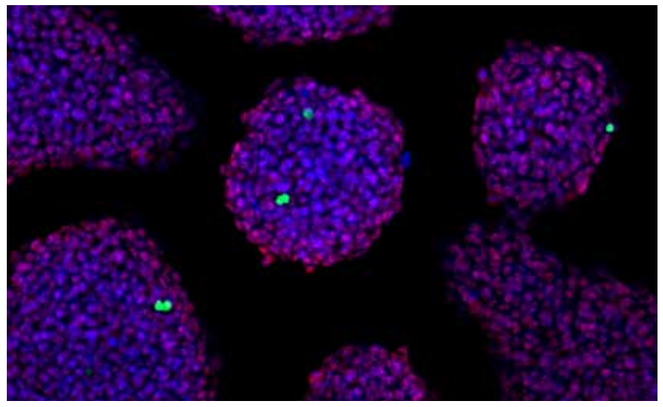


TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

3. Driving Impactful Discoveries

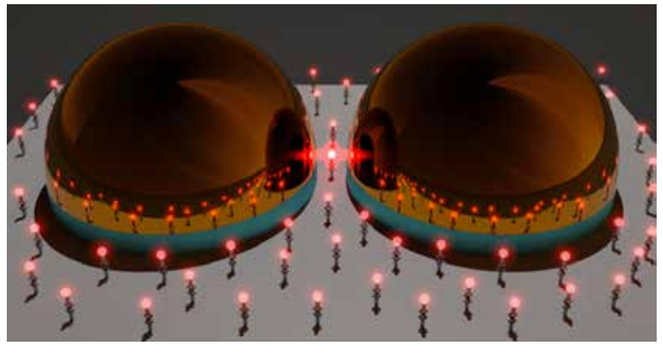
*As a world-class research organisation, A*STAR nurtures local talent while attracting global top talent to enable the local innovation ecosystem. Here are the highlights of their achievements in use-inspired basic science and high-impact R&D.*

Top High-impact Journal Publications *(in FY2019)*



*A*STAR researchers discovered that modifying how embryonic stem cells use sugar can switch them into a totipotent state.*

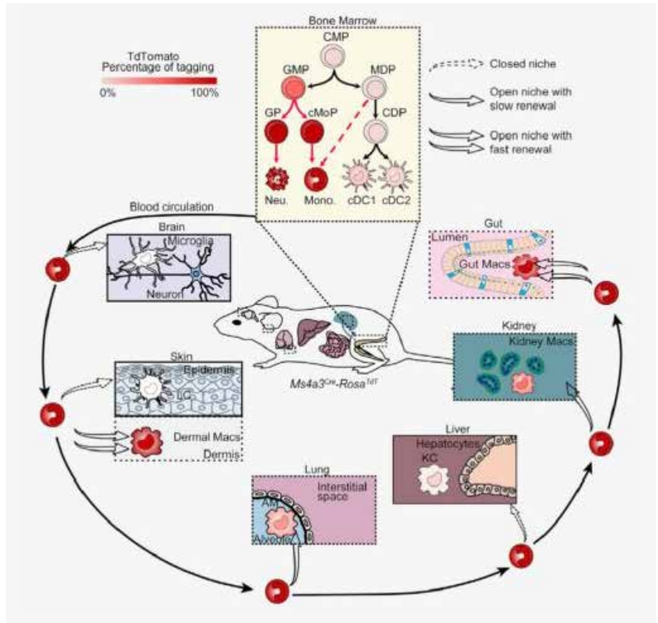
Tee Wee-wei, IMCB
Nature Cell Biology
Maternal factor NELFA drives a 2C-like state in mouse embryonic stem cells



Scientists discovered that biosensors designed with quantum properties are 15 times more sensitive than classical sensors.

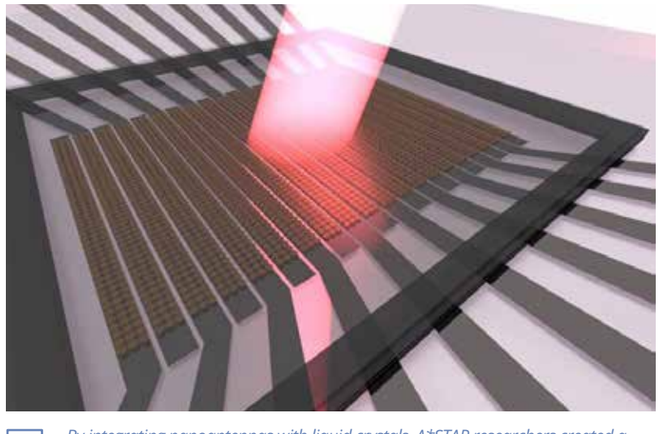
Wu Lin, IHPC
Nano Letters
Quantum Plasmonic Immunoassay Sensing

READ our High-Impact Publications.



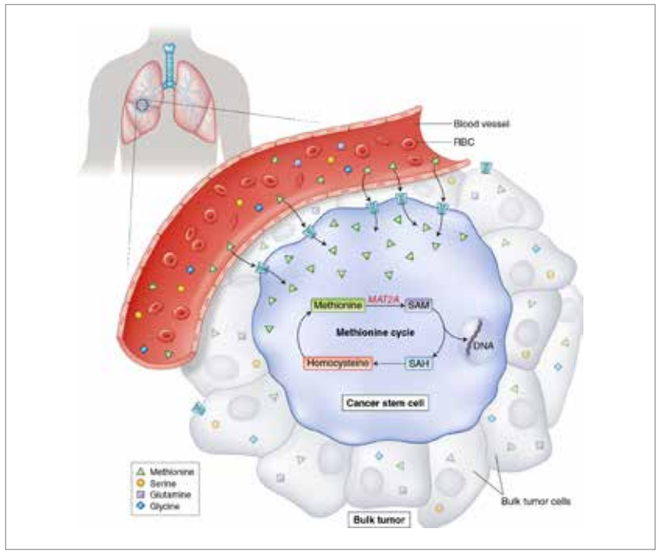
*A*STAR scientists identified a molecular marker for tracing the origins of immune cells that reside in tissues and organs.*

Florent Ginhoux, SIgN
Cell
Fate Mapping via Ms4a3-Expression History Traces Monocyte-Derived Cells



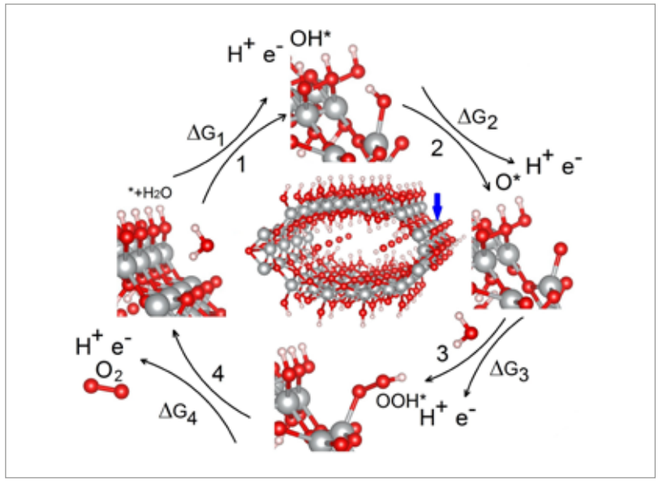
*By integrating nanoantennas with liquid crystals, A*STAR researchers created a metasurface that allows fine dynamic control over the properties of light.*

Arseniy Kuznetsov, IMRE
Science
Phase-only transmissive spatial light modulator based on tunable dielectric metasurface



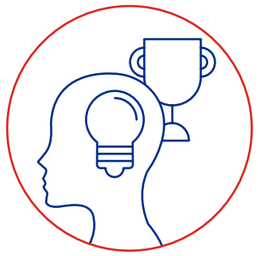
*A*STAR researchers found a novel point of weakness in tumor-initiating cells (TICs), opening up new opportunities for treating drug-resistant cancers.*

Tam Wai Leong, GIS
Nature Medicine
Methionine is a metabolic dependency of tumor-initiating cells



Scientists employed a combination of theoretical and experimental methods to optimise catalyst design. An improved design for nickel hydroxide catalysts could reduce costs and improve the efficiency of hydrogen fuel and oxygen generation.

Yu Zhigen, IHPC
Xi Shibo, ICES
Energy & Environmental Science
Strain stabilised nickel hydroxide nanoribbons for efficient water splitting



TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

Awards: International

Honorary Citizen Award - Professor Sir John O'Reilly, Chairman of SERC, A*STAR

Singapore has honoured Professor Sir John O'Reilly, Chairman of SERC, A*STAR and Professor Victor J. Dzau, President of the United States' National Academy of Medicine, with the Honorary Citizen Award for their valuable contributions to Singapore.

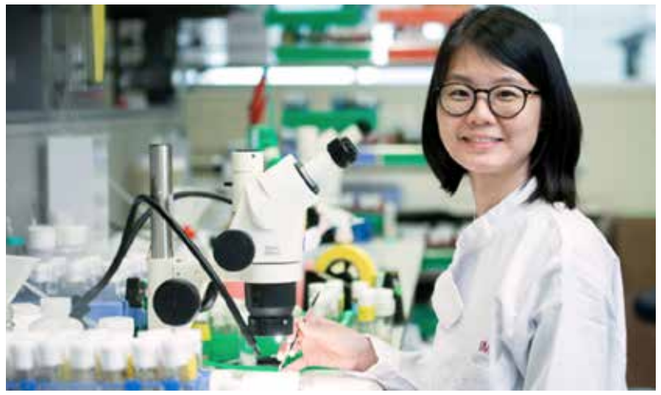
Sir John O'Reilly has played an invaluable role in charting the strategic direction for R&D in Singapore, particularly in the engineering and physical sciences domains. He has also been instrumental in fostering close links and R&D collaborations between Singapore, and British companies and universities.

From left: Professor Victor J. Dzau and Professor Sir John O'Reilly at the Istana

L'Oreal-UNESCO International Awards for Women in Science 2019 - Dr Sherry Aw, Independent Fellow, IMB

Dr Sherry Aw was awarded the L'Oréal-UNESCO regional fellowship Singapore.

Dr Aw's work in neuroscience could pave the way for better treatments for neurodegenerative diseases. Among the 275 national and regional fellowship winners that UNESCO supports each year, Dr Aw was listed as one of the 15 most promising researchers.



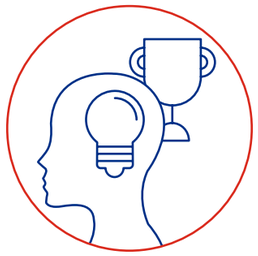
World Summit on the Information Society Prize 2020 Champion - Transforming Urban Tree Management project, IHPC

The team collaborated with botanists and ecologists to translate the botanical domain knowledge into large-scale representative biomechanical 3D models of actual, individual trees in Singapore. **These dynamic tree models will bring about more sustainable solutions for tree management in Singapore, as a response to climate change.** Support from stakeholders such as NParks, Singapore Land Authority, GovTech, and the National University of Singapore, enabled IHPC to form an end-to-end value chain from data acquisition, digital modelling, to tree management operations.

American Institute for Medical & Biological Engineering College of Fellows – Prof Malini Olivo, Director of Biophotonics and Head Laboratory of Bio-optical Imaging, SBIC, A*STAR

Picked for her pioneering work in developing biophotonics technology, Prof Malini Olivo was the only one from Singapore and the ASEAN region to receive this recognition.

The IHPC team (from left): Dr Daniel Wise, Dr Lim Chi Wan Calvin, Dr Like Gobeawan, Dr Su Yi, Dr Wong Sum Thai



TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

READ more about our 2019 Global Highly Cited Researchers.

Global Highly Cited Researchers 2019

Assoc Prof Loh Xian Jun

Senior Scientist, IMRE

Dr Seh Zhi Wei

Senior Scientist, IMRE

Prof Nicholas Barker

Research Director, IMB

Dr Subhra K. Biswas

Principal Investigator, SIgN

Dr Florent Ginhoux

Senior Principal Investigator, SIgN

Dr Liu Zhuangjian

Senior Scientist, IHPC

Dr Michael Meaney

Director, SICS

Prof Laurent Rénia

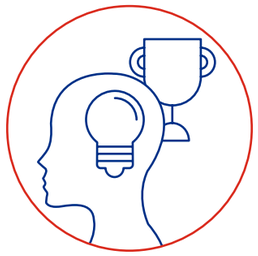
Executive Director, SIgN

Dr Zhang Lili

Scientist, ICES

Prof Zhang Yong Wei

Deputy Executive Director, IHPC



TALENT FOR THE NATION - STRENGTHENING A VIBRANT ECOSYSTEM FOR RESEARCH, INNOVATION, AND ENTERPRISE

Awards: National

President's Technology Award 2019 - Dr Poh Hee Joo, Senior Scientist, IHPC, and Mr Fachmin Folianto, Senior Research Engineer, I²R, Dr Koh Wee Shing, Senior Scientist, IHPC, and Mr Tan Sze Tiong, Director, Centre of Excellence for Environmental Sustainability Research, HDB

A joint effort by A*STAR and the Housing & Development Board (HDB), the Integrated Environmental Modeller (IEM) was adopted in the planning of the new Tengah town to build a cool and well-ventilated environment for residents. In addition to the President's Technology Award, the IEM project has also garnered other notable awards such as the ASEAN Outstanding Engineering Achievement Award, and the Minister for National Development's R&D Merit Award in 2019.

Exemplary Innovator Award – Dr Tan Puay Siew, Director, SIMTech

Recognised for breaking technological boundaries in developing the Model Factory@SIMTech, Dr Tan Puay Siew's work has helped companies remain competitive by adopting innovation and Industry 4.0 technologies. She is also commended for her efforts in designing customised technology upskilling courses to transfer expertise to industry. She received her award at the Public Sector Transformation Awards 2020.

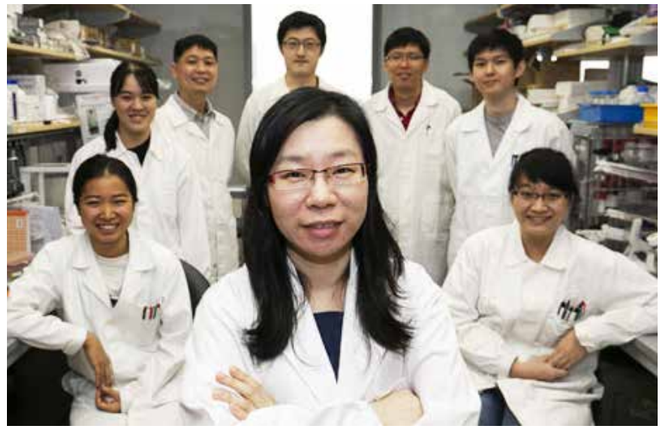
The IEM team receiving the President's Technology Award from President Halimah Yacob at the Istana in October 2019

2019 Outstanding Maritime R&D and Technology Award – I²R Team

Researchers from the I²R's satellite team, Dr Peng Xiaoming, Zhang Weiqiang, Dr Yen Kai, Mr Law Sie Yong, Dr Lin Zhiwei and Mr Richard Wang Bo, and industry partner ST Engineering, were awarded the Outstanding Maritime R&D and Technology Award for their work on a very high frequency (VHF) data exchange system (VDES) for safe navigation at sea.

The I²R team receiving the 2019 Outstanding Maritime R&D and Technology Award

A*STAR Scholar Dr Shao Huilin is a Joint Investigator with A*STAR's IMCB and was awarded the 2019 Young Scientist Award under the Physical, Information and Engineering Sciences category. Her work focuses on developing innovative diagnostic technologies to empower patient care. An Assistant Professor at the National University of Singapore, her pioneering technologies enable non-invasive early cancer detection and monitoring processes. Dr Shao and her team have also developed molecular switches that enable the rapid detection of infectious diseases such as human papillomavirus (HPV), hepatitis and flu. In 2019, she invented a blood test that would enable the accurate detection of Alzheimer's disease — even at early stages. The breadth of her work — spanning the fields of molecular biology, nanomaterials science and device engineering — not only enables clinical breakthroughs, but also strengthens Singapore's international reputation in healthcare technology and innovation.



Dr Shao with her team members from IMCB

ENGAGING THE COMMUNITY

A*STAR SCHOLARSHIP AWARDS CEREMONY 2019

29 July

*The A*STAR scholarships were launched in July 2001 to develop local PhD talent in Singapore. The A*STAR Scholarship Awards Ceremony celebrates newly awarded scholars, and welcomes them into the A*STAR family.*

Minister for Trade and Industry Mr Chan Chun Sing was the Guest-of-Honour.

LEADERS IN SCIENCE FORUM 2019

10 September

The Leaders in Science Forum is the opening event for the one-north Festival. Themed "Innovating for a Sustainable Future", the 2019 speakers addressed tech-policy innovations required in a fast-changing technology landscape, and discussed sustainability and its implications on science and society.

Minister for the Environment and Water Resources Mr Masagos Zulkifli was the Guest-of-Honour.

A*STAR SCIENTIFIC CONFERENCE 2019

16 October

*This annual event focuses on the latest advances in science and technology within the A*STAR community.*

The theme in 2019 was "The Next Bounds in Science", which explores the impact of R&D on advancing healthcare outcomes, transforming industry and enhancing sustainability.

ONE-NORTH FESTIVAL 2019

13 - 14 September

*The one-north Festival is an annual celebration of research, innovation, creativity, and enterprise. It is jointly organised by A*STAR and JTC, and supported by Science Centre Singapore, and many partners within and beyond one-north.*

X-PERIMENT! 2019

13 - 14 September

*X-periment! is a science carnival under the Singapore Science Festival, jointly organised by A*STAR and Science Centre Singapore. It is also held in conjunction with the one-north Festival.*

ANNEX

KEY PERFORMANCE INDICATORS

	RIE2020 KPIs	A*STAR Achievement (as at FY19 Q4)	RIE2020 Target
1	Industry R&D Projects*	6,056 (183%)	3,315
2	Industry R&D Spending (S$ mil)	1,136 (95%)	1,200
3	No. of Licences	977 (217%)	450
4	No. of Spin-offs	68 (131%)	52
5	Industry Cash Funding Received (S$ mil) [Tracking Indicator in RIE2020, subset of indication no. 2]	396 (126%)	315
6	Licensing Revenue (S$ mil)	23.6 (157%)	15
7	No. of RSEs from RIs seconded to industry	255 (93%)	275
8	No. of PhD Postgraduates trained or being trained	542 (99%)	545

** Excludes Characterisation, Measurement and Technical Consultancy (C/M/TC) projects.*

In addition to the indicators above, A*STAR's research was also published in 8,733 high-impact publications.

ORGANISATION DETAILS

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