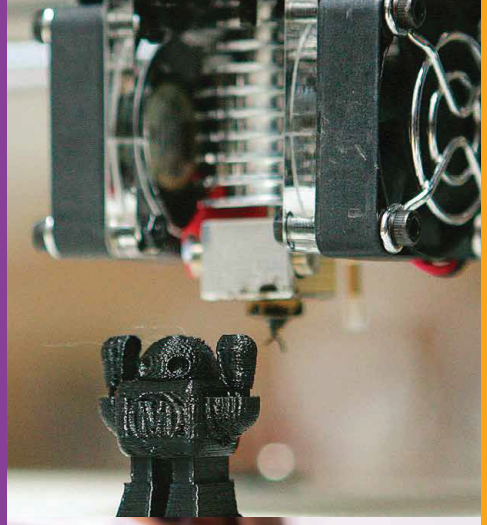
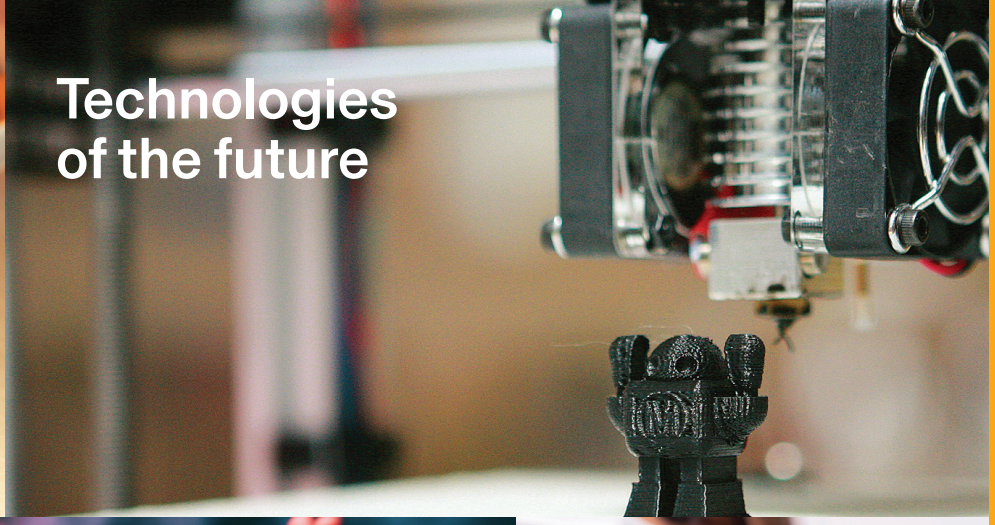
CUHK Research:

Changing the world




Technologies
of the future


Innovation and
discovery for health


Contributing to
and for China


Tackling the challenges
of sustainability

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Foreword by the Vice-Chancellor and President

2023 marks the 60th anniversary of The Chinese University of Hong Kong (CUHK). Over the past six decades, our planet has witnessed drastic changes – globalisation, the information revolution, the proliferation of smart technologies, the disruptive pandemic, and the imminent climate crisis, to name but a few. From our origins as a humble institution with a unique approach to collegiate education, to our transition as a comprehensive and research-intensive university, CUHK's story is woven in the fabric of social progress. It gives me great pleasure to present to you this publication, *CUHK Research: Changing the world*, which showcases how successive generations of CUHK's brilliant scholars have contributed to a thriving ecosystem of research and innovation, and how the University has embraced challenges as an integral part of its journey to becoming a world-class institution committed to research of critical importance in the 21st century.

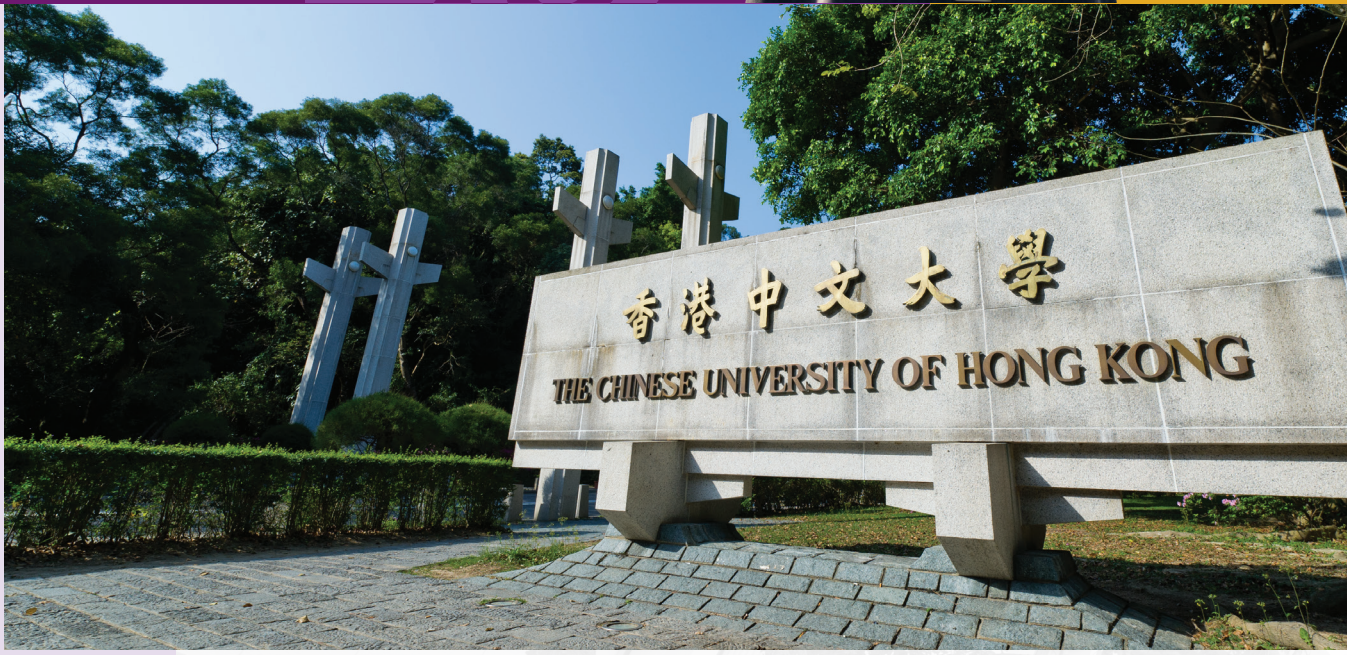
Our latest strategic plan, *CUHK 2025*, articulates our four strategic research areas, namely (1) China: Tradition and Modernity; (2) Innovative Biomedicine; (3) Information and Automation Technology and (4) Environment and Sustainability. These areas are characterised by their interdisciplinary and translational nature, as well as their strong resonance with some of the world's most pressing challenges.

CUHK capitalises on our strength as a talent engine to champion revolutionary research and innovation to deliver tangible benefits to society. We advocate research, innovation and enterprise as a continuum to translate outcomes of our pursuit of knowledge into practical technologies and products. We are committed to playing a leading role to promote Hong Kong's development as an international innovation and technology hub, as well as harnessing the fruits of our academic enterprise as a beacon to build collaborations.

CUHK has been blessed by the confidence of major stakeholders across our city and around the country, as well as a strong network of global collaborators. Today we are the host of six InnoHK Centres under Hong Kong's flagship scheme to incubate research; we are proudly home to five State Key Laboratories; and we have a rapidly growing network of satellites and research institutes in the dynamic Guangdong–Hong Kong–Macao Greater Bay Area.

CUHK Research: Changing the world showcases the inspiring stories of some of CUHK's best and brightest faculty members, as well as our rising stars who are blazing a new trail in their fields, making discoveries and innovations in healthcare, promoting the understanding of China and advancing sustainable development. I hope you will enjoy learning about their ground-breaking discoveries and how CUHK's research endeavours are contributing to some of the greatest challenges of our time, as well as using its great tradition of scholarship to bridge China and the world.

Professor Rocky S. Tuan
Vice-Chancellor and President


香港中文大學
THE CHINESE UNIVERSITY OF HONG KONG

Message from the Pro-Vice-Chancellor and Vice-President (Research)

Research lies at the heart of the vision and mission of the University. As a leading research university in Asia, CUHK has been dedicated to promoting interdisciplinary research and knowledge transfer in the 21st century. The University, known for its culture of research excellence, has been rated repeatedly as the most innovative university in Hong Kong.

A champion of research and innovation that brings benefits to society, CUHK has been committed to integrating research, innovation and enterprise as a dynamic and productive continuum to translate research into tangible output that benefits mankind. We foster the knowledge and technology transfer to tackle global challenges and leave a positive mark on the world.

This year marks the University's 60th anniversary. Over the six decades, we have grown from a humble beginning on barren hills to a comprehensive research university. Since its inception, the University has nurtured generations of bright minds and attracted numerous talented researchers to conduct world-class research. In strengthening the innovation and technology research activities, we have recruited internationally renowned researchers as our Global STEM scholars. *CUHK Research: Changing the world*, which is published to celebrate the diamond jubilee of the University, showcases our research impact and outcome by profiling more than 30 outstanding researchers and rising stars in various fields.

Over the years, we have broadened the scope of China studies, enabling the University to explore the country's challenges and opportunities and participate in its development. The support and resources we put into medical and technological research have yielded great success in innovative biomedicine. We have also excelled from Communication Technology to Information and Automation Technology. The innovative solutions developed by our researchers in areas such as renewable energy, sustainable agriculture, climate change and urban development help to create a more sustainable and equitable world for future generations.

Research is the source of knowledge that advances human thinking and powers innovation. Our groundbreaking achievements have made a huge difference in Hong Kong and other parts of the world. Our researchers have set new standards for diagnosis and treatment of diseases and created global paradigm shifts in cutting-edge technologies. Their success is also inseparable from the staunch support of the University which has established six InnoHK Centres and five State Key Laboratories. CUHK's state-of-the-art research infrastructure, which incorporates a range of advanced equipment platforms and expertise, helps our researchers scale new heights.

I hope you enjoy reading *CUHK Research: Changing the world* which gives tangible examples of how the University's research is contributing to the vision of becoming a national hub for innovation and technology excellence, and to the global competitiveness of Hong Kong. The remarkable achievements of CUHK researchers demonstrate that public investment in the University's research delivers significant social and economic value to Hong Kong and beyond. We will continue to make a contribution to the development of modern China and to solving global challenges through advanced technologies in the years to come.

Professor Sham Mai Har
Pro-Vice-Chancellor and Vice-President (Research)

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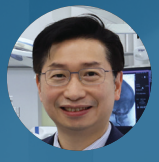
Technologies of the future

Surgical robotics

Advancing surgical robotics for better patient care



Philip Chiu Wai-yan
Professor of Surgery

Samuel Au Kwok-wai
Professor of Mechanical and Automation Engineering

Translating medical and engineering knowledge into healthcare technologies that directly benefit patients is a key pursuit and core strength of CUHK. Its Multi-Scale Medical Robotics Center (MRC) is a trailblazer in bringing the worlds of medicine and engineering together. In collaboration with other world-leading institutes – plus visionary commercial partners – the MRC is further advancing minimally invasive, high precision surgical robotic technologies. It is also incubating affordable medical robots as pressure mounts for better patient care in hospitals in Hong Kong, the mainland and world.

A synergistic circuit

Within a 15-minute drive in Hong Kong's New Territories is a med-tech ecosystem that is hard to match. It integrates CUHK's on-campus medical and engineering faculties, the medical faculty's Prince of Wales teaching hospital, the CUHK Medical Centre and, since 2020, the 12,000 square feet Multi-Scale Medical Robotics Center (MRC) at the Hong Kong Science Park. Together, they cover a spectrum from basic research to prototype and product development, to pre-clinical trials and physician training, to clinical application in hospitals.

"It's a total pathway for how we translate these technologies from bench to bedside," says CUHK Department of Surgery Professor Philip Chiu Wai-yan, Co-Director of the MRC. "CUHK was the first to introduce robotic surgery in Hong Kong. But then we needed to partner with expert engineers who could take robotic technologies from concept to product." Also needed was a robotic platform for pre-clinical testing, practice and training. "Our centre is the missing piece between driving surgical robotics technology forward and applying it clinically," he says.

Professor Samuel Au Kwok-wai of CUHK's Department of Mechanical and Automation Engineering, and the MRC's other Co-Director, explains why engineers, too, needed such a platform. "Beyond just talking, it allows surgeons to explain animal or cadaver anatomy more effectively to engineers, so that engineers can develop hardware that is safe, effective and easy for surgeons to use."

A collaborative culture

The MRC's hybrid operating room is a floodlit futurescape of intra-operational imaging monitors, streamlined control consoles and next generation robotic surgical arms. One of its kind in Asia, it bustles with the comings and goings of more than 70 researchers and practitioners, including 20 to 30 engineers and up to 20 surgeons from CUHK's Department of Surgery. It currently supports research programmes for three types of robotic platforms and robotic interventions at different scales, including micro and nano.

"The MRC is part of the collective efforts of our collaborators including three topnotch overseas universities," notes Professor Chiu. These are ETH Zurich, Imperial College London, and Johns Hopkins University. The centre is also wide open to innovative collaborations with other partners in Hong Kong, the mainland and overseas.

Shared dreams

Professor Chiu and Professor Au, both CUHK graduates, each had a dream to take cutting-edge medical technology from basic research to clinical practice in ways that benefit patients.

Their dreams converged in 2016 when Professor Chiu, founding Director of CUHK's milestone Chow Yuk Ho Technology Centre for Innovative Medicine, was searching for a like-minded engineer partner with whom he could forge new ways to translate biomedical engineering research innovations into medical practices. "We knew Sam and his outstanding work in the US through the alumni network," says Professor Chiu.

For Professor Au, the CUHK community's embrace of interdisciplinary research was an attraction. "It's the foundation to build medical robotics because we need a lot of people from different specialties to work together. I felt that CUHK was the place where I could explore the future." Returning to Hong Kong and CUHK in 2016, he became Co-Director with Professor Chiu of the Chow Yuk Ho Centre.

Team dynamics

For such interdisciplinary initiatives to work, collegial dynamics are all important: "I find the surgeons at CUHK very humble and open to working with engineers," says Professor Au. Professor Chiu reinforces the point: "We surgeons need to be very humble and accommodating to enhance our interdisciplinary collaboration," he says. "If a surgeon is arrogant and scolds an engineer, there'll be no more collaboration and we'll not bring the technology forward."

Currently in pre-clinical testing at the MRC is a magnetic-guided nano robot for evacuating clots in stroke patients or those with extreme heart disease. Along with Professor Au's image-guided robot – the most complicated yet to be built in Hong Kong – Professor Chiu expects major achievements from clinical translation of these breakthroughs over the next five to 10 years.

"The metric for how much we actually contribute to society is not how many robots we sell, but how many procedures are performed with the robot," says Professor Au. "Just because you sell a robot to a hospital, it doesn't mean you're helping people. If your robot is not easy to use, they'll just put it in the garage."

> **"We surgeons need to be very humble and accommodating to enhance our interdisciplinary collaboration.**
>
> Professor Chiu

Facing the future

The MRC draws on CUHK's long track record of robotic development and early breakthroughs in minimally invasive surgery. That seed work enabled Professors Chiu and Au to secure HK$470 million in government funding to establish their robotic surgery lab. It also gives the MRC an edge, today, in navigating the rigorous process of obtaining regulatory approval for human and hospital trials.

From an engineering perspective, says Professor Au, one possible future direction is to develop surgical robots with artificial intelligence and the ability to learn. "We would like to apply AI to optimise some tasks and make surgery more efficient," he says.

Computer vision

From stupid to smart – AI's escalating journey

Jiaya Jia
Professor of Computer Science and Engineering

Tightly connected with the Hong Kong Science Park nearby, CUHK helps to incubate globally competitive technology start-ups that serve advanced industries. Among them is a spin-off from the Department of Computer Science and Engineering, the "unicorn" SmartMore, founded by Professor Jiaya Jia. Large manufacturers use its systems for "Industry 4.0" production involving artificial intelligence (AI)-driven computer vision. SmartMore also provides significant funds for CUHK research collaboration, creating opportunities for professors and students to interact with manufacturers in real business settings.

"Few understood computer vision"

When Jiaya Jia entered Hong Kong's job market in 2004 with a PhD focused on computer vision, almost nobody outside the university knew what computer vision could do. "I doubted I could get a decent academic job because it was such a small research field," he recalls. "Few understood its ability to make real life better." CUHK was the first with an offer, which (then) Dr Jia speedily accepted.

CUHK's instincts were rewarded. Today, he is a professor with CUHK's Department of Computer Science and Engineering and acknowledged as a world-leading scientist in computer vision.

This is in addition to founding SmartMore in 2019, a fast-growing company for manufacturing optimisation and automation (MOA), serving advanced industrial enterprises in economies where human hands are increasingly in short supply.

Next generation "smart machines", Professor Jia notes, have already replaced "stupid traditional machines" in factories across Germany, Japan, the US and mainland China. Operating in the dark 24/7 without a human onsite, their sensors are equivalent to eyes, ears and noses. They have an AI "brain" intelligent enough to monitor production lines, spot defects and make decisions.

> **The intelligence level of AI is getting higher and higher. We need to keep our eyes very closely on what's hot in this area if we're going to catch the train.**

"AI was not a decent word"

Riding off advances in deep learning, computer vision is today part of AI in that it simulates human perception so that a computer can, say, distinguish between images of a cat and a dog. Professor Jia's discoveries are already in practical use. For example, to create a poster or beautify a photo, a user needs only key in an instruction and the computer does the rest.

Some 20 years earlier, "AI was not a decent word," according to the professor. "It could not achieve any challenging intelligence goal without the power of deep learning. AI looked fake – more science fiction than reality."

AI's turning point

The breakthrough, says Professor Jia, came in 2012 with research into neural networks. Up till then, algorithms connecting hundreds or thousands of computer "neurons" – like synapses in a human brain – mostly produced gibberish. But when Canadian-based scientists began applying algorithms to *millions* of computer neurons, things suddenly changed. Outputs became ordered and semantically meaningful. Computers could at last tell the difference between a cat and a dog.

"After that, we were called AI researchers," Professor Jia laughs, "because computer vision was not fiction anymore. It was really beginning to work. We could sense it would become powerful, useful, and applicable to a lot of areas. We were confident it could solve real problems in industry." So began another decade of hard work for Professor Jia and PhD candidates under his supervision.

Racing time

It is a race against time. "It's not just that computer engineering is changing fast. The intelligence level of AI is getting higher and higher," Professor Jia observes. "We need to

The Deep Vision Lab

keep our eyes very closely on what's hot in this area if we're going to catch the train."

To meet this challenge, he and his top students monitor what is new in their field. "The research intensity is very high, which means a lot of people are researching the same problem at the same time. What may once have been a 50-year research problem can now be solved in half a year – then my PhD students need to find another topic to study."

Professor Jia draws on his 20-plus years of experience to help 40 or so PhD students in his group see the big picture and focus on the most important topics in the computer engineering community, such as how to combine multi-modality information including natural language, images, videos, and sound.

A related initiative is the Deep Vision Lab, which Professor Jia set up informally so that computer engineering friends from other Hong Kong universities and top universities overseas can, together, review key papers and the latest developments. They aim to identify the most important problems to be worked on over the next five to 10 years.

Visualising through words

Professor Jia is taking on one of the toughest problems yet: how to bridge computer vision and natural language processing (NLP). "Originally, language and visual content processing were totally separate fields of research, but they are converging because the computer vision people are looking for NLP models to process visual data. There was also a time when NLP researchers used computer vision solutions."

Among many potential impacts, success would make it possible to create a poster by talking naturally to a computer instead of typing in keywords. That is easier said than done. "The way we encode information and messages for vision and language is completely different," says Professor Jia. "Joining these two is undoubtedly one of the most important tasks in my research pipeline."

Logistics robotics

Transforming logistics with artificial intelligence

Liu Yunhui
Choh-Ming Li Professor of Mechanical and Automation Engineering

Robotics, with numerous applications in manufacturing, services, healthcare and space, is considered as one of the most important technologies driving economic growth. With government support, the University set up the Hong Kong Centre for Logistics Robotics in 2020, focusing on developing technologies for "future workplaces" as well as innovative solutions to the pressing problems in the logistics industry. Professor Liu Yunhui, Director of both the centre and CUHK T Stone Robotics Institute, is renowned for his research in vision-based robotics, logistics robotics, medical robotics and construction robotics.

The autonomous forklift

At the Hong Kong Centre for Logistics Robotics in the Science Park, Professor Liu Yunhui is checking on a robotic arm under development, which may one day be installed in a robot to serve food in a restaurant, or work in a hotel.

How humans use their hands, arms and legs in perfect coordination with their vision has always fascinated Professor Liu. "A robotic arm should be as nimble, skilful, and gentle as a human hand. A robot should be able to respond to outside changes and move steadily like a human does. How this human intelligence can be translated into robotics

has been one of the most important research topics for me," he says.

Professor Liu has long established himself in the field of logistics robots, with his team's signature innovation, the world's leading **vision-based autonomous forklift** launched in 2016. Over the years, more than 350 projects have been deployed around the globe by VisionNav Robotics, which was founded by Professor Liu and his PhD students as the spin-off of the centre.

The forklifts, now deployed in a wide range of industries, have been programmed to run as unmanned storage facilities with racks of up to 9.4 metres high. They can handle tasks including loading and unloading, sorting and packaging, taking the tasks over from human workers and help reduce costs and risks of injury.

Professor Liu started to develop the smart forklift at the start of the e-commerce boom around 2010. He understood that while the logistics industry faced a manpower shortage, online shopping orders were wide-ranging and personalised, posing a big challenge to efficiency. "If the warehouse tasks can be automated, and artificial intelligence can fill in where human decision-making is needed, the bottleneck can be solved."

Computer vision, a field of artificial intelligence that enables machines to derive and analyse information from visuals, is the technical foundation that enables automated navigation of robots and also a topic Professor Liu has studied for 20 years.

The team, initially comprising Professor Liu and four of his PhD students, developed a smart guidance system that can convert manual forklifts into automated ones. The system is equipped with a three-dimensional vision that collects real-time data on the surroundings for guidance and positioning. The vehicle, with a gripper system, can navigate and carry goods around a complex and unreferenced depot with high precision and safety without human intervention.

After rounds of searching and pitching by his students, a personal-care product company in mainland China, offered a helping hand. The company, which needed to frequently transport its products to another warehouse after packaging, was willing to let Professor Liu test the forklift prototype in its plants. "They bore with us when we had some technical glitches in the beginning and needed time to fix them. They were also our first customer. I am grateful."

Today, VisionNav Robotics is a leading global supplier of autonomous forklifts and intralogistics automation solutions. It serves more than 30 countries, with 60% of its business in mainland China and 40% overseas. Its robots are used by more than 50 Fortune 500 companies from the automotive, food, petrochemical, e-commerce, third-party logistics, pharmaceutical industries and other sectors.

Surgery robots relieving doctors' burden

Another research area of Professor Liu is surgical robots. His team has developed surgical robots to assist doctors in sinus surgery and hysterectomy, which have undergone clinical trials at the Prince of Wales Hospital, CUHK's largest teaching hospital.

The team is now working on robots that can perform surgical procedures semi-automatically. "We hope robots can share doctors' burden and take over some simple and tedious procedures such as stitching, injection and biopsy, so the doctors get less tired. Doctors will only need to monitor the surgery and press a 'confirm' button before the robot proceeds," he says.

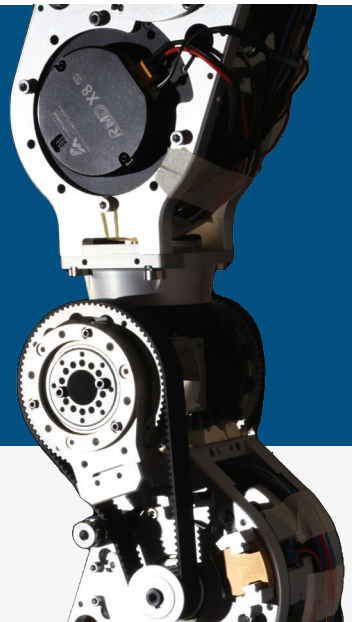
Service robots for smart city

Looking ahead, Professor Liu hopes to create robots to serve people's needs in daily life such as in restaurants and hotels, as the service industry plays a key role in Hong Kong's economy.

His team has been working on increasing the flexibility and vision of the service robots with the robotic arms, so that they can take up tasks such as serving dishes in restaurants and folding blankets in hotel rooms. "Our technology has reached practical level. Now we are discussing collaboration possibilities with many business partners to identify scenarios that are suitable for deploying service robots."

Professor Liu joined CUHK in 1995 after studying and working in robotic science in Japan for 10 years. "CUHK has an open academic environment, a productive research community, a well-connected global network and deep integration and cooperation with the Greater Bay Area on the mainland," he says. "These are all favourable conditions for us to continue scientific research."

"If warehouse tasks can be automated, and artificial intelligence can fill in where human decision-making is needed, the bottleneck can be solved.



Speech and language processing

Finding their voice again

Helen Meng Mei-ling
Patrick Huen Wing Ming Professor of Systems Engineering and Engineering Management

Patrick Chun Man Wong
Stanley Ho Professor of Cognitive Neuroscience and Professor of Linguistics

The onset of numerous neurological diseases can make communication difficult. Although research on solving these problems is ongoing, this is stymied by the lack of a relevant, sizeable language dataset to help researchers unlock what those affected are trying to say. Two CUHK professors are collaborating on technology solutions for Cantonese speakers in Hong Kong who suffer from dysarthria, which affects the articulation of sounds and words, and have since expanded their research to neurological diseases such as dementia. Their cross-disciplinary research combines multilingual speech processing, artificial intelligence, neuroscience and language learning.

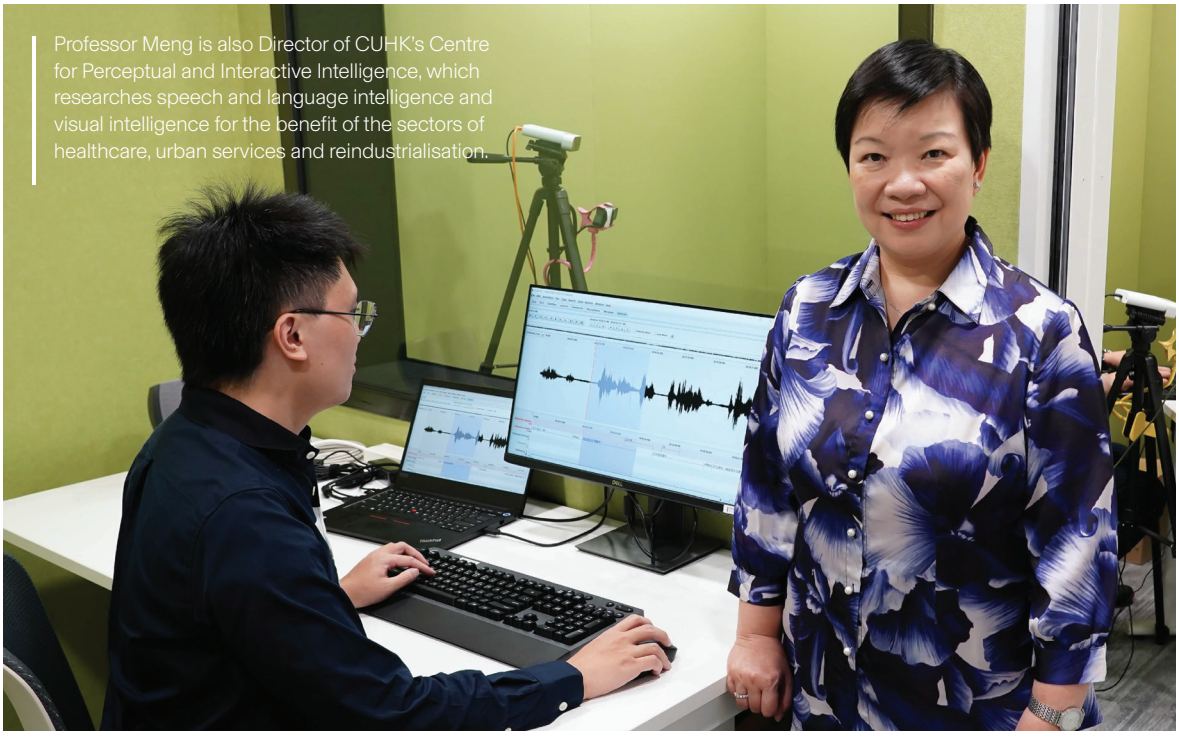
Neurological diseases can make communication by speech a struggle for many. When the muscles needed for speech become weak or hard to control, those affected begin to slur their words in a disorder called dysarthria. Treatment is difficult because, outside of Hong Kong, there is no body of relevant research in the Cantonese language to draw upon. Professor Helen Meng Mei-ling and Professor Patrick Chun Man Wong of CUHK have been working together for more than a decade on speech and language processing. While Professor Meng deals with the digital and AI-related aspects of their projects, Professor Wong brings neuroscience and linguistics know-how in a cross-disciplinary approach to the challenge. Their collaborative efforts have resulted in a variety of projects that cater to what they describe as "development across the lifespan."

The professors began by developing artificial intelligence models to recognise symptoms of dysarthria from speech samples, but have since broadened the scope of their research, hoping to distinguish signs of cognitive decline before patients begin exhibiting symptoms.

Hope for local dysarthric patients

Although databases for dysarthric patients are plentiful in the English language, no publicly available equivalent previously existed for Cantonese. The professors, together with a few other colleagues in CUHK, remedied this by carefully curating a selection of stimuli, the length of which range from single words to paragraphs and even full conversations in Cantonese. This allows them to gather data on the enunciation of certain words and vowels by dysarthric patients, as well as the rhythm of sentences they utter. As of 2021, some 27 dysarthric Cantonese speakers have participated in the project, generating up to 34 hours of data - a significant amount when compared to existing databases for other languages.

They have also been able to adjust their system so that it automatically translates dysarthric speech into normal speech, a predictive process on which Professor Meng has brought to bear her work in AI. Together, the two



Professor Meng is also Director of CUHK's Centre for Perceptual and Interactive Intelligence, which researches speech and language intelligence and visual intelligence for the benefit of the sectors of healthcare, urban services and reindustrialisation.

professors hope that their work will provide a foundation for further study into dysarthria in Hong Kong, which might, in turn, enable additional medical and therapeutic responses.

With their teams, Professors Wong and Meng have also done MRI experiments, with older adults at different cognitive levels as subjects, hoping to isolate the features of such decline by looking into how those affected might understand language or express themselves. "Ageing is a big risk factor in cognitive decline," says Professor Meng. "We can detect the decline of cognitive functioning through the patients' daily use of language in communication."

Professor Wong adds, "Most studies look at this from an anatomical perspective: is this brain area thicker or thinner? Our research in addition examines the patterns of neural activities associated with performing a task." These more "naturalistic" tasks enable the researchers to test for symptoms of cognitive decline, combining neuroscience and AI technology. Professor Meng credits former Vice-Chancellor Charles K. Kao with establishing the Department of Electronics in the 1970s, which opened up CUHK's research into electronic engineering and enabled it to get a foothold in the world of AI. "Artificial Intelligence is a newly added subject for ranking in the Best Global Universities Rankings 2023 by the US News & World Report, and it is encouraging that CUHK's research on AI is ranked top in Hong Kong and third globally." She adds that CUHK has also been very adept at bringing professionals across disciplines together, as their project has demonstrated.

A major problem the professors faced throughout their years of collaboration has been the relative lack of support for research involving the Cantonese language. While an estimated 80 million people speak Cantonese across the world, too often this is seen as insufficient (compared with, for example, Putonghua or English) to justify the allocation of significant research resources. Moreover, companies are reluctant to fund initiatives with limited commercial returns. Research in Cantonese speech, therefore, does not attract the same level of resources as more widely-used languages. Fortunately, the professors have received support from the Hong Kong Government's General Research Fund, which has enabled the formulation of a Cantonese corpus for their work.

> **We can detect the decline of cognitive functioning through the patients' daily use of language in communication.**
>
> Professor Meng

"Development across the lifespan"

Despite their long years of work together, the professors intend to continue their collaboration. For example, they are looking at how to support younger patients in language acquisition, and have developed an AI-based system that can accurately predict the progress of babies' language skills. Professor Wong asks: "Can we develop more effective tools to help children and their parents or caregivers communicate with each other? Or perhaps we can help autistic children improve their social communication skills?" They see their series of projects not as attempts to fix isolated issues, but as part of a wider effort to overcome fundamental social problems arising from speech difficulties and disabilities.

Network coding

A disruptive technology, ready for take-off

Raymond Yeung Wai-ho
Choh-Ming Li Professor of
Information Engineering

CUHK is at the forefront of transforming global communication systems and networks. The research field of network coding, a paradigm shift in network communication, is among world-leading breakthroughs. Co-founded by CUHK information theorist Professor Raymond Yeung Wai-ho, network coding is a fundamental theory which, through its efficient realisation BATS, makes it possible to extend wireless Internet to billions living in rural isolation and to communicate in settings where cellular signals and GPS are blocked.

Overturning folklore

For a time, it was folklore in communication research that the best way to transmit information through a network was by generating bunches of data packets and routing them through nodes acting like postal relay stations. That was before CUHK information theorist Raymond Yeung questioned the assumption some 30 years ago.

"My first question was whether data packets from different sources need to be mixed in the network," he explains. He followed a hunch that by mixing data packets from two different sources, it was possible to transmit more. "It took me a week to come up with an example showing that this is actually the case."

That discovery intrigued Professor Yeung, who in 1991 left a premier US research lab to join CUHK's then newly established Department of Information Engineering. At CUHK, he began his paradigm-shifting research. "At that point we didn't have a very comprehensive theory for this phenomenon of mixing data packets inside the network. So, for the next seven or eight years I worked with individual collaborators here at CUHK and overseas. I knew it was going to lead to something very important."

Indeed, it led to network coding, a revolution in network communication, enabling more information to be transmitted through networks at a faster rate so that, for example, data can be downloaded faster from the Internet and video streamed with less delay.

Breaking with convention, network coding introduced computation, or coding, at intermediate nodes within the network to increase throughput. "It's a completely new way of transmitting information through a network," says Professor Yeung. "Subsequently, we tried to find applications. However, after 10 years or so, there still was no real application." He was disappointed but philosophical. "Typically, going from theory to application may take decades."

A killer application

For applications of network coding to move beyond the laboratory, there were hurdles to overcome. For example, to mix data packets, it was necessary for intermediate nodes in the network to perform computation. But traditional networks used simple routers with little computing power. "Another hurdle was that we didn't have an efficient algorithm for implementing network coding. In other words, the benefit offered was not sufficient to lure network operators to use a more elaborate way of transmitting information," Professor Yeung recalls. "I began thinking we need a killer application – not one that merely improves network performance by 30-40% but one that is impossible *without* network coding."

He zeroed in on what is called the "multi-hop" curse in wireless communication. That is when packets of data are lost as they "hop" from one node to another because of noise or other channel interference. Accumulations of lost packets clog network transmission paths. Network coding can solve this problem by "opening" and mixing packets at intermediate nodes, encoding them, and then decoding them to reconstitute the original data using mathematical computation.

To develop a solution for this killer application, Professor Yeung turned to former PhD student Yang Shenghao who was proficient in coding theory. "I gave him the multi-hop problem and within a relatively short time he was able to come up with a very elegant solution. That was Batched Sparse Codes ('BATS')," says Professor Yeung. This disruptive network coding technology reduces the rate of packet loss per "hop" while significantly increasing the rate of data transmission.

> **Network coding is a completely new way of transmitting information through a network.**

In 2018, seven years after creating BATS, Professors Yeung and Yang established n-hop technologies, a start-up next door to CUHK at the Hong Kong Science Park, as a vehicle for pursuing pilot projects with the Hong Kong government, public-private partnerships, and for commercial ventures.

The unique BATS system, which comes in a compact, portable metal box, has since been successfully deployed in local trials of "smart lampposts"; in an experiment to extend potentially life-saving Wi-Fi coverage to remote hiking trails; in a power station where heavy machinery blocks cell phone signals, and for communication on construction sites where optical fibre cables have not yet been laid.

Catching the network coding wave

Network coding has already made an impact on academic research. As an interdisciplinary subject, it is heavily studied by leading research labs and universities around the world. "But the impact of network coding in the real world is only at its infancy," he observes. Perhaps not for much longer.

"People are putting more and more computational power inside networks. That favours the implementation of network coding, in particular BATS code," he says. Meanwhile, his growing list of potential BATS applications includes the Internet of Things, satellite networks, underwater communication networks and blockchain.

One potential application particularly intrigues him. "In Mongolia, sheep overgraze certain pastures, which causes soil erosion and sandstorms. A study shows that shepherds always gather where there is network coverage. By spreading Wi-Fi access, BATS could offer a sustainable solution."

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Innovation and discovery for health

The human microbiome

A vision to build Asia's microbiome biotechnology hub

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The human microbiome is a fast-growing field of research. The trillions of microorganisms living in our intestines are closely linked not only to gastrointestinal diseases, but also to a wide range of health issues such as obesity, allergy, depression, autism and cancers. At CUHK, a multidisciplinary team led by gastroenterologists Professor Francis Chan Ka-leung and Professor Ng Siew-chien believe that the microbiome is the next frontier of medicine. For over a decade, the two clinician-scientists have been making cutting-edge innovations to identify and treat different diseases and translating them into clinical service and products for the benefit of the community.

World's first microbiome immunity formula

In June 2020, six months into the coronavirus outbreak with a vaccine yet to emerge, a medical research team at CUHK made a groundbreaking discovery: synbiotic formula **SIM01** that can boost immunity against COVID-19.

"At the start of the pandemic, every COVID-19 patient in Hong Kong was admitted to hospital. I was working at a CUHK teaching hospital and was intrigued by why some COVID-19 patients became seriously ill or even died while others remained well with no symptoms. I believed that the human gut microbiome that regulates our immune system plays an important role," says Professor Ng Siew-chien, Director of the Microbiota I-Center (MagIC) at the Hong Kong Science Park. "We started saving stool samples from every COVID-19 case and examined how the gut microbiome influenced susceptibility to coronavirus risk and outcome."

The team found that a series of beneficial bacteria was missing in the patients' gut, especially the seriously ill. Using big data analysis and machine learning technologies, they developed the synbiotic formula, which was effective in hastening recovery, increasing antibody response and restoring gut dysbiosis. According to a large-scale, double-blind clinical trial, the formula can also improve immunity against other respiratory infections.

The team has also shown that SIM01 improved antibody response and durability of SARS-CoV-2 vaccines. Subjects who received oral SIM01 achieved sufficient good bacteria in their gut, had higher antibody levels, and fewer side-effects after the vaccines.

In 2020, Professor Ng and Professor Chan co-founded a biotechnology company, GenieBiome, which focuses on providing microbiome solutions to common health problems. They were able to license their discoveries to their own company to maximise the benefits of their research for the development of Hong Kong's microbiome industry. SIM01 was launched that year and is now also available in mainland China and Southeast Asia.

> **"We hope to leverage our gut microbiome research to provide effective solutions to common illnesses in our next generation such as obesity, eczema and autism.**
>
> Professor Ng

The team has investigated the effectiveness of SIM01 in treating long COVID symptoms including fatigue, sleep problems, difficulty in concentrating and shortness of breath. Early findings showed that the formula was effective in reducing those symptoms.

Professor Chan says: "Our scientific discovery and rapid launch of SIM01 was made possible with the collective efforts of a multidisciplinary team consisting of over 100 people."

A new frontier in medicine

Professor Ng joined CUHK in 2010. Her research interests include inflammatory bowel disease, colorectal cancer, gut microbiome and faecal microbiota transplantation. "As a young institution, CUHK is full of opportunities and encourages innovation and entrepreneurship. With that, I can continue to create knowledge that can benefit society," she says.

Professor Chan is a world-renowned expert in peptic ulcer bleeding, *helicobacter pylori* and endoscopic therapy. "The human body

has two sets of genomes – our own genome and microbial genome in our gut," he says. "We cannot edit our human genes, but we can manipulate our microbial genes to prevent disease, improve health, and even change our fate."

Apart from SIM01, their team has developed novel non-invasive diagnostic tests, including a stool microbiome precision test to detect colorectal cancer (known as **M3CRC**). They also planned to launch a stool microbial biomarker test for early detection of autism.

Success in stool transplant

CUHK established Asia's first fecal microbiota transplantation (FMT) and research centre in 2018. FMT is a therapy that transfers gut microbes from a healthy human donor to a patient to help restore gut dysbiosis. The Faculty of Medicine has performed over 500 successful FMT treatments for recurrent *Clostridioides difficile* infection, a life-threatening disease causing profuse diarrhoea and rectal bleeding. It is also researching the role of FMT in other diseases such as obesity, autism and irritable bowel syndrome.

The faculty is partnering with the Hospital Authority to provide stool transplant as a clinical service to all public hospitals in Hong Kong for recurrent and refractory *Clostridioides difficile* patients.

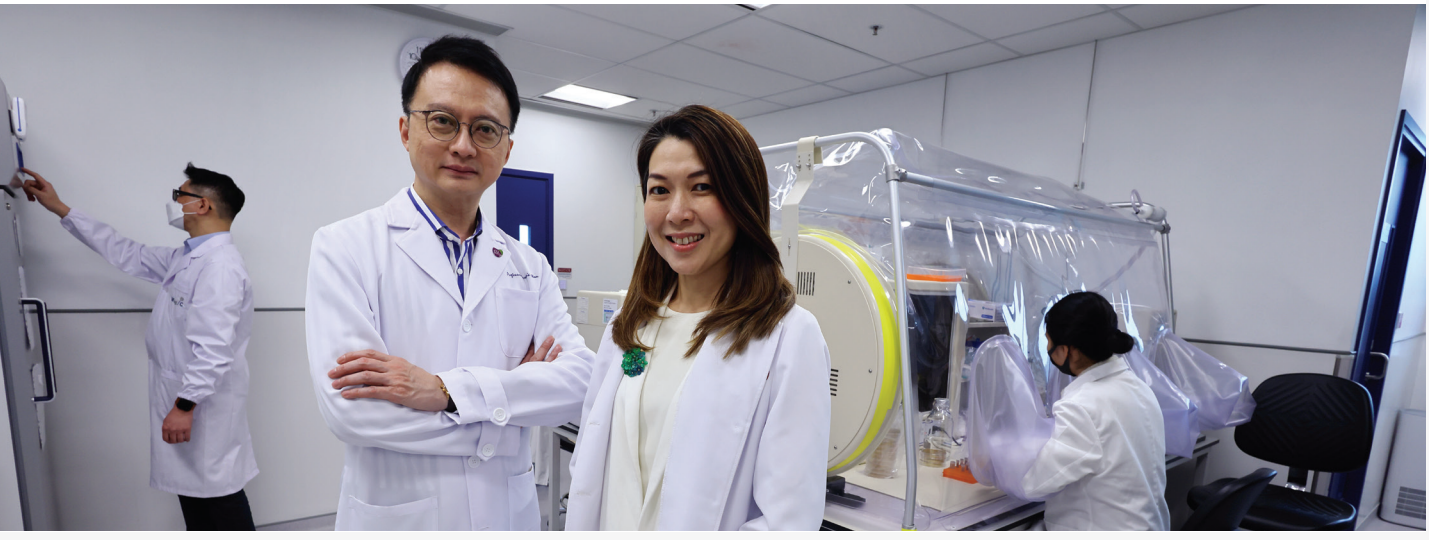
"Noah's Ark" in the Greater Bay Area

For the past five years, the CUHK team has been collaborating with over ten hospitals in southern China in a project involving 100,000 pairs of mothers and babies, regularly collecting biosamples from the women from pregnancy until the birth of the infants.

"The first three years of life is the golden period to keep us healthy for the rest of our lives. If we maintain a good set of gut bacteria, we are likely to be protected from many chronic illnesses," says Professor Ng. "One day, we will be able to provide personalised microbiome therapy in pill form to treat common diseases including eczema, autism and obesity."

Professor Chan says an expedited approval process for new drugs developed in the Greater Bay Area (GBA), covering Hong Kong, Macau and Guangdong Province, would be vital to develop the city into a microbiome innovation and technology hub in Asia.

CUHK is proposing to set up a microbiome biobank at the border with the mainland. "We are ready to lead with our world-recognised expertise and innovative discoveries. It is our dream to build a 'Microbiome Noah's Ark' for the 80 million people living in the GBA," he says.



Molecular diagnostics

From safer prenatal tests to early cancer detection

Dennis Lo Yuk-ming
Professor of Chemical Pathology

CUHK's Faculty of Medicine is home to a team of leading researchers who contribute extraordinary expertise to Hong Kong's public healthcare system. Among them is Chemical Pathology Professor Dennis Lo Yuk-ming, often referred to as the "father" of Non-invasive Prenatal Testing (NIPT). Last year, he was awarded America's top biomedical research prize for his discovery, which has revolutionised prenatal testing for Down syndrome. That clinical breakthrough has also laid foundations for the early detection of multiple types of cancer, creating life-changing impacts on patients around the world.

About one in 700 children around the world is diagnosed with Down syndrome, a chromosomal disorder caused by the presence of an extra copy of chromosome 21 in a human embryonic cell, itself associated with delayed physical growth and intellectual disability.

Traditionally, expectant mothers opting to take early pregnancy tests to detect whether their children might have Down syndrome bore the risk of miscarriage, as certain tests needed to penetrate the womb near the foetus.

That changed after Professor Lo, who is also Associate Dean (Research) of CUHK's Faculty of Medicine, entered the international research scene. "Previous testing methods such as nuchal translucency scan and blood testing did not have high accuracies," says Professor Lo. "Amniocentesis, another invasive test with relative higher accuracy could cause miscarriages. I was therefore motivated to develop a safe alternative with a high accuracy." He started working on a solution in 1989, while still a medical student at the University of Oxford.

A correct hypothesis

Professor Lo's approach was to search and test for foetal cells in pregnant women's blood, balancing research while studying for finals. "At first, the research didn't go very smoothly – the number of foetal cells was too small to be translated into clinical medical diagnosis," recalls Professor Lo.

He returned to join CUHK in 1997, determined to make a breakthrough. "I came across two articles about cancer patients carrying cancer DNA in their plasma or serum, from which I thought – tumours grow in patients' bodies in a way somewhat similar to foetuses developing in wombs. While many scientists at that time had a general assumption that DNA belonged only within a cell, I took the bold move to propose that foetal markers could also be found in maternal plasma. It turned out to be a correct hypothesis."

Building on the momentum, Professor Lo's team eventually identified the ratio of chromosomes via massive parallel sequencing to efficiently use the information stored in plasma DNA. They found a way to use critical information stored in plasma DNA to detect the presence of a foetus with Down syndrome to an accuracy higher than 99%.

A paradigm shift

"Our research created a paradigm shift in prenatal medicine," Professor Lo acknowledges. Since its introduction to clinical practice in 2011, NIPT has been adopted globally, helping expectant mothers in over 60 countries. "The technology has now become the standard prenatal testing method for Down syndrome, obviating the need for

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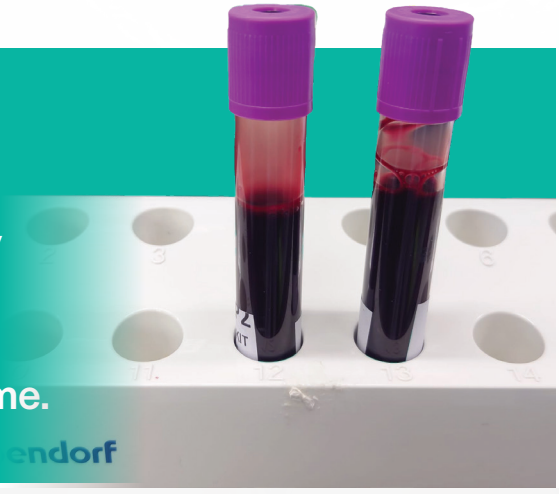


invasive methods in many pregnant women."

The Hong Kong Hospital Authority has been providing NIPT tests for free since 2019. On the mainland, over 60% of expectant mothers each year have taken the test, and some insurance companies overseas now include it in their policy coverage.

Professor Lo credits CUHK with its comprehensive platform for conducting research. "CUHK demonstrates its leading practices in intellectual property and patent creation. It allows my teammates and me to conduct research in a friendly and supportive environment. Our team has developed a close relationship with other departments of the University," says Professor Lo.

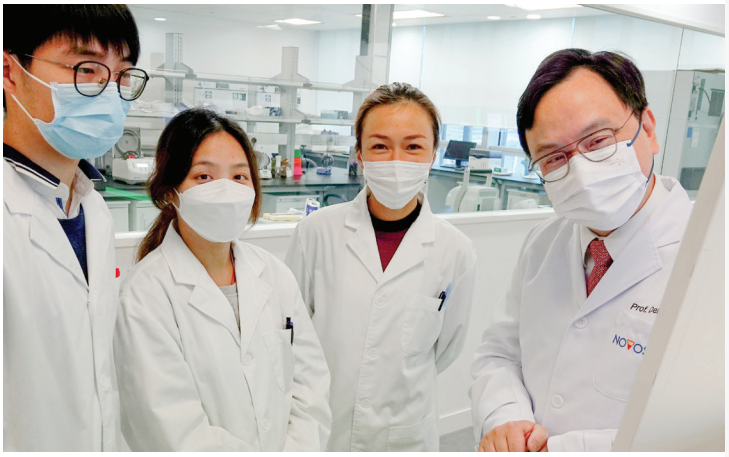
From womb to head and neck

For Professor Lo, success in Down syndrome detection was just the beginning. "While insights into cancer is where I got my burst of inspiration for NIPT, I started probing cancer screening by developing 'NIPT-like' technologies. Our team began with asymptomatic nasopharyngeal carcinoma (NPC), which is the 12th leading cause of cancer deaths in Hong Kong.

"In 2017, we demonstrated that plasma Epstein-Barr virus (EBV) DNA analysis is useful in screening for NPC. Previously, most NPC patients in Hong Kong were identified at stages 3 and 4. With this technology, 70-75% can be identified at stages 1 and 2," says Professor Lo.

In 2019, Professor Lo became the co-founder of healthcare startup Take2 Health at the Hong Kong Science Park which offers NPC screening services in Hong Kong.

The NPC study gave rise to **a multi-cancer early detection (MCED) test**, a method to screen for many types of cancer

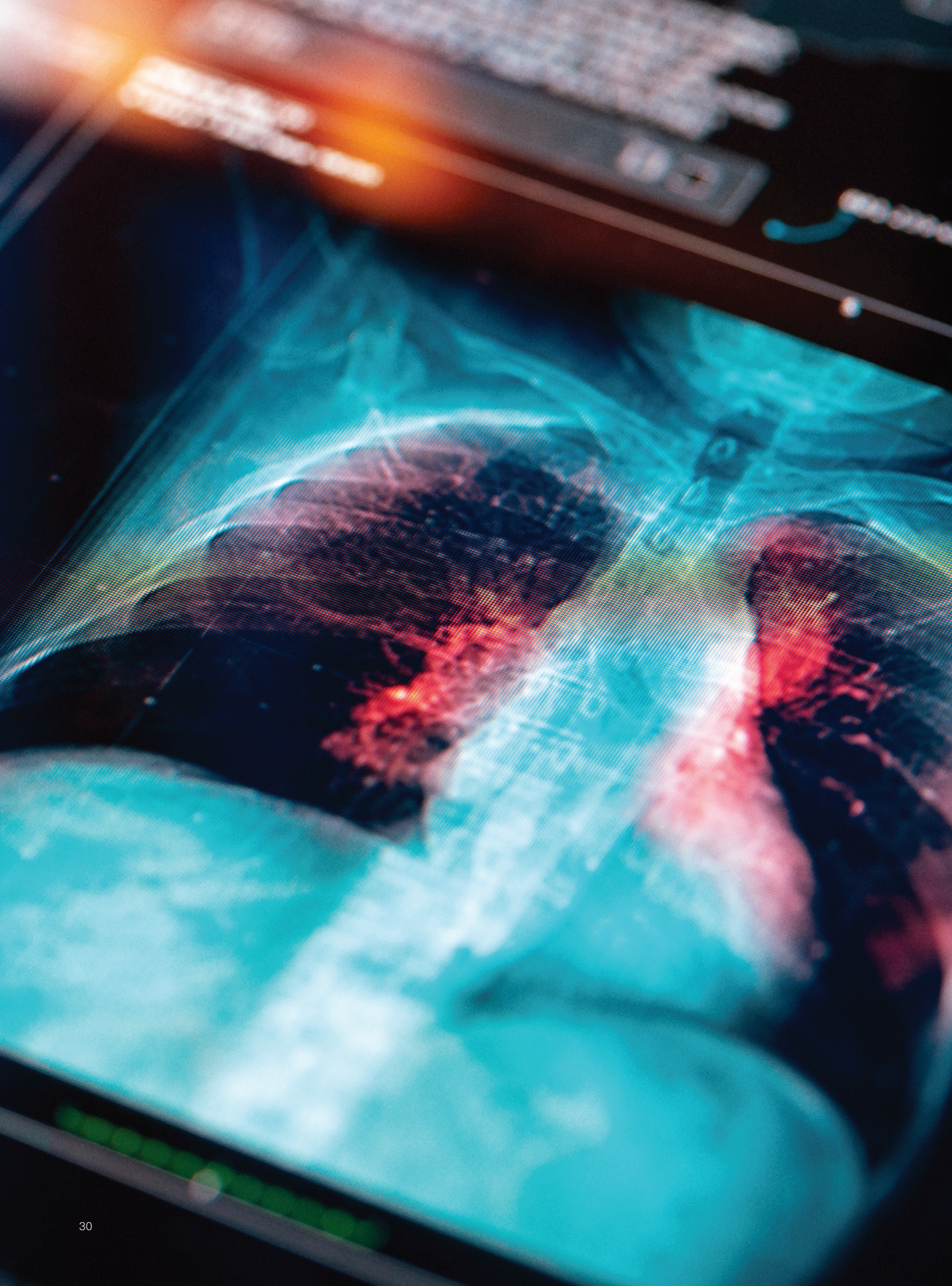


simultaneously. The test enables cancer markers to be detected through a simple blood draw, a landmark achievement hailed as one of *Time* magazine's best inventions of 2022.

Freer flows, bigger samples

Efforts by Professor Lo to achieve even greater impact with his research face hurdles outside the laboratory. "Barriers in the flow of samples are making research a more challenging task," he says. "I hope that the flow of samples between Hong Kong and the mainland can be strengthened. Apart from innovative ideas and insights, access to large sample sizes is always crucial for clinical research."

More than just a clinician, Professor Lo is also a medical scientist and an entrepreneur. "Having received training as a scientist, I am well aware of the development of latest scientific technologies. As a doctor, I am more sensitive to how these technologies can possibly help patients. My entrepreneurial expertise enables me to venture beyond laboratories. I actively engage with the real world and thoroughly understand the actual needs of society while remaining down-to-earth. It also allows me to draft more comprehensive patents for inventions," he says.



Lung cancer treatment

Refining global paradigms in lung cancer treatment

Tony Mok Shu-kam
Li Shu Fan Medical Foundation
Professor of Oncology

The CUHK research group led by Professor Tony Mok Shu-kam has decoded the common mutated genes in lung cancer and developed targeted therapies that have successfully increased patients' lifespans. These innovative therapies redefined global paradigms in lung cancer treatment, providing patients with fresh hope. Professor Mok has established himself as one of the leading oncologists of the world, with his work on targeted EGFR inhibitors marking a significant milestone in the use of immunotherapy.

The grand challenge

Lung cancer is one of the deadliest killers of the world, with some statistics estimating that it accounts for 1.8 million deaths every year. Yet such is its complexity that 20 years ago there was no specific way with which it could be targeted and treated. Back when Professor Mok started researching the subject, more than 70% of patients who had lung cancer only showed symptoms when their illness was already significantly advanced. Even when they were diagnosed, the prognosis was often extremely dire, with patients given at most a year or so to live, a short period of time which chemotherapy only helped extend by a few months.

It was in 2004 when a team from Harvard discovered that epidermal growth factor receptor (EGFR) mutations were responsible for cases of lung cancer. This is particularly prevalent amongst Asian cancer patients, 30-40% of whom normally do not have a smoking habit, compared to a third of that in other regions. "It was therefore imperative that there was a study suited to the situation in Asian countries, and I had built up a research network of Asian scientists around that

> **"Now we are level with researchers in Western countries, and realising the significance of EGFR inhibitors played a huge part in that.**

period," Professor Mok says. With CUHK as his base, he conducted his **IRESSA Pan-Asia Study (IPASS)** — a large-scale study that involved more than 1,200 patients — and they announced their major breakthrough in 2008.

Professor Mok explains that many of the EGFR mutations that cause lung cancer are caused by driver oncogenes, and that the best way to prevent the growth of cancer cells is to cut down the signalling pathway. His groundbreaking paper, published in the prestigious *New England Journal of Medicine* in 2009, has subsequently been cited more than 10,000 times.

Overcoming struggles

Professor Mok emphasises that the academic freedom of CUHK allowed him to undertake this research project, and he has benefitted from the many collaborations with other staff at the Faculty of Medicine. "As long as you follow certain principles, the space for collaboration is vast." Besides CUHK, he suggests that being based in Hong Kong has been beneficial to his research. The IPASS study drew on patients from nine different countries and regions, and he suggests that the city's connections to Southeast Asia, and mainland China in particular, have been a boon for his research processes. "One of the visions I had when coming back was that I needed to work in China."

Nevertheless, the process of research still presented Professor Mok with many obstacles. "When you are doing research, it can only be positive or negative. How do we learn from a negative study?" The professor says that his research was initially stymied by the treatment of lung cancer as a single disease; it was only when they started treating it as a collection of different diseases that they finally broke through. From there on, it was relatively plain sailing: as Professor Mok says, "Once you have a breakthrough, you can have a lot of results."

Discoveries

Once Professor Mok and his team discovered that they should be treating each cancer case individually, they started researching medicines that could respond more effectively to the diseases. In addition to only helping the patient survive a few extra months, chemotherapy also causes the patient intense discomfort and can only deal with the disease generically. Professor Mok discovered that the use of EGFR inhibitors was much more effective, acting as targeted medicine on patients and improving their quality of life. "Each new medicine needs a Phase III study before it can be marketed, and you need to do a lot of research work for that." Thanks to his research, no less than eight medicines have been approved for sale. The targeted immunotherapies his team developed have successfully increased patients' lifespans by at least two years. The therapies are now adopted as clinical applications in more than 75 countries. Professor Mok cites in particular the circulation of third-generation EGFR inhibitor Tagrisso as a major breakthrough. In his 2017 study published in the *New England Journal of Medicine*, he found the drug to be particularly useful in dealing with lung cancer, and it now annually has US$5 billion in turnover.

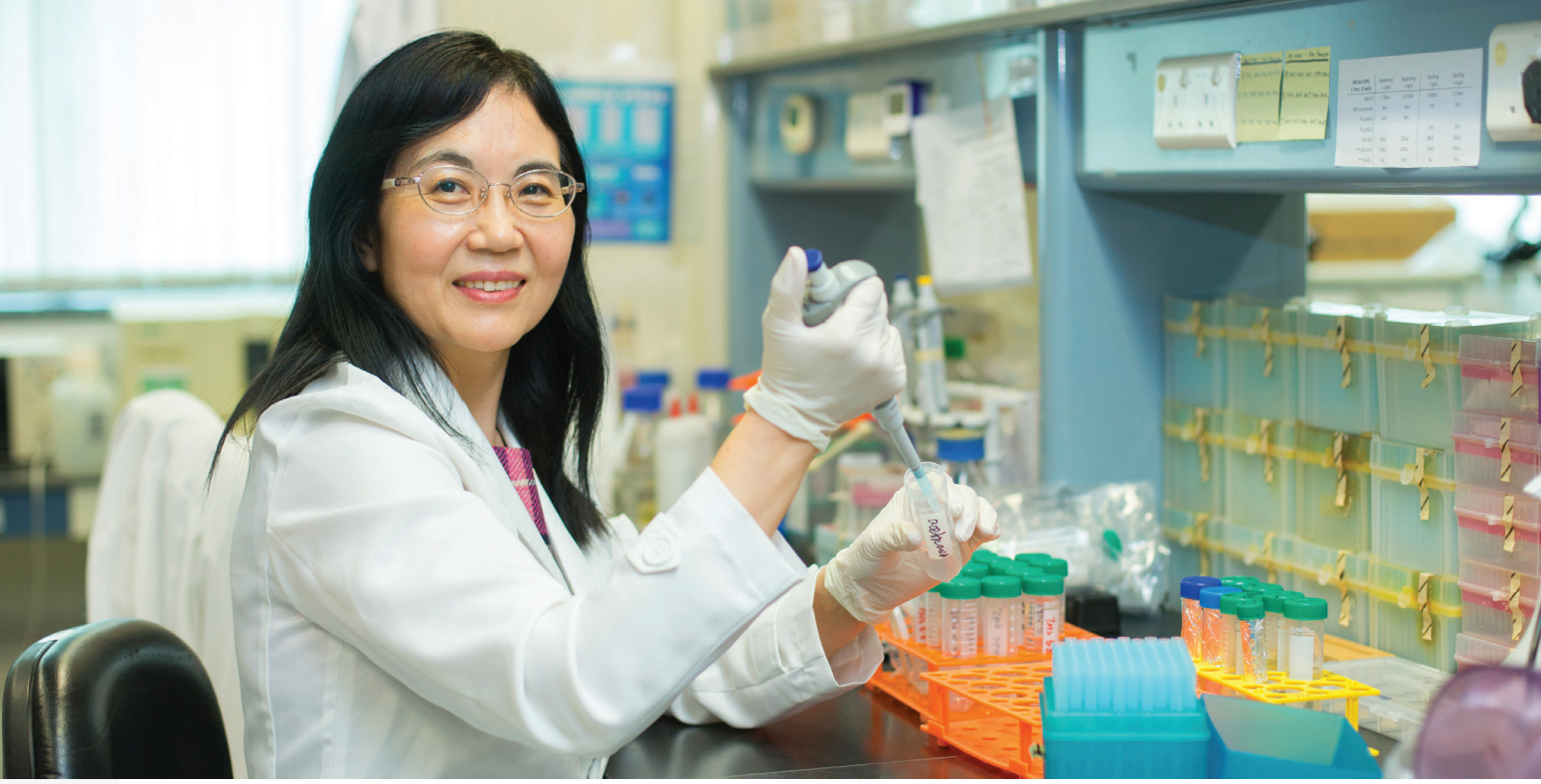
Despite all his achievements: the paradigm shift of the IPASS study, the advances in care for lung cancer patients — Professor Mok still wishes to continue his research and guiding other researchers for the future. "Hong Kong and Southeast Asia never had a significant role in lung cancer research," he says. "Now we are level with researchers in Western countries, and realising the significance of EGFR inhibitors played a huge part in that. But I hope this can be continued, so now my responsibility is to help younger researchers to shine on the international stage."

Digestive diseases

A life-saving quest for cancer biomarkers

Jun Yu
Choh-Ming Li Professor of
Medicine and Therapeutics

Cancers of the stomach, colon and liver are among the top causes of death globally. CUHK's world-leading multi-disciplinary research in gastroenterology and hepatology has helped save countless lives by revolutionising early detection of gastrointestinal cancers, fatty liver disease and liver cancer. Breakthroughs in this field by Professor Jun Yu, Director of both the Institute of Digestive Disease and the State Key Laboratory of Digestive Disease at CUHK, have already been translated into clinical applications across China and Southeast Asia.



From clinic to lab

Professor Jun Yu joined CUHK in 1999 as a post-doctoral research fellow of Professor Joseph Sung Jao-yiu, the renowned researcher in gastroenterology and hepatology who later became CUHK's Vice-Chancellor, after practicing medicine at Peking University's Hospital.

"When I was working as a gastrointestinal specialist in Beijing, patients coming to see me were all in the late stages of cancer for which there was really no cure," Professor Yu recalls. "As a young doctor, I felt so helpless. I wondered: Why can't we detect these cancers early so that timely intervention is possible?" Colonoscopy is one of the most sensitive tests available for colon cancer screening and investigation. "However, because it is invasive, costly and labour intensive, it is hard to apply it for screening with the large population of China," she says.

"I realised that the only way to make a different kind of clinical breakthrough was to do basic research to find out the cause of cancer." She began studying the molecular mechanism that causes gastrointestinal cancers, as well as molecular alterations.

Very "basic" research

At the time Professor Yu started research at CUHK, there was no molecular non-invasive diagnostic test for colorectal cancer. A key discovery by Professor Yu and her team was that the microRNA-92 molecule present in stool is a reliable molecular biomarker for early diagnosis of colorectal cancer based on genomic and metagenomic analysis. Their **fecal miR-92a diagnostic kit** is the first molecular biomarker approved by the China Food and Drug Administration (now the National Medical Products Administration, or NMPA) for colorectal cancer early diagnosis in 2018.

From initial research to producing a test kit approved for nationwide application took over 15 years. At the start, Professor Yu and her students found themselves conducting the most "basic" of basic research — probing large piles of stool collected from patients to identify malignant cells shed from the thin outer layers of tissue lining their gut. "We washed the stool, removed food residues

and bacteria, purified it with solution buffers, collected the cells that come off the surface of the colon, stained them with chemicals on slides and examined the cells under microscope to find any malignant cells.

"That phase of our research was, frankly, unpleasant. Identifying malignment cells with the naked eye under microscopy was labour intensive and ultimately not sensitive enough. So, we had to find another way."

The CUHK team moved on to experiments with other possible biomarkers and found that a single-stranded, small non-coding RNA molecule — miR-92a — was the most stable, sensitive and cost-effective. Moreover, each test requires only 300 mg of stool sample per individual. Patent applications have been made to authorities in the US, Europe and Taiwan.

As the gut microbiome emerges as a new frontier in medicine, Professor Yu, teaming with other CUHK gastroenterologists, has developed the world's first faecal bacterial gene marker test for detecting colorectal cancer. It is now available commercially in private hospitals and clinics in Hong Kong.

State approval

Another non-invasive blood diagnostic kit developed by the CUHK team is based on a **plasma (RNF180 methylation DNA) biomarker for gastric cancer screening** and early diagnosis. With a superior performance to that of conventional blood protein detection methods, it was approved by the NMPA in 2020. It is the only NMPA-approved molecular detection kit available in mainland China for the early diagnosis of gastric cancer and is commonly applied in clinical practice.

Given the rising incidence of cancer in the world, there will be increasing demand for improved diagnostic procedures to identify high-risk individuals. Professor Yu believes that these diagnostic kits, based on simple, low-cost tests on a polymerase chain reaction (PCR) platform, should remain highly sustainable.

Detecting fatty liver disease

Another research focus of Professor Yu is non-alcoholic fatty liver disease, the most common chronic liver disease globally. "Some Chinese people do not look obese. But if you check with ultrasound, their internal organs are full of fat. This is due to their rich westernised diet, which is low in fibre, and to a lack of exercise," Professor Yu says.

"Non-alcoholic steatohepatitis (NASH) is the more severe form of fatty liver disease and can progress silently towards cirrhosis and liver cancer," Professor Yu cautions. "Liver biopsy remains the gold standard for its diagnosis, but it is limited in routine clinical practice due to its invasiveness and high cost, among other reasons. Many Chinese will not accept having a piece of their liver sliced," she says. "That's why we set out to find another way for early detection."

Recently, Professor Yu and her team discovered a group of **blood-based biomarkers for diagnosis of NASH**. She has applied for a patent for the technology on the mainland.

This research on non-alcoholic fatty liver and its related cancer has, for the second time, earned Professor Yu and her CUHK colleagues the prestigious State Natural Science Award (second-class).

> **"These diagnostic kits, based on simple, low-cost tests on a PCR platform, should remain highly sustainable.**

Restorative medicine

Rejuvenating old human cells

Patrick Yung Shu-hang
Professor of Orthopaedics
and Traumatology

Humans are living ever longer with the advancement of medical science and technology, but many of us have to bear with pain in our muscles, bones, cartilage and joints as we age. These disorders, such as osteoarthritis, osteoporosis, low-back pain, muscular defects and tendon injuries, compromise quality of life and mobility. At CUHK, the Centre for Neuromusculoskeletal Restorative Medicine is dedicated to addressing these health problems, bringing together its own talents and expertise and those from the Karolinska Institutet in Sweden, one of the world's leading medical universities.

(Above)
A stem cell sheet developed by Professor Yung's team

Stem cell sheet for tissue repair

Professor Patrick Yung Shu-hang, Co-Director of the Centre for Neuromusculoskeletal Restorative Medicine and a world-recognised leader in orthopaedic sports medicine, joined CUHK's Faculty of Medicine in 2016 after practising as an orthopaedic surgeon for more than 20 years. He leads a team of researchers to make advances in sports medicine and arthroscopy surgery and is also committed to serving the professional sport communities in Hong Kong.

"In the course of my clinical work, I have come across a lot of literature on basic research. But not all of them are practical for doctors and patients when it comes to clinical application," Professor Yung says. "That's what drove me to go into basic research. I want to develop something that is good for clinical use."

Professor Yung is currently working on two projects at the centre. The first one, which he collaborates with Professor Pauline Lui Po-yee, Associate Professor of Orthopaedics and Traumatology, is to develop a therapy for tendon repair with **tendon-derived stem cells (TDSC)** ***in vitro***.

About half of people aged 50 or above suffer from tendon problems in their knee joints or shoulders, including adhesive capsulitis (also known as frozen shoulder) and rotator cuff tears, according to Professor Yung. The ability to heal is further limited by conditions such as diabetes and high blood pressure.

"A broken bone can heal if it is fixed in the right position, but a torn tendon is not so easy to heal," Professor Yung says. "Even if it is reconnected, it may not restore its function due to degeneration from ageing. So I want to look into stem cell therapy to strengthen tendon repair."

The CUHK team, which started stem cell research for tissue repair nine years ago, has been exploring a different path. Traditionally, stem cell therapy involves an autograft, a procedure in which a patient's healthy stem cells are collected from the bone marrow of their hips to replace the damaged cells. But there are risks. Such transplants are prone to immunogenicity i.e. a tendency to trigger an unwanted immune response from the human body.

"Also, stem cells are primitive and they can evolve into various types of tissues – they can duly become bones and tendons, but they can also run out of control and evolve into cancer cells in the worst-case scenario. So the biggest challenge of this therapy is to manage the cell cultivation and make sure they become tendon cells," Professor Yung says.

"Why don't we cultivate stem cells outside the human body? Then we can reduce the chance of immunogenicity.

"We thought, 'Why don't we cultivate stem cells outside the human body and wait till they really grow into tendon stem cells?' Then we can reduce the chance of immunogenicity."

The CUHK team has successfully cultivated tendon stem cells outside the human body into a decellularised stem-cell sheet using tendon, which has the cells removed but retains the cells' extracellular matrix i.e. secreted proteins and other molecules that surround and support the cells. Without the cell itself, the risk of uncontrolled action of implanted cells is eliminated. The sheet can be used as a bioactive material and wrapped around a damaged tendon or ligament, via minimally invasive surgery, to stimulate tissue regeneration.

Having tested the cell sheet on mice and rabbits, the team is planning to conduct tests on large animal models such as cattle and sheep, whose joints are of similar sizes as humans', before starting clinical trials.

The invention would be suitable for patients suffering from musculoskeletal injuries. "The global demand for anterior cruciate ligament surgeries is huge. If we can have donors of stem cells and set up a stem cell bank for *in vitro* cultivation, a lot of people will benefit," Professor Yung says.

Stem cell therapy for osteoarthritis

Another research, led by Professor Yung together with Wayne Lee Yuk-wai, Assistant Professor of Orthopaedics and Traumatology, is the development of stem cell therapy to treat osteoarthritis, a common degenerative joint disease. Osteoarthritis occurs when the protective cartilage that cushions the ends of the bones wears down over time. In serious cases, a joint replacement surgery is needed, but it is expensive. Scientists around the world, including the CUHK team, have been finding ways to regenerate cartilage.

"Millions of people suffer from osteoarthritis around the world. In Hong Kong, it is a four-year wait for a patient to get a knee joint replacement at a public hospital. If our stem cell therapy can make its way through to clinical success, it will be of great benefit to many," Professor Yung says.

Apart from Professor Yung, other CUHK researchers and 12 scholars from Karolinska Institutet in Sweden are working in five directions at the centre, namely, stem cells and cell-based therapies, tissue engineering and 3D microtissue modelling, cellular and molecular mechanisms, pre-clinical and clinical translation, and enabling technologies.

3

Contributing to and for China

Art and China

Bringing together China and the West

Pedith Chan Pui
Assistant Professor of Cultural Management

Xu Xiaodong
Associate Director of Art Museum, CUHK

Tong Yu
Associate Curator of Art Museum, CUHK

A forward-looking comprehensive research university, CUHK has been making tireless efforts to combine tradition with modernity, and to bring together China and the West. Research into art history is instrumental in developing Hong Kong as an art hub of Asia. Cultural Management Professor Pedith Chan Pui, Art Museum's Associate Director Professor Xu Xiaodong and Associate Curator Dr Tong Yu, in their areas of expertise, contribute to telling stories of China from the perspectives of art history and art research.

Restating Chinese art history and global modernism

Professor Chan meticulously presents art history to the public in a systematic and comprehensive manner. "Speaking of art history and its concepts such as visual modernism, people often see the west as the centre of discussion," she says. "However, recently there is growing awareness of the importance of decentring the Eurocentric modernism. I hope to contribute to the discussion and bring this concept to a wider audience by restoring and spelling out the art history of China and Asia."

The interdisciplinary approach adopted by Professor Chan makes her research stand out. Her 2017 work ***The Making of a Modern Art World*** examines Shanghai's artistic and social activities during the late Qing and Republican eras. It views art production from a sociological perspective that constitutes art institutions, magazines, exhibitions and the market, and addresses materials – like artists' price lists – seldom discussed in standard modern Chinese art history. She adjusts and challenges prior conceptualisations of *guohua* (national painting), debunking how western perceptions of modernity affects the way people perceive art today. "The book explores the Republican Shanghai art world, looking into art from the perspectives of production, consumption and distribution. I hope to tell readers that art doesn't merely involve artists, but also many other parties like agents, dealers and art scholars," says Professor Chan.

The professor is eager to promote Chinese and Asian art to the western world. In 2020, she published a journal article, "Picturing Mount Yandang: The Travel Albums and Landscape Aesthetics of Yu Jianhua" (1895-1979) in the *Burlington Magazine*, which primarily focuses on European art and has a history of over 100 years. The article presents how Chinese artists' landscape perceptions were shaped by traditional aesthetics, paying attention to observing nuanced elements of the mountains, and distilling natural landscape into two categories, namely *shan* (mountain) and *shui* (water). It explores how a Chinese artist experienced and approached landscapes in the 1930s when European plein air sketching and modern tourism were being introduced. "I hope to bring the Chinese perspective of art to the international stage," Professor Chan says. For her research, identifying and collecting modern Chinese artworks from collections around the world is challenging, especially as they were scattered during wars: "It is hard to obtain copyright permissions from the artists' descendants as well."

Discussion of art history goes beyond theories. By digging into Chinese history, Professor Xu and Dr Tong from CUHK's Art Museum are devoting much attention to unveil the mystery of Chinese gold techniques.

Preserving the legacy of ancient Chinese art

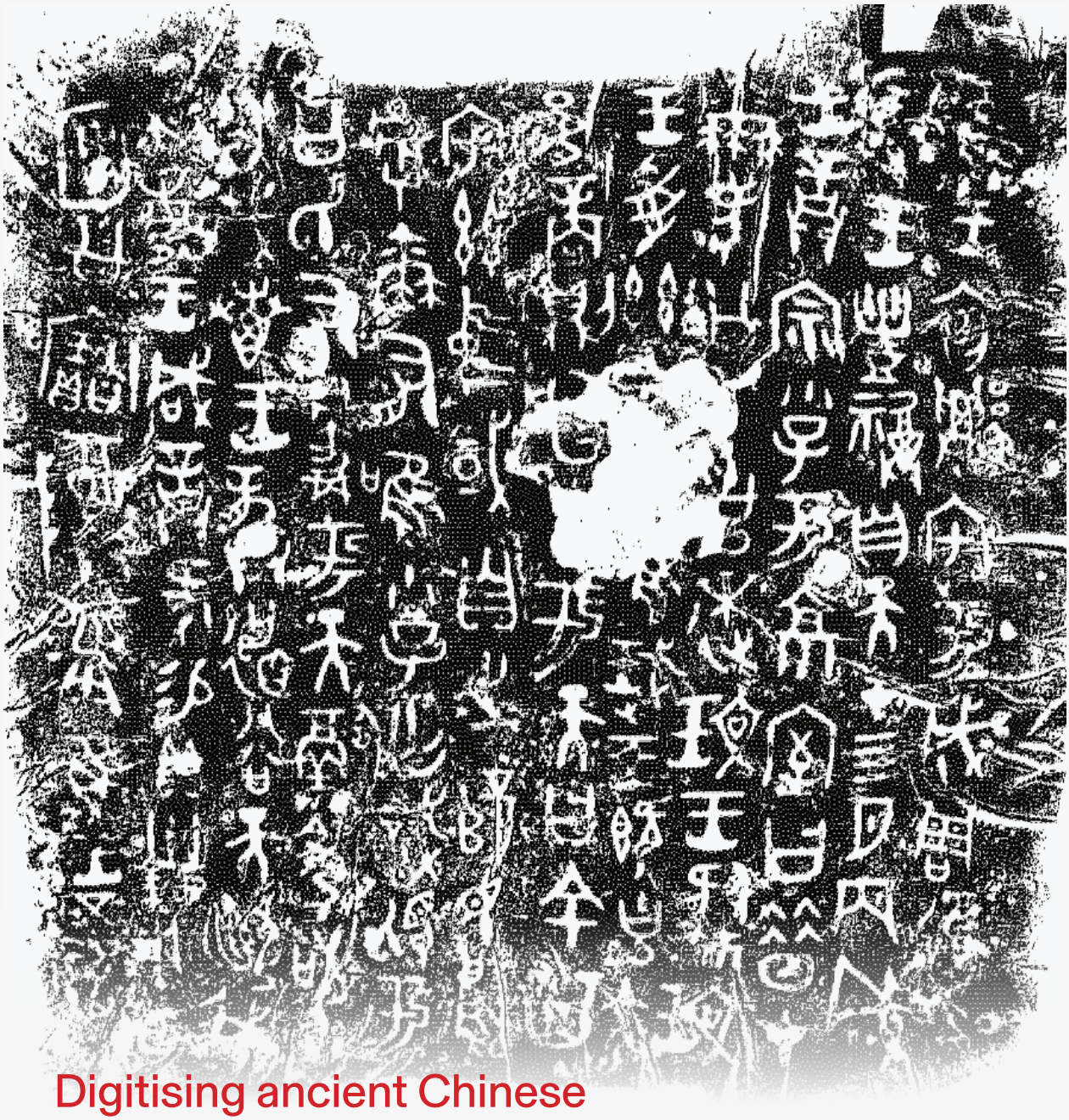
"In the past, scholars were particularly interested in the research into bronze ware. Gold techniques were rarely discussed," says Professor Xu Xiaodong, Associate Director of the CUHK's Art Museum. "As early as 2007, we curated the Museum's first gold exhibition – *Celestial Creations: Art of the Chinese Goldsmith, the Cheng Xun Tang Collection*, followed by another one in 2013 from the Mengdiexuan Collection." The Chow Tai Fook Jewellery Group was intrigued by the exhibitions and sponsored a more profound project – *Gold Techniques: Art of the Chinese Goldsmiths*. The two-phase project, co-organised with the Chow Tai Fook Master Studio since 2014, was led by Professor Xu and Dr Tong Yu, Associate Curator of the Museum. The second phase in early 2023 spotlighted gold and silver inlay, damascene, and the production and use of gold wire, alongside hammer-chiselling, casting and prevision gold soldering. "We hope to present a revival of ancient Chinese gold craftsmanship to the public, especially to a younger group of audience, to preserve the legacy of these delicate and precious skills," says Dr Tong.

CUHK's Art Museum is renowned for its quality exhibitions and research. The hard work from generations of peers also makes the Museum a top-tier one. "We adopt an interdisciplinary approach involving the collaboration of three parties – gold masters from Chow Tai Fook, testing centres and the Art Museum. The artistry of gold demonstrates the early cultural exchange between East and West in Eurasia," says Professor Xu. By conducting archaeological and historical studies, restoration experiments and scientific testing, the project examines gold pieces and techniques from multiple perspective, unveiling valuable craftsmanship that can stand the test of time. From September 2023 to August 2028, the Museum will prepare for the third phase of this project.

> **"I hope to bring the Chinese perspective of art to the international stage.**
>
> Professor Chan

CUHK's tireless efforts in delivering outstanding art research has earned trust and support from collectors vital in driving the industry forward. "The Art Museum maintains a friendly relationship with Hong Kong collectors. We exchange thoughts and they donate their collections. A virtuous cycle is created," says Dr Tong, grateful for the collectors' generous donations.

Apart from ancient Chinese gold craftsmanship, the two academics have also been involved in other projects of the Museum, probing into the history of enamels, imperial arts, and artistic interaction between ancient China and the West. Looking forward, they hope to further cultivate, promote and preserve Chinese art history to integrate traditional artistry with modern techniques.



Digitising ancient Chinese texts for global impact

Combining tradition and modernity

Ho Che-wah
Choh-Ming Li Professor of Chinese Language and Literature

The sheer volume of ancient Chinese texts is so tremendous that it is a tough job for retrieving data and conducting research. Since 1989, the Institute of Chinese Studies (ICS) at CUHK has built a unique, globally leading electronic database of ancient Chinese texts and its subscribers include prestigious universities around the world. Professor Ho Che-wah, who has spearheaded the project since its inception, has leveraged the database to successfully challenge some longstanding arguments in academia.

A 34-year journey

In 1989, the ICS started to develop a database of ancient Chinese texts under the leadership of Professor D. C. Lau, a master of Chinese studies. Researchers input ancient Chinese texts spanning the two millennia from 1500 BCE to about 600 CE into a computer system and produced software for studying the texts with the electronic database.

"To combine tradition with modernity, and to bring together China and the West" has been CUHK's mission since its establishment in 1963. "CUHK has strong foundations in traditional Chinese studies and renowned scholars like Professor Lau have cultivated generations of leading experts in the field. The University enjoys a global reputation for information engineering and given its excellent information technology infrastructure, we have unique advantages in conducting research that combines traditional Chinese studies and information technology," Professor Ho observes.

Prior to the data entry process, researchers strived to select the best versions available for inputting to electronic database. "The ICS did not only convert the texts from books to computer-readable format in the process of developing the database. It was actually a systematic project of collating ancient Chinese texts. There are many electronic databases of ancient Chinese texts in other countries, but their investment in time and effort pales in comparison to ours," he says.

A CUHK-trained scholar, Professor Ho completed his undergraduate study from CUHK's Department of Chinese Language and Literature in 1986 and subsequently obtained a Master's degree and a doctorate at the University.

In 1992, Professor Ho's team completed the development of Extant Han and Pre-Han Traditional Chinese Texts Database and subsequently edited the *Ancient Chinese Texts Concordance Series*, with information about where the words can be found and in which sentences. In 2000, the Institute uploaded the 8-million-word database, which is called **CHANT** (Chinese Ancient Texts Database 漢達文庫), onto the internet. "We also provide online programmes to enable users to retrieve information in more than 1,000 titles of traditional and excavated ancient Chinese texts," says Professor Ho, also Director of D. C. Lau Research Centre for Chinese Ancient Texts at CUHK.

CHANT has received funding of nearly HK$22 million from the Research Grants Council and the Chiang Ching-kuo Foundation for International Scholarly Exchange since the 1990s, one of the biggest granted to humanities studies in local universities.

CHANT records more than 100,000 annual users and counts 80 prestigious universities including Harvard, Princeton, Oxford, Cambridge, and Peking University among its subscribers. ICS researchers also developed the **Lexicon Database** (「中國古代詞彙」電子資料庫) by digitising words and phrases in ancient Chinese texts. "We have challenged some longstanding academic arguments by utilising the Lexicon Database," Professor Ho says.

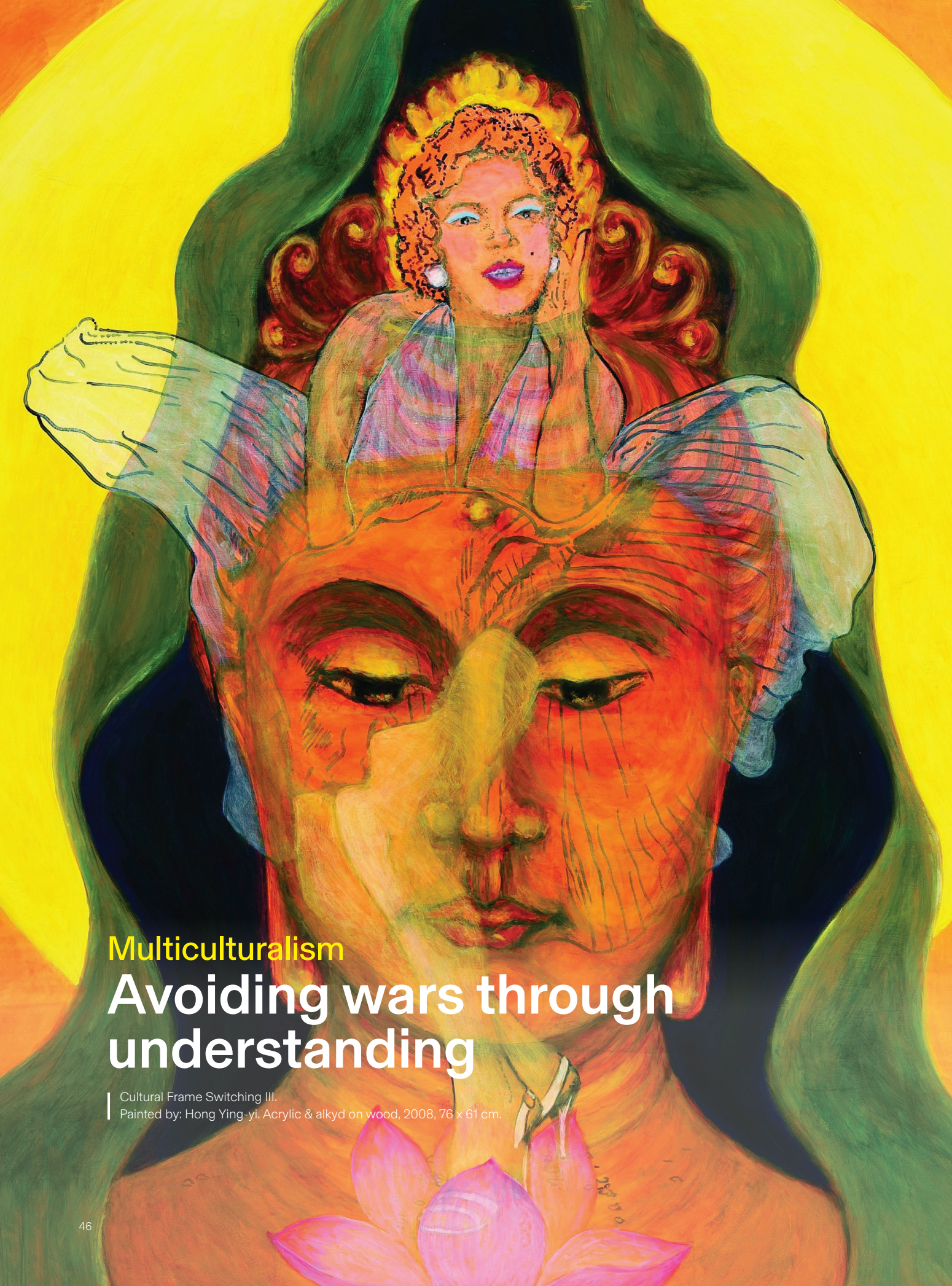
Utilising the database to challenge longstanding arguments

He said for instance, the conventional view in academic circles that the bamboo version of the *Wenzi* (《文子》), an ancient Chinese text, which was excavated from a tomb in Hebei Province in 1973, was written in the second half of the Warring States period (476—221 BCE). Utilising the Lexicon Database, Ho noted a phrase "*chao qing*" 朝請 on slip no. 2212 in the bamboo version of *Wenzi*, is a Han dynasty custom which was used in Han legal documents under which feudal princes were required to pay respect to the emperor. Based on this and other textual evidence, Ho concludes that the *Wenzi* dates to the Former Han dynasty, a view that gradually finds footing in *Wenzi*-scholarship. Hence, the text was probably written between the beginning of the Former Han dynasty and the closure of the tomb, in 55 BCE.

"Therefore, *Wenzi* can't be a book written during the Warring States period. My argument, which was presented in a paper in 1998, was cited by many academics around the world. It challenged some longstanding conclusions shared by academics," he says.

"Over recent years, our achievements have drawn widespread attention from overseas academics. Our research centre is expanding its scope of study to cover more ancient Chinese texts in the hope of making a bigger impact," Professor Ho says.

> **"There are many electronic databases of ancient Chinese texts in other countries, but their investment in time and effort pales in comparison to ours.**



Multiculturalism

Avoiding wars through understanding

Cultural Frame Switching III.
Painted by: Hong Ying-yi. Acrylic & alkyd on wood, 2008, 76 x 61 cm.

Hong Ying-yi
Choh-Ming Li Professor
of Management

In more than two decades of research, Professor Hong Ying-yi has provided valuable insight into how multicultural identities are constructed. With her interdisciplinary studies, she has shown that individuals' actions cannot simply be explained by one cultural framework. Having proposed the "dynamic constructivist theory" to explain how multicultural individuals can incorporate multiple cultures, she has gone on to provide the world with a more nuanced understanding of the Hong Kong identity, with her work featured in both academic journals as well as popular media like *The New Yorker*.

For Professor Hong Ying-yi, the "grand challenge" she sees as the impetus of her research is simple and concise: she simply seeks to "avoid wars". She says, "The underlying rationale behind my research is: how do people from different cultural backgrounds see things from different perspectives? How can we make use of interculturalism to help everybody communicate better, and cultivate positive relationships?" Comparing the historical, social and political contexts of a place, as well as discovering how these different contexts contribute to "'who we are' and 'what we stand for'", is something that fascinates Professor Hong.

CUHK has long been a homebase for cultural psychology, but multicultural studies were still a relatively underdeveloped subject when Professor Hong started her research, and whenever it was discussed, most academics would opt for a more comparative approach; but having grown up in Hong Kong, Professor Hong was acutely aware of the potential for coexistent perspectives. Her start in research coincided with many people experiencing crises in identity concerning the 1997 handover — a research topic she calls her "first love". Over the years, her research has coalesced around the thorny issue of Hong Kong identity, as she realised its critical nature. She says: "I want to understand how Hong Kong citizens identify themselves now, after all the changes that have happened in the past 25 years".

A new way to bridge cultures

Nowhere is the complexity of identity and its effects on culture more obvious than in Hong Kong, where many citizens are familiar with facets of both Chinese and Western cultures. "In typical multicultural studies, these people are treated as 'contaminated' and don't make good research subjects because they are not typical, pure Chinese or American," she says. But for Professor Hong, these subjects were valuable because "they really show the impact of culture on people."

Building on the "frame switching" phenomenon commonly reported in multicultural individuals, Professor Hong proposed in 2000 the dynamic constructivist theory. Explaining this concept in 2014's *Oxford Handbook of Multicultural Identity*, she wrote that "bicultural individuals can adjust their thoughts, affect and behaviours spontaneously and appropriately in different cultural contexts". In other words, since an individual can host more than one cultural system within them, their cultural frame

of reference shifts when prompted with culture-specific tasks. Professor Hong discovered this by observing respondents' reactions to specific symbols or the way they completed certain tasks, from which her team compared the similarities and differences in their behavioural, emotional, and neuro-physiological responses. This allowed them to better elicit their cultural knowledge systems, thereby enabling them to extrapolate "the effect of culture on one's own actions and beliefs, and interpreting the causality within".

This new method of approaching culture and cognition has ensured that Professor Hong remains an authority on the subject: as of February 2023, her work has been cited more than 25,000 times. She has also won many awards for her work in the realm of social psychology, including the Otto Klineberg Intercultural and International Relations Award, and in 2021 was also appointed as a Fellow for the Research Grant Council's Senior Research Fellow Scheme.

Professor Hong says the biggest problem comes from the delicacy required to broach the topics she works on. Some of her interviewees were extremely reluctant to talk about the nuances of their identity, often self-censoring or even refusing to think about these issues. Besides the sensitivity of respondents, the issue of "Hong Kong identity" is also a sensitive one. But as Coordinator of China Studies at CUHK, Professor Hong simply hopes that her work will enable people to understand China better.

Future directions of identity

Having spent a quarter of a century on her research, Professor Hong has already provided the outside world with valuable insights into intergroup relations, and examined how multiculturalism affects the city. She continues to operate in both Hong Kong and the US, where she and her research team, collectively known as "The Culture Lab", are currently working on studies that examine cultural problems and changes engendered by the COVID-19 pandemic. Their recent research has encompassed both anti-Asian hate as a response to the pandemic, as well as the recent rise of conspiracy theories in both China and America, particularly those connected to vaccines and climate change. Of the latter, she asks: "Abnormal climate change has led to weather occurrences like the recent blizzards in America; has this led to people being less convinced by climate-related conspiracy theories?"

Her research output still finds itself at the centre of academic discussions: citing a recent paper she wrote on the responses to the mainland's zero-COVID policy as an example, she says: "It didn't take long for it to become the top hit on that platform, where it stayed for the whole month. It shows everyone still wants to know about these things."

"The underlying rationale behind my research is: how do people from different cultural backgrounds see things from different perspectives?

Daoist studies

Into the mind of the Daoist master

Lai Chi-tim
Professor in Daoist Studies

CUHK's mission to preserve Chinese culture and bridge East and West lies at the heart of its Department of Cultural and Religious Studies, where five research centres study world religions in Chinese and global contexts, past and present. Only Daoism is indigenous to China, where it has flourished for millennia among common folk. CUHK was the first university in Hong Kong to grasp that Daoism as a field of academic study is crucial to understanding Chinese people, their culture and spiritual world. Its Centre for Studies of Daoist Culture has no equal.

A cultural irony

Professor Lai Chi-tim's epiphany came when, as a PhD candidate at the University of Chicago's Divinity School, he realised that scholars in the West knew more about Daoism than he did. "I was born, raised and educated in Hong Kong but suddenly found that I didn't understand my own tradition. I was ashamed to tell people that I didn't know anything about indigenous Chinese culture, or the importance and impact of Daoism in Hong Kong or other Chinese communities."

Back then, Daoism was not considered worthy of serious study in Hong Kong, he recalls. "Daoism was ignored by academia as just the popular beliefs of lower-class people who pray and offer incense to deities," says Professor Lai. "Yet I could see that Daoism is one of humanity's most beautiful and rich religious civilisations."

Part of Daoism's "image problem" has been that it lacks a charismatic historical founder, emerging as it did in the 2nd century CE in Sichuan as an indigenous, localised religious movement of ordinary people – far removed from the elite courtly circles of imperial China.

"It's integrated with religious faith, practice, philosophy, literature, music and other aspects of Chinese culture in daily life," says Professor Lai. "I came to realise that without studying Daoism, we could not have a balanced, comprehensive understanding of the spiritual world and religious practice of people in China."

A new academic paradigm

Encouraged by his American mentor at Chicago – Anthony C. Yu, English translator of the Chinese classic *Journey to the West* – Professor Lai committed to redress biases back home about Daoist studies. His dream was for it to become a respected academic field with world-class scholarship on par with that, say, of medicine or engineering.

In 1995, he returned to his alma mater CUHK and joined the Department of Religious Studies. "The motto of our university is to preserve Chinese culture and integrate China and the West," says Professor Lai. "I had a very clear mission and vision to put Daoism back into our understanding of Chinese culture, even though this field of study was rare and beyond most people's imagining."

True to its motto, CUHK was receptive to Professor Lai's endeavours to build rich undergraduate and graduate programmes for Daoist studies. Also supportive were major Daoist institutions and donors in Hong Kong. For example, between 2006 and 2020, CUHK received donations totalling HK$30 million from Hong Kong Fung Ying Seen Koon for its Centre for Studies of Daoist Culture, headed by Professor Lai and still the only one of its kind. "We have been able to create a new paradigm for Daoist studies in Hong Kong," he says.

Professor Lai's methodology for studying Daoism includes phenomenological, psychological and anthropological theories of religion. It values empathy and immersion in the religious mind and looks beyond Daoist philosophy to broader aspects of Daoism as a culture with its own scriptures, ritual liturgy, meditation, mindfulness, and even alchemy.

Professor Lai has since nurtured 30 doctoral scholars of Daoism from as far away as Brazil and Italy. Most now teach Daoism in universities. Professor Lai also enlivens undergraduate courses by taking students on field trips to Daoist temples and festivals for direct encounters with Daoist masters. "Where an anthropologist or historian studies Daoist rituals and society, I try to understand the Daoist master's mind," he says.

Scholarly riches

Professor Lai is proud that CUHK is now a world-renowned centre of scholarship in Daoist studies. Its collection of Daoist reference works in Chinese, Japanese and English is, he believes, the world's best. "We could only help to turn around Daoism's poor image through scholarly research outputs," he says.

These have been copious, with several "firsts" for CUHK's centre. They include a 12-year project, with contributions from 70 Daoist scholars around the world, to compile and publish the first annotated Daoist Canon of the Qing dynasty. They also include a multi-media Daoist Digital Museum – digitising CUHK's vast repository of academic research into Daoism in Guangdong – and the first complete collection of stele inscriptions in Chinese temples in Hong Kong, some dating back nearly 800 years.

> **"I wanted to establish a field of Daoist studies to help students and society rediscover this rich and important Chinese cultural and religious tradition.**

The Lingnan heartland

Now, Professor Lai is leading a collaborative research project, funded by Hong Kong's Research Grants Council, on southern China's Lingnan culture. "Many projects related to the Greater Bay Area (GBA) emphasise economic development over cultural components," he observes. "As scholars of the Guangdong people, we need to bring Lingnan culture into GBA studies."

Professor Lai wants to help CUHK build a centre for multidisciplinary studies of Lingnan culture, covering Daoism, literature, art, printing, periodicals, and translation.

Much Western knowledge and culture, he notes, was imported into China through Guangzhou where it was absorbed into Cantonese culture and language. "We will be able to rediscover the vitality, significance and impact of Lingnan culture for the world," says Professor Lai.

Chinese economy

Unlocking the mystery of China's rapid economic growth

Song Zheng
Wei Lun Professor of Economics

Economists in western countries have been puzzled by China's extraordinary growth over the past three decades despite its perceived weaknesses in the rule of law and protection of intellectual property. Song Zheng, head of CUHK's Department of Economics which ranks among the world's top five in study of the Chinese economy, attributes the rapid growth to "special deals" adopted by local governments in China. His argument, which has been cited by many international organisations, has made an impact in the international arena.

It appears inexplicable that China has been witnessing remarkable economic growth although it has been in the middle of international rankings on business environment. In "Special Deals with Chinese Characteristics", a paper published in 2019, Professor Song and his two co-authors unlocked the mystery of China's economic miracle over the past three decades. They argue that the answer lies in the set of informal institutions that emerged in China in the early 1990s, the special deals provided by local governments in China for favoured companies.

"The helping hands for favoured firms range from exemptions to compliance of certain regulations, provision of land below market prices to blocking competitors," Professor Song explains. "Unlike their counterparts in developing countries, local governments in China have strong administrative capacity and abundant financial resources. In China, fiscal expenditure of local governments

accounts for 90 per cent of the national total, compared with about 25 per cent in most countries."

Professor Song notes local government officials in China have strong incentives for introducing special deals because they want to boost their career trajectories, which have often depended on strong economic credentials. "There are about 300 prefecture-level cities in China and their top officials want to promote economic development. You can conceptualise local government officials as venture capitalists who fiercely compete with one another," the Shanghai-born economist says.

Reducing misunderstanding between China and the US

According to recent narratives prevalent in some western countries, China's economic miracle stems from the top-down grand strategy devised by the Chinese government. "Western countries are worried about China's emergence as an economic superpower and consider it a serious threat because China's economic growth appears unstoppable," Professor Song says.

> **"It is the combination of special deals and powerful local governments that underpinned China's economic success over the past 30 years.**

But he believes that the extraordinary economic growth in China did not result from deliberate strategic planning by the central government. "It is precisely the

combination of special deals and powerful local governments that underpinned China's economic success over the past 30 years," he says. "It will help reduce misunderstanding between Beijing and Washington, and reduce the tension between the two superpowers by explaining the true dynamics behind China's economic miracle."

The paper on "special deals" has been cited by international organisations such as the Organisation for Economic Cooperation and Development, the World Bank and the International Monetary Fund, and the US Congress.

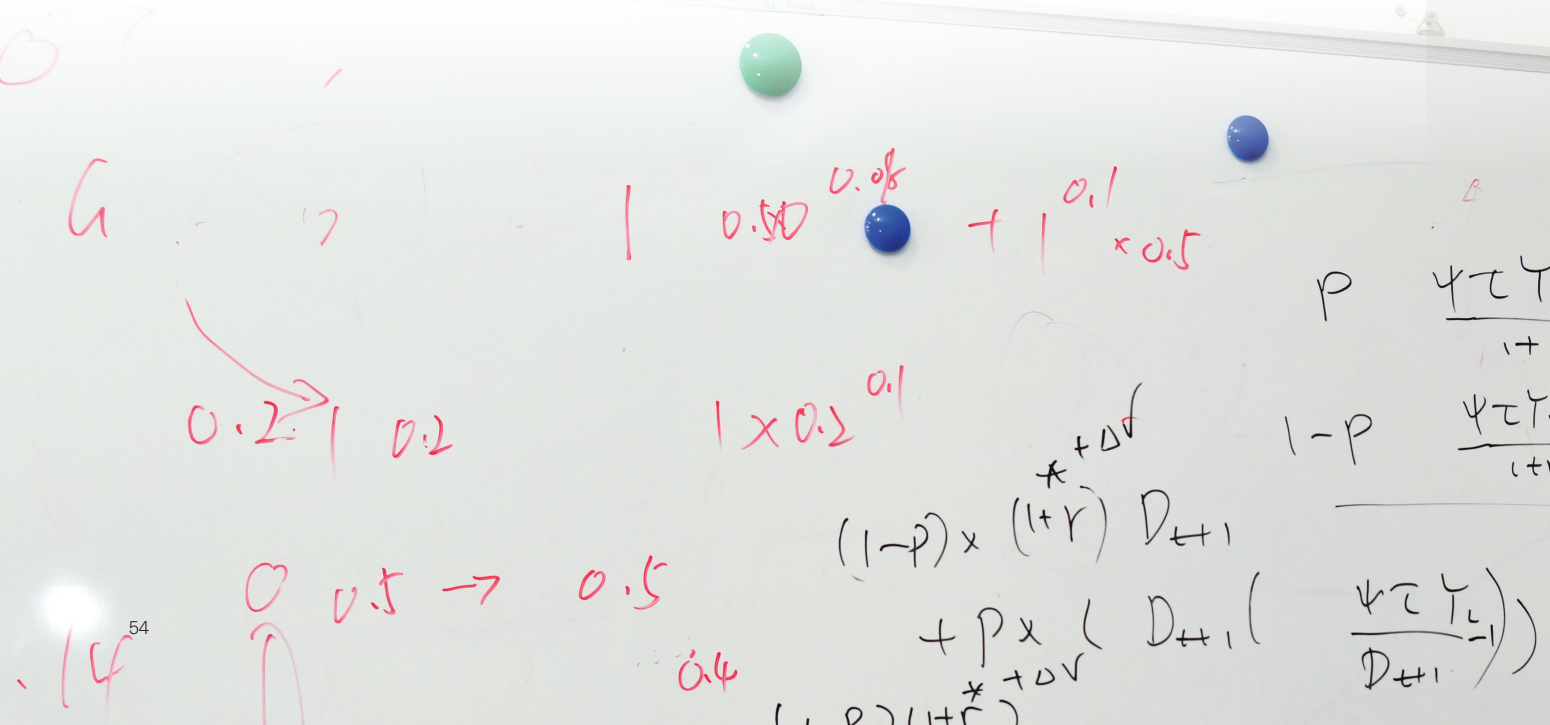
He is adamant that CUHK provides an excellent environment for his study on the Chinese economy. "Apart from reading newspapers and academic journals, we need to see for ourselves by visiting the mainland. I have been travelling to various parts of the mainland to meet different people. It would be very difficult for me to do so if I were in the US," he says.

Hong Kong's edge in studying the Chinese economy

Professor Song, also Co-Director of the Chinese University of Hong Kong-Tsinghua University Joint Research Center for Chinese Economy, highlights the importance of the collaboration with Tsinghua University for his research. "CUHK's senior management are very supportive of the research centre. Vice-Chancellor and President Professor Rocky S. Tuan and his predecessor, Professor Joseph Sung Jao-yiu have taken part in activities organised by the centre," Professor Song says.

"Hong Kong enjoys a unique status under the One Country Two Systems framework. In Hong Kong, we can explain the complexity of the Chinese economy in ways that can be understood by westerners," he says, adding that the city is still a crucial bridge between China and the rest of the world.

In another paper co-authored in 2019, he made use of data such as value-added tax and electricity consumption to find out that China's GDP growth had been overstated by 1.7 percentage points per year between 2008 and 2016. Professor Song noted that local governments had overstated their industrial production and investment, resulting in inflated national GDP growth rates. His work on demographic age structure, fiscal decentralisation, shadow banking, innovation and growth, the US-China trade war, and the digital economy is not only well cited in academia, but quoted by newspapers like *The Economist*, *Financial Times*, and *The Wall Street Journal*.



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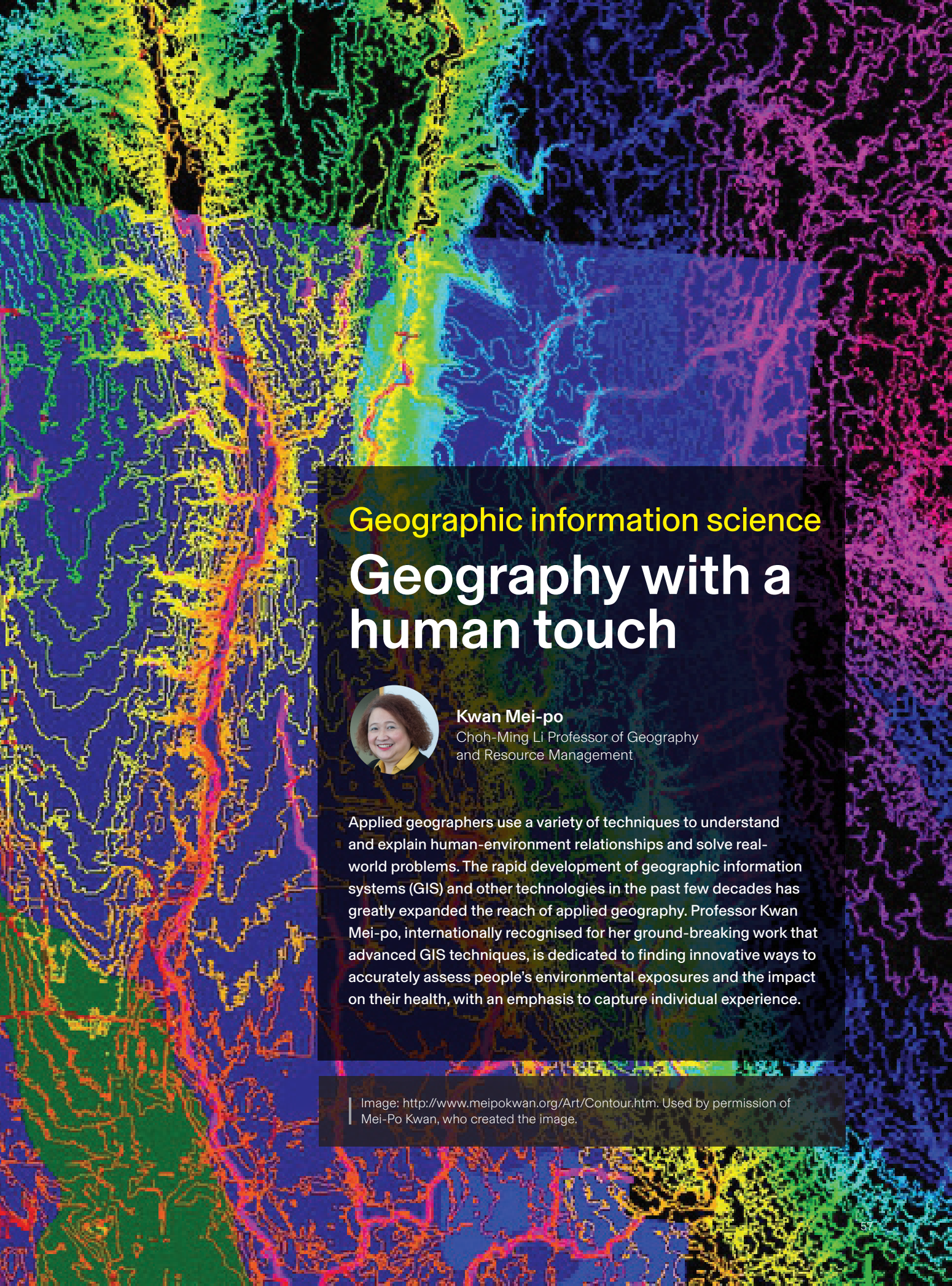
Tackling the challenges of sustainability



Geographic information science

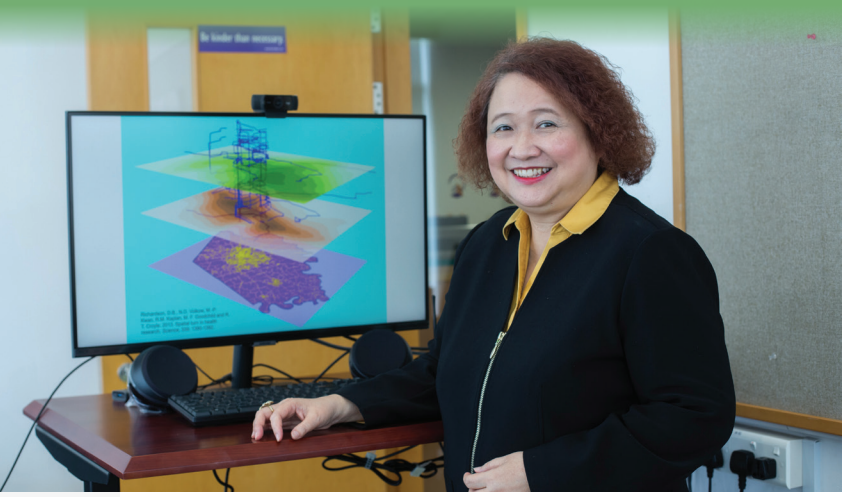
Geography with a human touch

Kwan Mei-po
Choh-Ming Li Professor of Geography and Resource Management

Applied geographers use a variety of techniques to understand and explain human-environment relationships and solve real-world problems. The rapid development of geographic information systems (GIS) and other technologies in the past few decades has greatly expanded the reach of applied geography. Professor Kwan Mei-po, internationally recognised for her ground-breaking work that advanced GIS techniques, is dedicated to finding innovative ways to accurately assess people's environmental exposures and the impact on their health, with an emphasis to capture individual experience.

Image: http://www.meipokwan.org/Art/Contour.htm. Used by permission of Mei-Po Kwan, who created the image.

> We are able to combine GIS with qualitative analysis, even to visualise feelings and emotions.



Identifying COVID-19 risks over space and time

Returning to her alma mater CUHK in 2019 after a fruitful research career in the United States spanning three decades, Professor Kwan Mei-po has continued to break new grounds with GIS technology. One of her first projects at the University was to use GIS methods to identify high-risk areas and vulnerable groups in the COVID-19 pandemic.

Professor Kwan notes that the COVID-19 transmission in Hong Kong was driven by superspreading events at the early stage, such as a hot-pot family gathering, or a dance cluster. "Using innovative GIS spatial analysis methods and plotting activity data of each infected person on the map, we found these superspreading events tended to happen in a small number of places. These places usually are dotted with dense, old buildings and are mostly inhabited by old people.

"More importantly, we found that 70% to 80% of local COVID-19 cases were concentrated in these few places in the first few waves of the pandemic. The new knowledge can complement the government's methods in tracing the virus and help policymakers more promptly design effective place-based control measures for reducing transmission risk," she says. For instance, the government can advise people to avoid visiting high-risk areas and undertaking high-risk activities before the viruses continue to spread.

"The methodology and the spatial-temporal perspective would be useful for building pandemic readiness for the future," she says.

Feminist perspectives

Professor Kwan is recognised for her transformative contributions to geography. In awarding her the Wilbanks Prize for Transformational Research in Geography in 2021, the American Association of Geographers remarked: "Employing feminist perspectives, Dr. Kwan has dramatically altered geo-visualization, the inclusion of qualitative data through geo-narratives, and she has broadened geographic information science beyond a narrow 'objective' standard to more humanistic standards that include perceptions, emotions, and behaviour as core concerns."

"People used to think GIS was only about plotting numerical values on the map, like air pollution, and that's all. But I said no - we are able to combine GIS with qualitative analysis, even to visualise feelings and emotions," Professor Kwan says.

In one of her major projects in the United States, funded by the US National Institutes of Health, Professor Kwan used GIS data, spatial statistics and interactive mapping to identify HIV concentration hotspots in Tijuana, a city at the US-Mexican border plagued by the violence of drug cartels and the sex trade. In her field work, she collected and mapped the narratives of female sex workers

to understand their working conditions and visualised their fears. The project culminated in the government's proactive health intervention, such as HIV testing and education to the affected communities.

New dimensions in environmental health

As Director of the Institute of Space and Earth Information Science of CUHK, Professor Kwan is committed to developing the application of innovative GIS methods in researching environmental health, transport and urban planning in Hong Kong and mainland China.

"One of the major issues we want to tackle is the uncertainties in individuals' environmental exposures, such as green space, air pollution as well as COVID-19 risk. Most studies tend to use spatially aggregated data to examine the roles of environmental factors in health outcomes. But using such data may generate misleading conclusions," Professor Kwan says. "These studies tend to link people's health to their residential contexts, assuming that the residential neighbourhood is the most relevant area affecting people's health but ignoring how their mobility exposes them to other contexts."

"My current major research interest is to integrate environmental science and health and establish a causal relationship between the environment and health so that policymakers can direct resources to the most needed areas and groups."

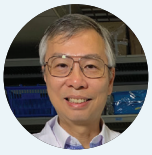
Her team is conducting two projects funded by the Research Grants Council on individual environmental exposure and health impact assessment, using Global Positioning System (GPS) tracking and real-time mobile sensing technology. One project focuses on noise and air pollution and their health effects in Hong Kong, Chicago, Beijing, Shanghai, and Guangzhou. The other project, focusing on Hong Kong, considers more environmental factors, including green and blue spaces (rivers, lakes and seas), light at night, air pollution and noise, and comprehensive health outcomes including physical health, mental stress and sleep disturbance.

The team's mobile sensing technology can sense in real time the exposures that individuals experience every second, momentary subjective perceptions and psychological responses in real life scenarios, enabling more accurate assessment.

Some of the major findings are that mobility-based exposure to green space is significantly higher than residence-based exposure, and that air pollution exposure assessments based on the government's monitoring stations and the researchers' real-time mobile have significant differences. The findings suggest policymakers should consider providing more green space in areas outside of people's residential neighbourhoods instead, and review its biased estimates of personal pollution experience, she says.

Climate smart and sustainable agriculture

Groundbreaking research, written on the land



Lam Hon-ming
Choh-Ming Li Professor of Life Sciences

The UN Sustainable Development Goals (SDGs) are an important framework for CUHK to organise its research enterprise. Life Sciences Professor Lam Hon-ming's research into climate smart soybean cultivation on marginal land is impacting multiple SDGs – from ending hunger, to improving nutrition and food security, to halting and reversing climate change, restoring degraded land and promoting gender equality. As Director of the State Key Laboratory of Agrobiotechnology at CUHK, he is also leading groundbreaking experiments in space.

Humanity's challenge

In an era when climate change and extreme weather threaten the survival of smallholder farmers everywhere, CUHK is renowned for work led by Professor Lam Hon-ming on the soybean and how to improve its climate resilience.

Using advanced genomic and genetic studies, Professor Lam's team pioneered genomic research on soybean seed resources. By decoding the genomes of 31 wild and cultivated soybeans, and with subsequent detailed analysis, they discovered the most important gene for salt tolerance. In collaboration with breeders in mainland China, this information was successfully used to breed three new non-GMO soybean cultivars with double tolerance for drought and salt.

Soybean cultivation is part of the climate change solution for sustainable agriculture

because the soybean can perform nitrogen fixation. It converts atmospheric nitrogen into organic nitrogen which enriches depleted soil and benefits other crops in the same field.

By contrast, artificial nitrogen fertiliser is highly energy-demanding and can release nitrous oxide, a greenhouse gas whose warming effect is about 300 times that of carbon dioxide. CUHK is working to increase soybean's nitrogen fixing capacity whilst also reducing the need for fertilisers that can harm the environment and, by increasing particulate pollutants, people.

Another reason for the CUHK team's interest in soybean is its nutritional value. Soybeans, which are 38-40% protein, account for nearly 70% of the world's plant protein. In poor regions where people are malnourished and cannot afford animal meat, soybeans can provide sufficient protein.

Professor Lam started his soybean project in 1997, focusing on the dry, salty province of Gansu in China's northwest. Seeds from CUHK's three new cultivars were distributed free of charge to poor smallholder farmers there. By 2022, the cumulative planting area had reached 55,333 hectares, adding about 69 million yuan to local farmers' income and contributing to poverty alleviation in that region.

Sharing discoveries

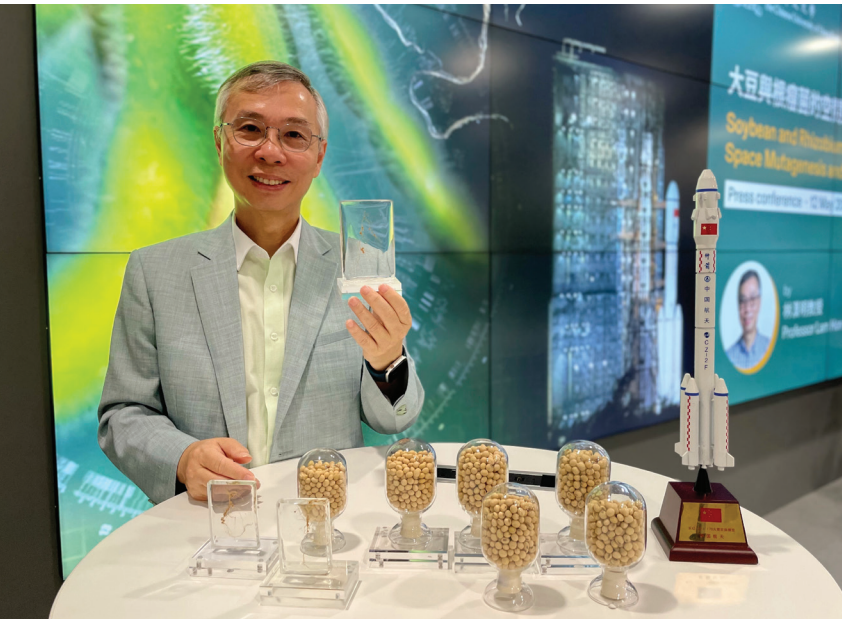
Professor Lam sees his role as bringing together experts in different aspects of life sciences and organising part of their time and effort around research projects that will make an impact. "Soybean is one of them. But I believe our soybean research should radiate to other understudied ('orphan') legumes because a single crop cannot save the world. We need diversity, with different crops in different regions, to keep the entire food chain going.

"I learned from a mainland colleague that, in agricultural research, a paper is not written in a journal, it's written on the land. I needed to leap from the laboratory to the land to substantiate my research. The only possible way was through collaboration.

"I did genomic studies in collaboration with Shenzhen-based genomics specialist BGI; Professor Zhang Guohong of the Gansu Academy of Agricultural Science did plant breeding and field surveys. We used this unique combination of advanced molecular biotechnology and traditional breeding to solve a real-world problem. During many visits to Gansu, I also drew on the wisdom of farmers planting our seeds."

Overcoming hurdles

Finding funds for fieldwork has always been a challenge. "I did receive some scientific research grants, but these were not for direct agricultural application. That's why I've used some of my own salary to kickstart various projects.



"Recently, I've given money to build fences in a drought-stricken, underprivileged village in South Africa that will enable farmers there to start cultivating our drought-tolerant soybean and other crops. My South African collaborators hope that by using one village as a starting point, they can show that agriculture can increase local incomes. This may help to relieve serious unemployment among their youngsters."

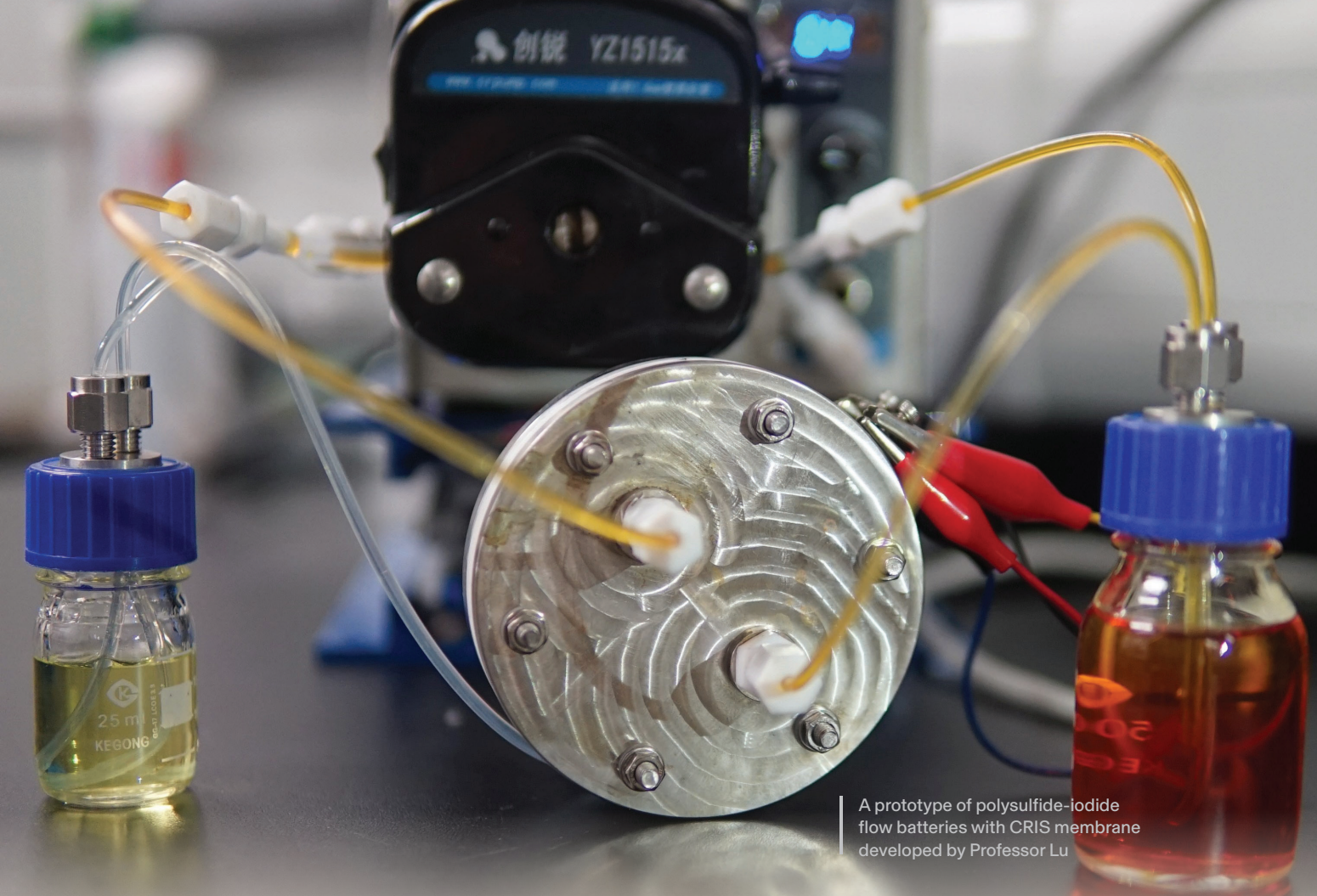
In Pakistan, Professor Lam has started a project to test the heat tolerance of his soybean cultivars. An additional aim is to help local Muslim women acquire agricultural knowledge that may improve their social status.

Experimenting in space

In May 2023, Professor Lam and his team became the first to launch a Hong Kong agricultural research project into space. With support from the China Manned Space Agency, they sent rhizobia (soybean nitrogen fixing bacteria) samples to the Chinese space station Tiangong, in collaboration with the China Resources Research Institute of Science and Technology and Shenzhou Space Biotechnology Group.

The professor sees it as a rare chance to escape terrestrial limitations and, under conditions of microgravity and space radiation, experiment with genetic variations to increase the bacteria's nitrogen fixing ability. This could help to reduce use of chemical nitrogen fertiliser, improve soil quality and, ultimately, boost crop yields. "Through this project, we are combining advanced agricultural technology with aerospace technology to develop new strategies for agricultural field applications and food security. We hope these new horizons in agrobiotechnology will benefit farmers and communities in China and around the world."

> **We are combining advanced agricultural technology with aerospace technology to develop new strategies for agricultural field applications and food security.**



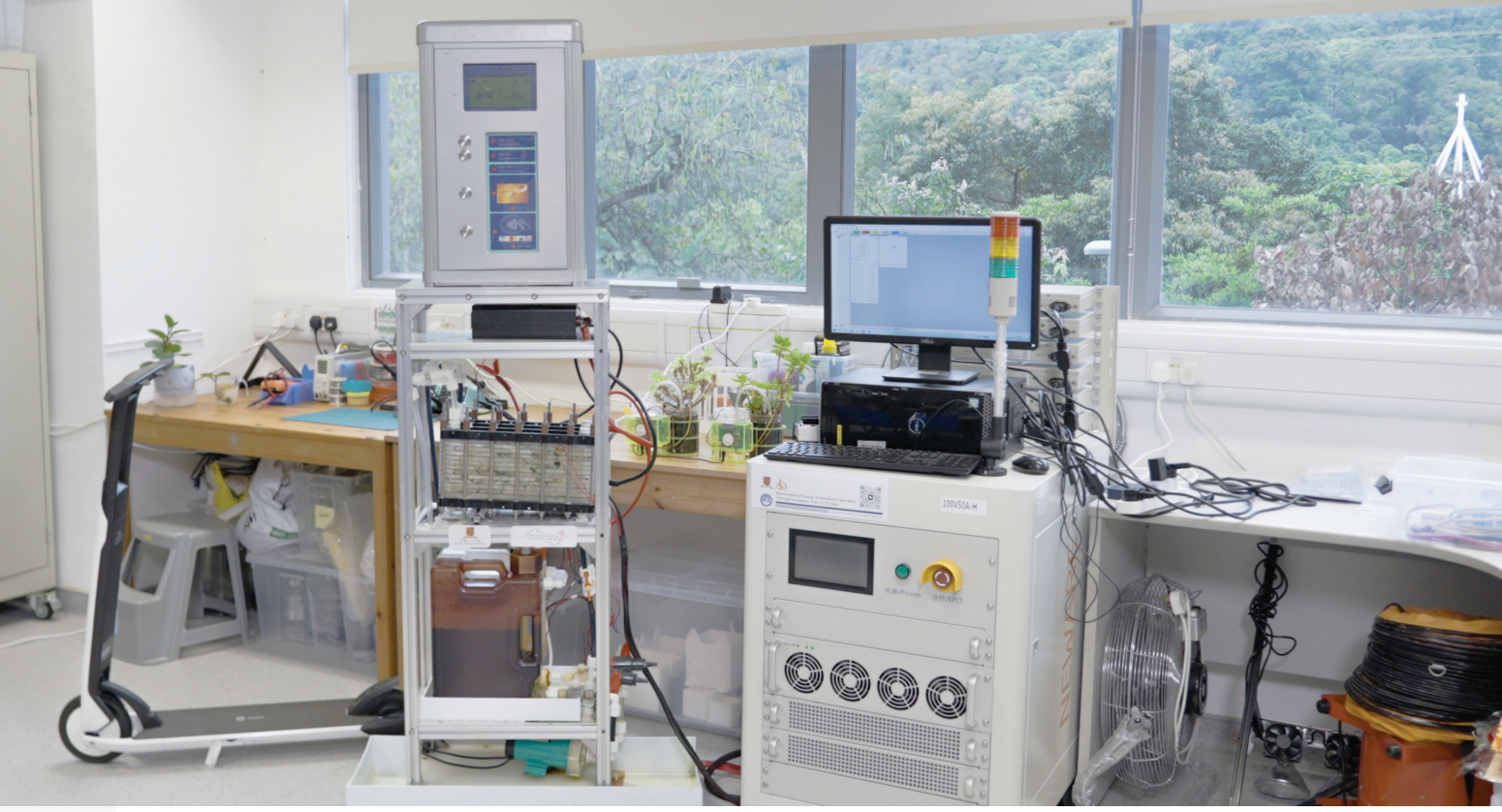
A prototype of polysulfide-iodide flow batteries with CRIS membrane developed by Professor Lu

Green energy

Powering a green and safe future

Lu Yi-chun
Professor of Mechanical and Automation Engineering

For more than a century, scientists have been finding ways to move towards a fossil fuel-free society, harnessing renewable energy from the sun, wind, water and other sources. Technological advances on different fronts are ever fuelling the demand for cheaper, safer and more efficient methods to store energy. In the race for advanced battery technologies, CUHK materials scientist Professor Lu Yi-chun, committed to clean energy storage, is building a new aqueous lithium-ion battery that is absolutely safe and a flow battery that promises commercially-viable massive storage of energy.



Bridging the gap in battery technologies

In the spectrum of battery technologies, on one end is the lithium-ion (Li-ion) battery used in gadgets and electric vehicles, which is lightweight and powerful but also flammable and toxic. On the other end, flow batteries are safe and allow easy expansion of the storage capacity in large-scale applications such as solar and wind farms, but they have a lower energy density.

"In the world of batteries, you have something of a very high energy density which is usually flammable and very dangerous. You also have something that is very safe but with a low energy density. We are trying to bridge this gap," Professor Lu says.

She joined CUHK in 2013 after obtaining her PhD degree in material science and engineering at the Massachusetts Institute of Technology.

"When I was a student, I worked on more conventional, non-aqueous types of batteries – those that have the safety hazard issues but have the highest energy densities," she recalls. "But coming to CUHK, I decided that building an absolutely safe battery with a high enough energy density is one of the things I wanted to address the most."

"The grand challenge we are tackling is to make energy storage technology both safe and energy-dense so that it can be widely used to store renewable energy."

Making flow batteries high-powered

Safe, low-cost energy storage technologies are critical for large-scale utilisation of renewable energy. Flow batteries, in which electrolyte flows through one or more electrochemical cells in large external tanks, are used in solar farms. But flow batteries on the market are too costly to be widely used because vanadium, the element composing the electrolyte, is limited and expensive.

Professor Lu wants to break the bottleneck by using a much cheaper element – sulphur – to replace vanadium.

Different polysulfide-based flow battery systems have been developed since the 1980s. But extensive commercialisation has

been prohibited by the crossover of the tiny molecules of sulphur. The sensitivity of the Nafion ion-selective membrane is insufficient to prevent severe crossover of molecules and self-discharge, leading to a rapid capacity decay and poor lifetime.

To address the problem, the team added several layers to the commercial membrane, not only to prevent the crossover, but also to complete the chemical reaction before the crossover. One of the layers added is carbon bounded by a hydrophobic polymer, which helps to absorb sulphur and block water migration.

It took the team three years to invent the **charge-reinforced ion-selective (CRIS) membrane** for polysulfide-based flow batteries. Their breakthrough findings were published in *Nature Energy* in 2021, the first time a highly stable polysulfide flow battery was demonstrated.

With the patented CRIS membrane, the polysulfide-iodide flow batteries have revealed an ultralow capacity decay rate (0.005% per day) over 2.9 months, or 1,200 cycles. It has a calendar lifetime with over 2,000 hours cycling, in comparison to only 160 hours cycling with the commercial membrane. On fully charged, the battery with CRIS can run for 15 consecutive hours.

Luquos Energy, a startup set up by Professor Lu in 2020 with the support of CUHK, is developing a prototype with a larger CRIS membrane aiming for commercialisation, expanding the size from 10cm x 10cm to 10 or 20 times larger. The team plans to create a five-kilowatt prototype by the end of 2023.

If the CRIS membrane is successful, Professor Lu believes it can be adapted to the vanadium flow battery, which also has a crossover issue.

Turning the Li-ion battery inherently safe

The lithium-ion battery, though extensively used, has posed serious safety concerns with its flammable electrolytes. While replacing the electrolytes with an aqueous one could be a solution, the voltage window is limited by the instability of water (electrolysis will occur and break down water into hydrogen and oxygen when voltage is over 1.23 volts).

Professor Lu's team has discovered a way to improve the aqueous Li-ion battery. In 2020, her team introduced a novel **molecular crowding electrolyte for aqueous Li-ion battery**. It used the water-miscible polyethylene glycol – commonly used in skin cream and food additives – to decrease water activity and achieving a wider voltage window. The material is 30 to 100 times cheaper than toxic battery salts commonly used in Li-ion batteries.

The new electrolyte has proved to be non-flammable and with an expanded voltage window of 3.2 volts. It enables the use of many electrode materials that cannot be used in the conventional aqueous electrolytes, providing a new platform for designing safe batteries with large voltage window and high stability. The team is working hard to raise the energy density of the aqueous battery by about 50% to match that of the non-aqueous one.

"I hope this battery and chemistry will allow us to use massive renewable energy without hesitation. This is my dream," she says.

> **Our grand challenge is to make energy storage technology both safe and energy-dense so that it can be widely used to store renewable energy.**

Climate change and sustainable development

Promoting an interconnected earth system

Amos Tai Pui-kuen
Associate Professor of Earth and Environmental Sciences

Professor Amos Tai Pui-kuen believes that, with the complexity of Earth's systems, a more rounded, interdisciplinary and integrated framework is needed to address sustainability issues, and that it is one that also requires the participation of consumers, such as in the alteration of eating habits.

The twin issues of climate change and environmental pollution are prompting scientists to look for solutions which might alleviate the pressure on human societies, other species and Earth's ecosystems. Many have suggested reducing carbon emissions from the use of fossil fuel and by increasing vegetation cover. Professor Amos Tai, Associate Professor of the Earth and Environmental Sciences Programme at CUHK, approaches the problem from a broader perspective, instead finding the answers in how the Earth's atmosphere and land surfaces interact with each other.

Atmosphere to land

Professor Tai's starting point is the pursuit of human health. "Many diseases, such as asthma and cancers, can stem from environmental pollution, and that comes from a variety of human activities such as fossil fuel combustion," he says. "These pollutants also significantly harm vegetation and crops, which provide the essential nutrients for humans to stay healthy and productive. Climate change often worsens such impacts."

The professor's research warns that a combination of continued changes in climate and worsening air pollution in many developing countries will have severe consequences for global food security. Early adoption of emissions control strategies, maintains Professor Tai, will not only help alleviate environmental pressures on the global food supply but will also improve human and ecosystem health. "Immediate actions against climate change and air pollution can bring self-multiplying benefits to human individuals, societies, and all other forms of life on Earth."

Land to atmosphere

Although the causes of environmental pollution and climate change have been traditionally attributed to energy production from fossil fuels, Professor Tai also considers factors closer to home in addressing these issues. Specifically, he looks at modern agricultural practices, believing that the ozone, nitrogen, and fine particulate matter they produce bear heavily on air pollution and climate change. "In the past decade or so, we can see that agriculture is an important factor behind air pollution and climate change — it's not just the use of fossil fuels."

He has suggested that excessive use of fertilisers, deforestation for farming purposes, and the farming of animals for meat together account for 30-40% of greenhouse gases and up to 30% of particle pollutants in major agricultural countries, including China, where the increasingly affluent lifestyles of Chinese people over the past four decades have caused a fivefold surge in demand for meat. Professor Tai and his team have developed computer models to simulate the long-term effects on the planet of such drastic meat consumption. "Ours was the first study to quantify the contribution of Chinese dietary changes to national particulate matter pollution."

Finding solutions to this massive challenge forms the other focus of Professor Tai's research. He and his team believe the answer lies in making subtle changes such as introducing better agricultural production methods, improved dietary habits and forest management. "This of course includes how food producers can reduce carbon and nitrogen emissions through better management of fertiliser, irrigation water and

agricultural waste. But there is also a case for us to adjust our own food consumption. If we reduce our demand for meat and other high-emission foods, then we can help reduce climate change and air pollution, which could ultimately benefit our own health." He says that changing to a less meat-intensive diet, such as that suggested by the 2016 revision of the Chinese government's Dietary Guidelines for Chinese Residents, could reduce China's nitrogen emissions by 20% and prevent up to 75,000 pollution-related premature deaths each year.

Everything is interconnected

"My research forms a closed circle," Professor Tai explains. "I look into how air pollution and climate change affect agriculture and ecosystems; but I also look at how we can manage agriculture and forest ecosystems to address these pressing environmental problems." For him, such two-way interaction goes to the heart of overcoming present challenges to sustaining life on our planet.

His commitment to viewing the Earth as a complex system aligns with CUHK's own Earth and Environmental Sciences Programme, which treats the Earth's complex dynamics as part of one interconnected system. In his current role as Director of the Earth System Science Programme, he believes that an approach focusing only on individual issues neglects the full scale of the Earth's complex problems. Only by seeing the entire system as one whole can sustainable development for our planet and human communities be achieved.

Changing people's choices

Professor Tai's work has already garnered many awards and scholarships. Among them, he was Hong Kong's first recipient of the World Meteorological Organization Research Award for Young Scientists. He intends to continue his work on addressing climate change and environmental pollution from multiple, integrated perspectives, and his wish is that his work will "move the impacts of food production, dietary preferences and personal choices more towards the centre of the conversation", encourage consumers to think more about their everyday actions and, together with producers and policymakers, strive for an economically thriving, more socially equitable and environmentally sustainable future.

> **"Immediate actions against climate change and air pollution can bring self-multiplying benefits to human individuals, societies, and all other forms of life on Earth.**

5

Rising stars

Infectious diseases and viruses

A continuous battle with infectious diseases

Peter Cheung Pak-hang
Assistant Professor of
Chemical Pathology

Hong Kong has been at the centre of numerous infectious disease outbreaks, and its dense, ageing population makes it significantly susceptible to being affected. Assistant Dean of Medicine (Research) at CUHK, Professor Peter Cheung Pak-hang has been conducting research on infectious diseases like influenza A virus and COVID in the past decade, and has contributed significantly to the understanding of how viruses mutate, the workings of antivirals and the formulation of vaccine strategies.

Professor Cheung's motivation to understand infectious diseases comes from a simple desire to minimise the impact of future outbreaks. “Throughout human history, pathogens such as influenza, cholera, and the SARS coronaviruses have caused tremendous impact on human health, and these viruses have the ability to evolve rather rapidly, causing what we call pandemics or epidemics.” The deadly nature of some of these diseases have in turn impacted human health and the global economy, as demonstrated by the COVID pandemic. For Professor Cheung, “understanding the basis for virus evolution and transmissions can help us understand how we control and prevent future pandemics caused by these viruses, such as by designing effective antivirals and vaccine regimens.”

Professor Cheung joined CUHK in 2021. He describes the University as the perfect place to conduct research. He is inspired by top scientists here like Professor Dennis Lo from the same department: "He serves as an inspiration for local Hong Kong scientists to conduct excellent scientific research." Hong Kong is also a city perfectly placed for academic work on infectious diseases, and Professor Cheung believes that not only does the city have the necessary data in place, but the demand for such research

and the infrastructure and funding needed to complete it is already well-established.

To counter the viruses, which can replicate and mutate frequently and unpredictably, the professor has contributed to dozens of research papers spanning epidemiology to computational and structural biology in top journals such as the *British Medical Journal*, *Lancet Microbe*, and *Nature Catalysis*. Over the years, his team has contributed to understanding the mechanistic basis for infectious diseases caused by RNA viruses, such as influenza and SARS-CoV-2. In particular, his team discovered the first strain of influenza that was mutation-defective: "We showed that this virus can fail to have the ability to generate mutations that are advantageous to the virus adapting to the environment, leading to a reduced ability to infect mice." These developments are essential in using mutagenesis to develop antivirals that can treat severe COVID-19 cases.

As for the diagnostics of infectious diseases, Professor Cheung has contributed to developing and evaluating methods to detect RNA viruses in wild birds, which helps risk-assess viruses circulating in the wild to assess how clinical diagnostics can be improved for sensitivity and accuracy. His research on viruses has also been spun into practical uses, particularly in antiviral drugs and vaccines. Most significantly, he and his team published a paper in April 2022 on the efficacy of different vaccines worldwide which garnered significant attention. They discovered that "a three-dose mRNA regiment seems to be the most effective in preventing COVID-19 infections", especially for high-risk populations, and that a booster shot would help prevent COVID infections and variants regardless of whether the shots used differed. As the Omicron variant spread worldwide, the paper provided valuable information to governments on booster jabs. Professor Cheung's multidisciplinary research has undoubtedly contributed to the understanding and preventing of infectious diseases caused by deadly viruses.

Despite this recognition, Professor Cheung continues to explore new ways of tackling the problem of ever-mutating viruses. "We need to employ a more multidisciplinary approach: one of the main reasons I joined CUHK was how it fostered such effective collaborations among people of different expertise." His team has developed technologies that help fight the spread of epidemics of infectious diseases, from mapping out how RNA viruses could unconventionally "jump" from one region of genomes to another to using complex statistical approaches in figuring out the optimal use of vaccines. The extraordinary spread of the COVID-19 virus has impressed on him the necessity of keeping up with the times. For Professor Cheung, future outbreaks can be prevented only by such continual development.

> **Understanding the basis for virus evolution and transmissions can help us understand how we control and prevent future pandemics caused by these viruses.**

Neuroscience and brain deterioration

Tackling the “tsunami of dementia”

Owen Ko Ho
Assistant Professor of
Medicine and Therapeutics

It is expected that in 2050, more than 130 million people will suffer from dementia worldwide. “I describe it as a ‘tsunami of dementia’,” says Professor Ko, Assistant Dean (Research) at the Faculty of Medicine at CUHK. “We are focusing on how our research can tackle the upcoming tsunami, an urgent matter that deserves much attention by society and policymakers.”

The brain is the most complex part of the human body controlling all body activities. Professor Ko leads a team with expertise in biology, chemistry and engineering to conduct pre-clinical scientific and clinical studies about the ageing brain and its deterioration in diseases. They focus on studying causes of gliovascular dysfunction in ageing and neurodegenerative conditions with brain imaging tools developed by themselves, and seek to devise solutions to counteract age-related brain deterioration. “While most existing research focus on post-diagnostic treatments, our team is eager to explore ways to achieve primary prevention as early as when the symptoms are mild, or even before any symptoms are visible,” says Professor Ko.

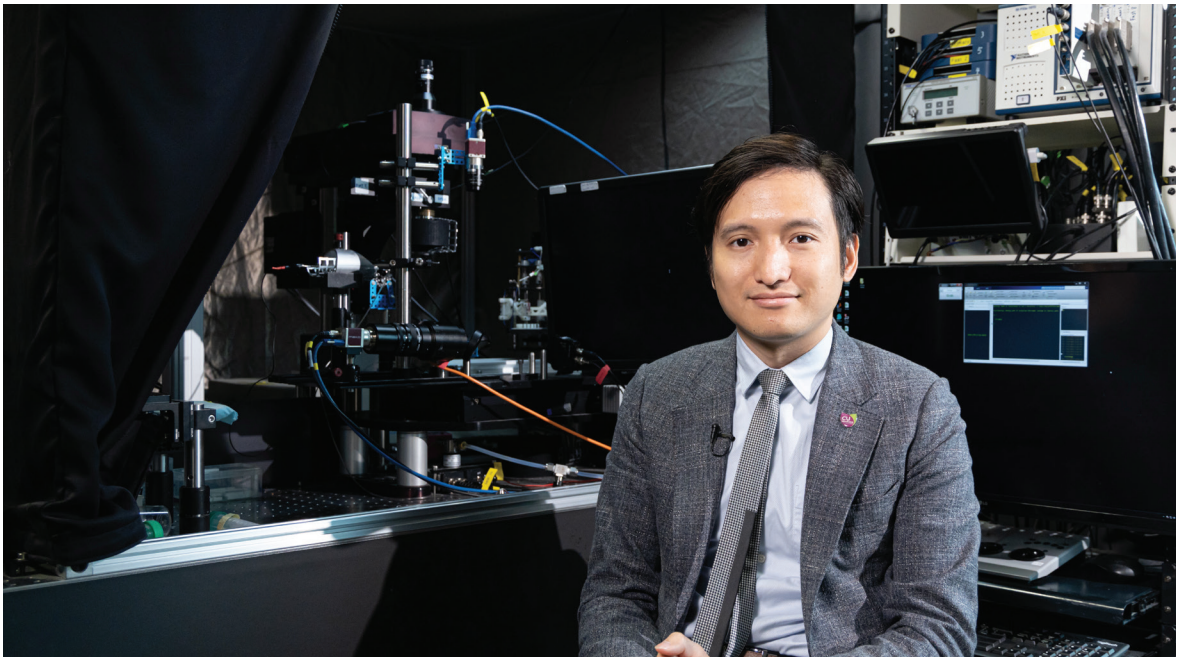
The team started out in a small laboratory in 2016. “Establishing a laboratory is very challenging,” says Professor Ko. “Our experiments rely heavily on optical imaging equipment, such as fluorescence microscopy, two-photon excitation microscopy, and a wide range of molecular assays. We dig deep into mechanisms about how the brain works and fails to work, and in particular deterioration and dysfunction caused by ageing.”

Their efforts have yielded positive outcomes at the pre-clinical level. In 2020 and 2021, the team demonstrated that a class of drugs can halt and even reverse brain cell ageing. Their mouse studies showed that treatment with GLP-1R agonist slows down age-associated changes in brain glial and vascular cells at both gene expression and functional levels. “The blood-brain barrier is a vital barricade preventing toxic substances from getting into the brain. Our experiments showed that these drugs can reduce the leakage of blood-brain barrier, a common problem appearing when the brain ages. They allow the brain to recover by producing molecular alterations and presumably also a physical change that restores the effectiveness of the blood-brain barrier,” says Professor Ko.

"We must go through many steps to achieve primary prevention. From pre-clinical scientific research to clinical trials, and then upscaling them before applying the outcome to society– it is a long journey," says Professor Ko. Based on positive experimental results, the team is conducting clinical trials in humans with Professor Vincent Mok and Dr Bonaventure Ip. "Patients with cerebral small vessel disease and blood-brain barrier leakage are a few times more prone to having dementia in five to 10 years. As our data suggested a GLP-1 agonist could be useful to all ageing patients who develop problems with their brain vessels, we hope to perform clinical trials on these patients to test if the GLP-1R-targeting drugs can help slow down the progression of pathology, perhaps via reversing brain vessel ageing."

The team's research works have been recognised by the 2021 Excellent Young Scientists Fund from the National Natural Sciences Foundation of China and the 2022 Sir David Todd Lectureship from the Hong Kong College of Physicians. Beyond clinical trials, the team also attempts to establish the mechanism of what happens in an ageing brain, which can lead to the creation of whole other classes of drugs. "We will conduct research about pathological and biological mechanisms to broaden our understanding of cellular pathways," says Professor Ko. "I do hope the clinical trials will be successful. By translating our findings in the laboratory, we hope our research in neuroscience can make a difference to the world."

> **"We dig deep into mechanisms about how the brain works and fails to work, and in particular deterioration and dysfunction caused by ageing.**



Gravitational-wave physics

Opening a new window to understanding the universe

Tjonnie Li
Associate Professor
of Physics

"One of the grand challenges in modern physics is that 95% of the universe is dark, meaning that it doesn't emit light," says Professor Tjonnie Li from CUHK's Department of Physics who has made significant contributions to the discovery of gravitational waves. "It is problematic because when we look up at the sky, nothing is visible. We see the effect, but not the universe itself."

Professor Li, heading the CUHK gravitational-wave research group with Professor Hannuksela Otto Akseli, strives to uncover and interpret signals from gravitational waves that can open a new window to understanding the universe.

Gravitational waves, which can be regarded as ripples in spacetime, are emitted by anything that accelerates. The challenge is that these waves are extremely weak, and massive, explosive mechanisms are required for detection. While Albert Einstein predicted the existence of gravitational waves a hundred of years ago, he noted that these waves were too weak to be measurable. Today, technological advancement has made it possible – In 2015, they were first detected by the twin Laser Interferometer

Source: ESO/WFI (Optical); MPIfR/ESO/APEX/A.Weiss et al. (Submillimetre); NASA/CXC/CfA/

Gravitational-wave Observatory (LIGO) detectors. Three international scientists who contributed decisively to the project were awarded the 2017 Nobel Prize in Physics.

Professor Li is leading the only group in Hong Kong involved with the work of LIGO. "The LIGO and Virgo detectors are unique L-shaped interferometers that can measure things we did not think were possible. The groundbreaking detection of gravitational waves by these advanced detectors is a technological marvel, able to measure small changes in spacetime. The experiments involved more than 80 institutes around the world, and is a testimony of what humans can achieve when we work together across borders, languages and cultures."

Hearing the universe's voice

In addition, it is also challenging to differentiate gravitational waves from noises. "We spent a lot of time trying to understand the source and doing calculations, hoping to find out what kinds of unique signals we expect from these waves," says Professor Li. The breakthrough came in 2015 as scientists, for the first time, observed gravitational waves arriving at the Earth from colliding black holes in the distant universe. "The first day I joined CUHK was actually the day when the hints of detection appeared," says Professor Li. The detection has opened a new window to the universe, revolutionising the study of the cosmos and its content.

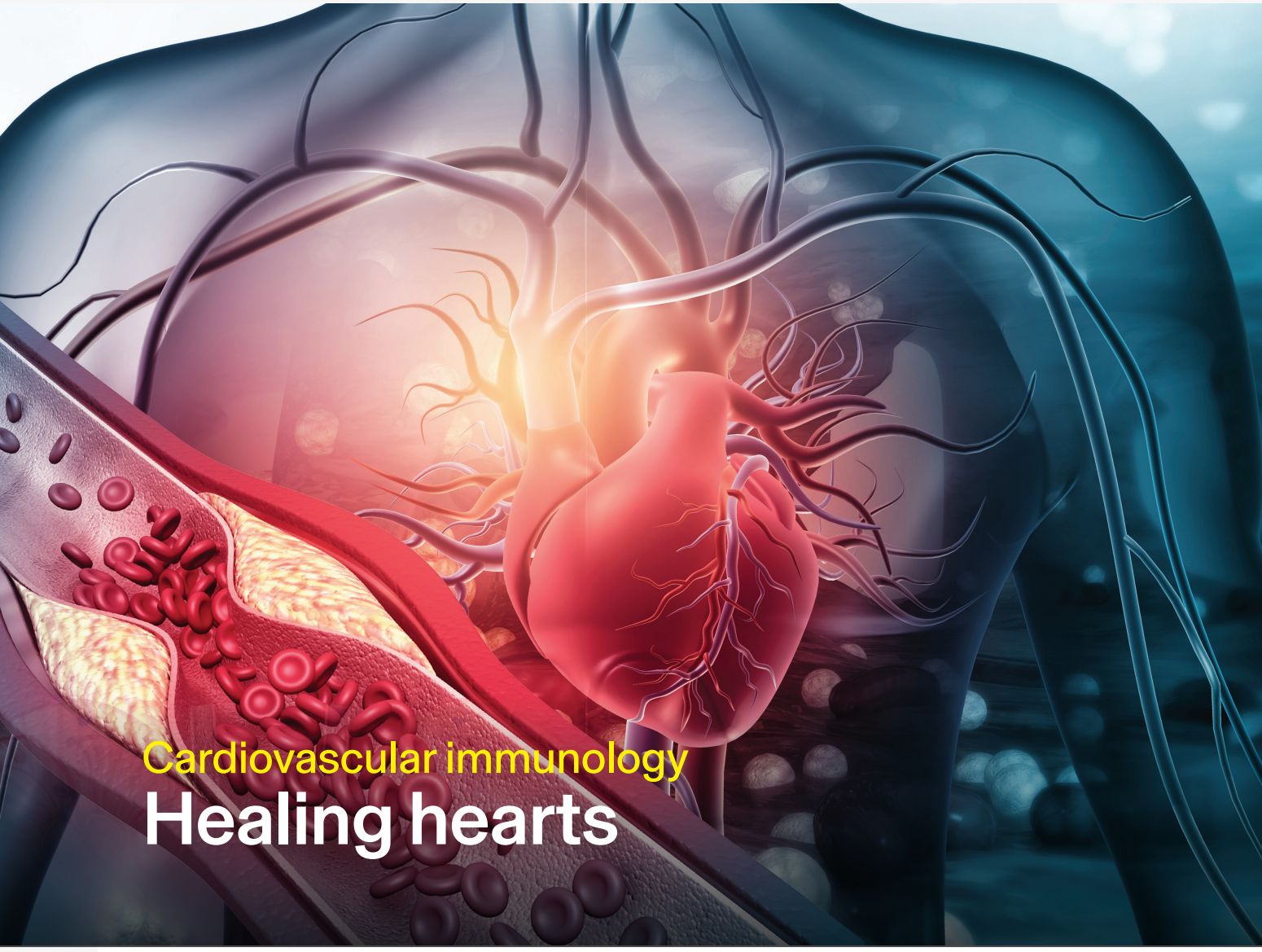
"Understanding the universe has been a persistent desire throughout the history of mankind," says Professor Li. The universe's darkness will never be observable with conventional astronomy using light. Gravitational waves bring scientists to better understanding the universe. "To me, the theory behind gravitational waves, that is Einstein's general relativity, is one of the most beautiful theories in physics. By doing research in this seemingly mysterious field, I am confident it has a tremendous potential to inspire future generations in doing research in STEM sciences," he adds.

Interpreting the universe's signals

Following the discovery of gravitational waves, the CUHK team seeks to interpret interesting signs within. "The current challenge is to map out what is in the universe by observing it on a larger scale," he notes. "Our next step is to extract signals carrying crucial sub-structures and extra information." For instance, the team is looking into gravitational lensing where the signal itself gets deformed by a massive object between the source and the observer. By being able to disentangle that from the signal, our understanding of the universe can go beyond what is shown on detectors.

"We really need gravitational waves as the avenue to bring us to the next stage of the understanding of the universe. I believe gravitational waves can broaden our understanding about the cosmos in the upcoming decades and centuries of mankind," says Professor Li. "There is so much more to be done."

> **"We really need gravitational waves as the avenue to bring us to the next stage of the understanding of the universe.**



Cardiovascular immunology

Healing hearts

Kathy Lui Oi-lan
Associate Professor of
Chemical Pathology

Cardiovascular disease is a leading cause of death worldwide, accountable for 13% of deaths in 2020. Kathy Lui Oi-lan, Associate Professor at CUHK's Department of Chemical Pathology, has been researching ways to solve this urgent problem. Her work has gained her the Croucher Innovation Award in 2017 and Research Grants Council Research Fellowship Award in 2022.

There are many factors behind cardiovascular diseases — while some of them are genetic, lifestyle also plays an important role, and the prevalence of diabetes in Chinese-speaking areas has worsened the diseases' widespread nature. Professor Lui has suggested that current approaches have overlooked this, creating an inability to get to the root of the problem. "There has never been medication that can unblock these blood vessels — all current medicines address the problem of lowering blood lipid levels."

For Professor Lui, such treatments only delayed a potentially lethal problem. Her

background in immunology inspired her to look at ways to empower the immune system instead, and she found the key within those clotted vessels. She discovered that many immune cells lay within these plaques, yet their potential uses remained unexplored. "After we discovered this problem, we started many projects to see if we can control these immune cells, so that these plaques can be dissolved."

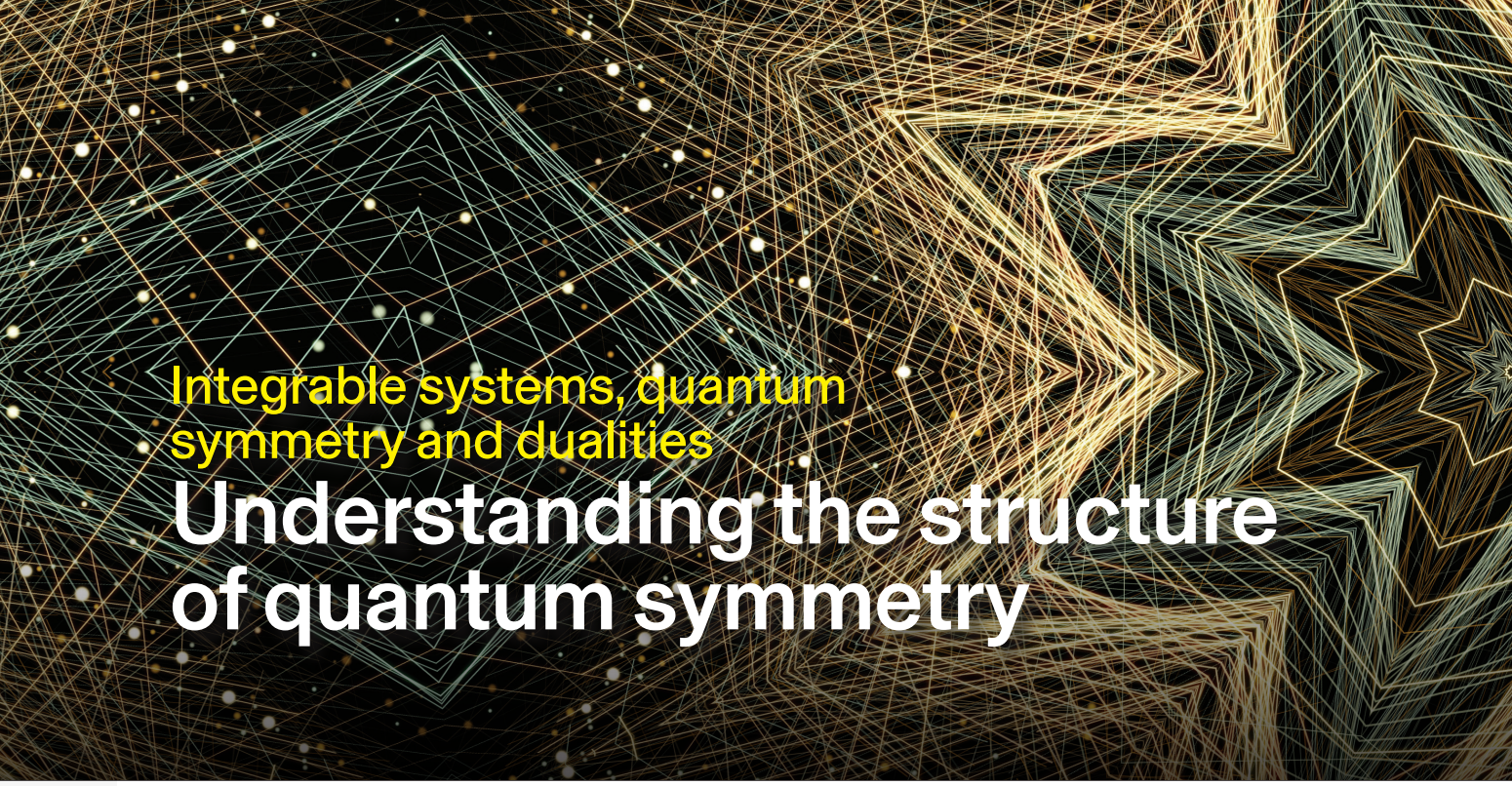
The professor knows that the exploration of immune cells and their therapeutic value is relatively uncharted territory. "These cells are tricky in that they can prove beneficial at times and malevolent at others, and only by pinpointing their beneficial uses can we use them on patients… Our research is all about stabilising these wild swings."

Although her academic journey has taken her to both Oxford and Harvard — gaining her three patents and allowing her to translate her bench work into clinical trials, uncovering the therapeutic potential of modified mRNA vaccines against cardiovascular disease — Professor Lui emphasises her desire to do research at CUHK, her alma mater, and Hong Kong. One reason is the potential to work with international academics: "CUHK is a very international university, and we collaborate with laboratories, both in the mainland and globally." But she also notes how homegrown talent in her field is currently lacking. With more researchers becoming interested in immunology and cardiovascular diseases, she has established the Lui Laboratory for Cardiovascular Immunology and Regeneration, hoping to do cardiovascular research while inspiring and nurturing future talent.

One of the main goals of the Laboratory is to further elucidate the connection between immune cells, stem cells and human diseases. To enable that, Professor Lui and her team developed mouse models with a humanised immune system to understand how human cardiovascular disease develops. "Many of our bench trials were conducted on mice, and we hope to see if humans can have the same pathophysiology." Her laboratory is also looking into T cells and their role in vascular regeneration: the regenerative ability of diabetic patients is often hampered by inflammation of blood vessels. Moreover, she feels that the developmental difference in the immune systems of children and adults has great implications for cell renewal and ageing, and is interested in exploring this further in her research.

Besides academics, Professor Lui hopes to work with pharmaceutical companies and contribute to the development of medicines. "During my training, I met many scientists and some of them have not stayed in academia; instead they have launched or work for pharmaceutical companies. We occasionally meet up to discuss whether our research is applicable."

> **"Only by pinpointing the beneficial uses of immune cells can we use them on patients… our research is all about stabilising these wild swings to target cardiovascular disease.**



Integrable systems, quantum symmetry and dualities

Understanding the structure of quantum symmetry

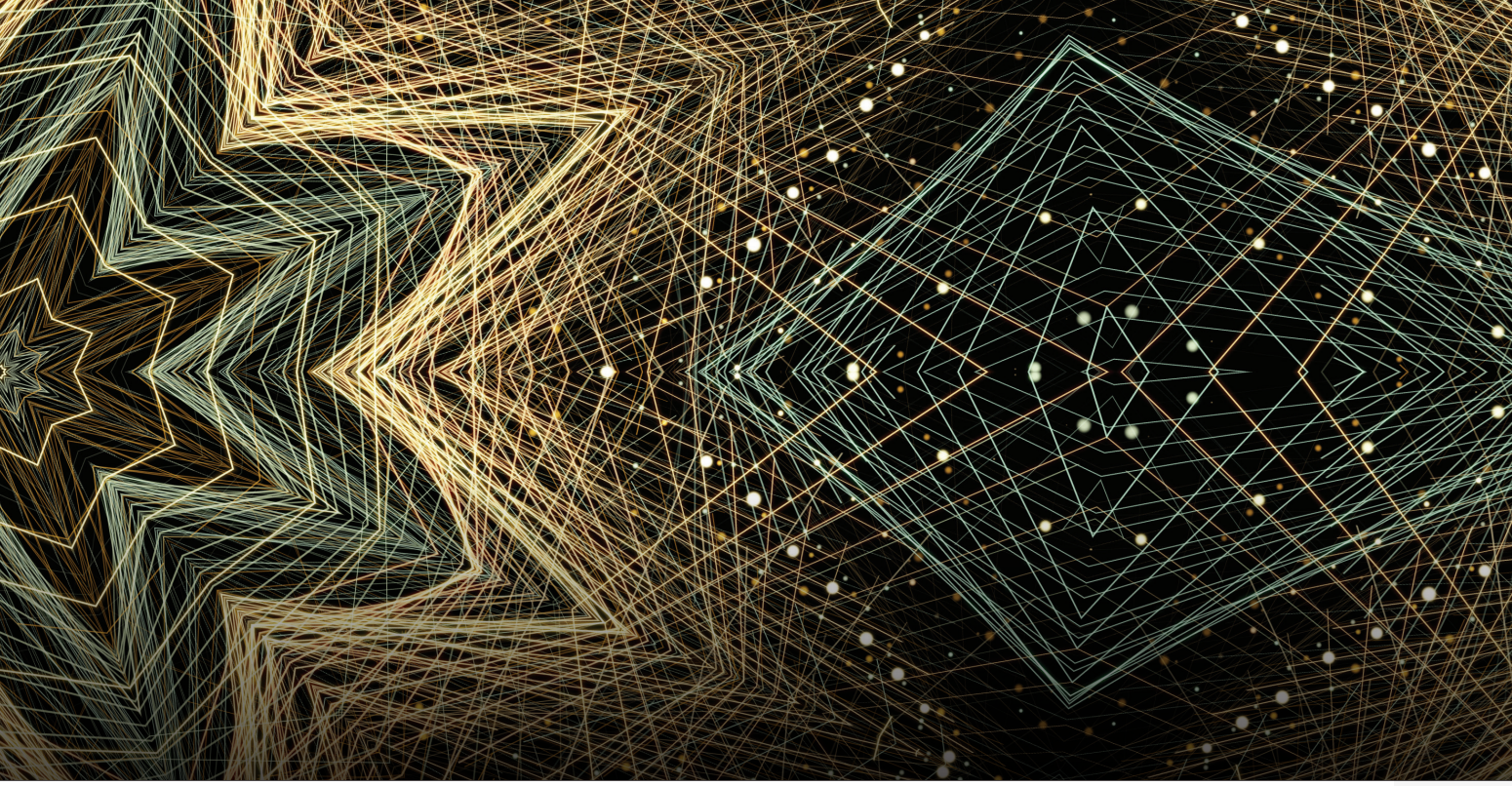
Michael McBreen
Assistant Professor of Mathematics

CUHK's Department of Mathematics is home to a team of outstanding mathematicians who contribute expertise to the advancement of mathematics. Among them is Professor Michael McBreen who studies the intersection of representation theory, symplectic geometry and mathematical physics. He was recognised by the Research Grant Council and won the Early Career Award in 2021. A young mathematician who believes in the importance of intuition, Professor McBreen's research centres around integrable systems, quantum symmetry and dualities.

Knowing more about the "chaotic world"

"The grand challenge of my research is to understand how symmetries behave in a world governed by quantum mechanics. I work with tools from algebra and geometry, especially from the field of integrable systems – a class of physical systems with an extraordinary level of symmetry," says Professor McBreen. In a world consisting of things that are chaotic and unpredictable, some special physical systems behave in an orderly and structured way. Many used to think they were an exception carrying less importance in sciences. Not until the 1960s did scientists start to realise how crucial integrable systems are in physical phenomena such as solitary waves, phase transitions in thermodynamic systems and high energy physics, and areas of pure mathematics such as number theory and representation theory. Today, they have become a central part of modern mathematics. "Almost every subject in pure mathematics has an interesting relationship with integrable systems," notes Professor McBreen. "In the 20th century, it was realised that these systems can explain stability and self-similarity in complex phenomena. We have developed sophisticated mathematical tools for obtaining precise information about their behaviour and classification."

Professor McBreen also contributes to the study of quantum symmetry and dualities, topics that are closely associated with integrable systems. "Quantum symmetry,



a form of symmetry arises in quantum mechanics, is a way to understand how quantum mechanical objects can be self-similar," says Professor McBreen. "It is particularly useful in understanding fundamental physics, especially high-energy physics. It is also a key part of condensed-matter physics, which studies the structure of materials such as metals, alloys and foams." Quantum symmetry has intimate connections with other topics such as pure algebra and number theory.

Adding to the list of Professor McBreen's research is the study of dualities. "The many dualities in physics often give people new ways of looking at familiar things. A lot of my research is about physical objects called supersymmetric gauge theory, understanding what various dualities can tell us about the fundamental structure of quantum symmetry – what this symmetry means and what possibilities are out there," he says. The supersymmetric gauge theory describes force fields, such as gravity, that can give rise to integrable systems.

CUHK provides a supportive environment for quality research. Professor McBreen believes that pure mathematicians start from an internal mathematical intuition. "It has already been realised that quantum symmetries and integrable systems are vital in the study of condensed matter physics and advanced materials, such as designing advanced ceramics or advanced topologically stable materials. My research started out as a pure intuition. I believe if the intuition is good, it will often – at a later stage – be revealed that it carries extensive applications."

Professor McBreen uses tools from high energy physics, combining them with classical mathematics to push the knowledge of quantum symmetry further. "I hope to come up with a complete description of the structure of these symmetries," he notes.

"The grand challenge of my research is to understand how symmetries behave in a world governed by quantum mechanics.

Palaeontology

Putting dinosaur flesh back on the bones

Michael Pittman
Assistant Professor of
Life Sciences

Dinosaur-to-bird transition

For the past 150 years, vertebrate palaeontologists have focused on the study of bones of dinosaurs and other prehistoric life. There are a lot of gaps to be filled in understanding prehistoric ecology, such as how dinosaurs moved, their diverse lifestyles, and how some dinosaur species including early birds developed the ability to fly. The lack of data has given rise to speculations and myths.

At CUHK, Professor Michael Pittman, a leading scientist in the field of vertebrate palaeontology, has been using innovative technology to revolutionise our understanding of prehistoric life. "Birds are a type of dinosaur. I am interested in how dinosaurs that could only walk and run became ones that were able to fly," he says. "This is a key evolutionary transition, arguably the most important one since fish walked out of water. My grand challenge is to plug important gaps in our understanding of the dinosaur-to-bird transition that have puzzled scientists for years."

New light on fossils

Professor Pittman's team first introduced **laser-stimulated fluorescence (LSF)** technology in palaeontology in 2017. Before the application, ultraviolet imaging was the closest method used to study fossils.

The groundbreaking LSF technique co-developed by Professor Pittman is able to expose hidden anatomy preserved in fossils.

This can outline the body and show details of the skin and other soft tissues at levels of precision that were previously impossible. In addition, LSF can show differences in the chemical composition of fossils, as the laser beam shining on a specimen interacts with the minerals that make up a fossil.

"With LSF, we have been able to put flesh back on the bones and find information that UV cannot," he says.

Discoveries and collaborations

The CUHK team, in collaboration with experts from mainland China and United States, has discovered key information about the origin of the modern flight system of birds in a paper published in *Proceedings of the National Academy of Sciences* last year.

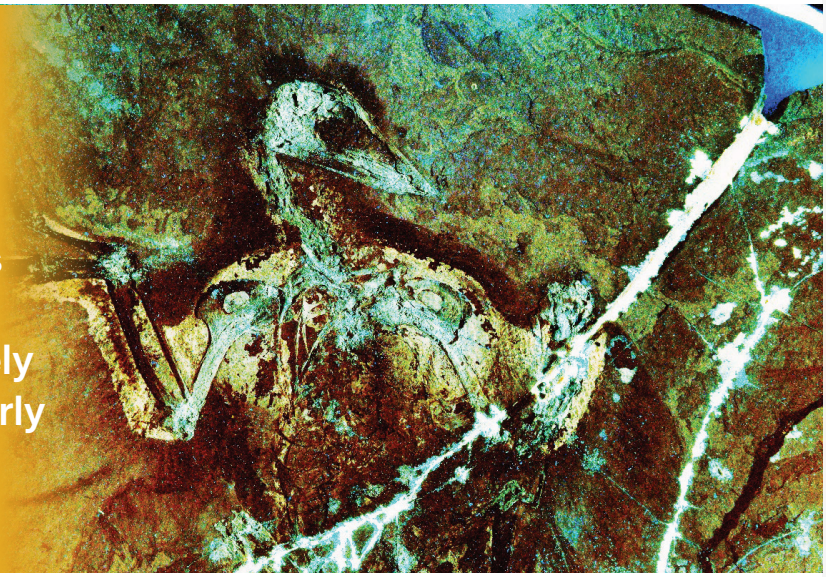
"Birds today fly using muscles that are all on their chest. Using LSF, my team can now see elusive soft tissues that are rarely preserved in the fossils of early birds and validate earlier speculation that flying dinosaurs used not just muscles on the chest, but also muscles on the shoulders," says Professor Pittman, lead author of the study. "Our discovery has moved the field closer to accurately reconstructing early flight capabilities."

In the study, the team applied LSF to more than 1,000 fossils of early theropod flyers that lived during the Late Jurassic and Early Cretaceous periods in what is now northeastern China. The specimens came from the Shandong Tianyu Museum of Nature on the mainland, with which Professor Pittman maintains a long-term working relationship.

Professor Pittman is regularly invited to study fossils in museums and universities around the world using LSF. His work featured in a special exhibition at the National Museum of Nature and Science in Tokyo this year. His LSF technique has also been applied by international researchers in the study of early birds and other animal groups, such as ammonites. His LSF work extends beyond palaeontology to archaeology.

Professor Pittman also conducts regular fieldwork in the Gobi Desert, which led to the discovery of two dinosaur species, and in the Patagonian Desert, where he investigates the Gondwanan dinosaur ecosystems.

Our discovery has moved the field closer to accurately reconstructing early flight capabilities.



LSF image of the *Confuciusornis*, showing large shoulders that powered the wing upstroke

6

Pathfinders

Special education

Using social robots to improve autistic children's social skills

Catherine So Wing-chee
Professor of Educational Psychology

"When someone is talking to you, you make eye contact with that person without verbally interrupting and when you greet a friend, you wave and say 'hello'. These are basic social skills we learn during childhood but for autistic children, it is not that easy," says Professor Catherine So Wing-chee from the Department of Educational Psychology.

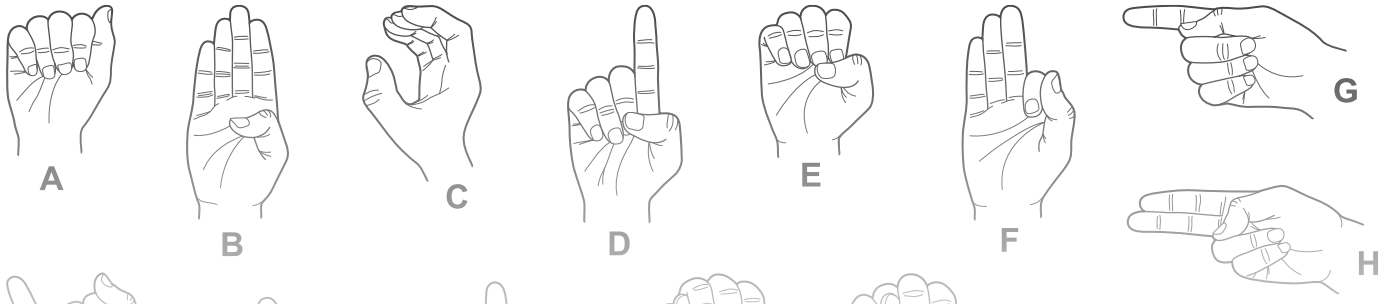
In 2016, Professor So introduced the use of social robots to assist teachers in improving autistic children's social skills. "I launched the Robot for Autism Behavioural Intervention (RABI) programme to effectively improve autistic children's communications skills. First started in 2016, RABI is the world's first programme containing a comprehensive robot curriculum in treating autistic children. A direct instruction method was adopted, allowing autistic children to imitate the robot's correct way to connect with people – it resulted in a positive outcome."

The encouraging results did not stop Professor So from advancing her research. "The programme was rather monotonous in the beginning," said Professor So. "I hope autistic children can learn beyond imitating – understanding the rationale behind all gestures is a crucial part of learning."

In 2018, Professor So and her team started introducing more interactive elements into the curriculum. Robots are equipped with a speech recognition function, specialised in performing dramas and role-playing with autistic children. "By simulating real-life situations, children will understand why particular actions and gestures are performed. In 2020, robots started demonstrating both right and wrong actions, so that autistic children can learn from mistakes and acquire appropriate communication skills."

Robots play a vital role in assisting human teachers to produce better learning outcome. "Some autistic children can be sensitive to sensory simulations, which distracts the learning process. The use of robots prevents it from happening, and through repeated actions that are meticulously and consistently formulated, autistic children can concentrate on learning, producing a more effective learning outcome."

Since August 2022, the team started providing workplace training to autistic teenagers aged 18 and above, hoping to assist them in identifying their career paths. "CUHK is a precious platform for us to bring research findings to society," says Professor So. "The competent young scholars here are key to creating a healthy research ecosystem."



Sign language and deaf studies

Helping the hard of hearing

Gladys Tang Wai-lan
Professor of Linguistics

Felix Sze Yim Binh
Associate Professor of Linguistics

Although the 2021 Census reported 314,800 local persons with varying degrees of hearing difficulty, the lack of understanding and misconceptions about sign language means these people are rarely provided appropriate support in pursuing education. Oftentimes, they end up with low literacy skills and lack the means to participate fully in society or receive tertiary education. To fill this gap, CUHK established the Centre for Sign Linguistics and Deaf Studies in 2003. It is currently managed by Professors Gladys Tang Wai-lan and Felix Sze Yim Binh, both from the Department of Linguistics and Modern Languages. "Back then, no university in Asia had a centre that focused on sign language research. So we thought we had a responsibility as linguists to develop this research at CUHK," says Professor Tang.

The Centre's Asia Pacific Sign Linguistics Research and Training Program (APSL) has enabled many deaf and hearing adults, both local and international, to study sign linguistics and engage in sign language research at CUHK, resulting in the creation of the award-winning Asian SignBank. The professors are also eager to establish this discipline in other Asian countries, where according to Professor Sze people do not see deaf people as "minority language groups" but as "persons with disabilities". Therefore, the Centre has made it its mission to work with Asian universities, governments and deaf associations in establishing the disciplines of sign linguistics, deaf studies and sign language education to change their attitudes.

Locally, the Centre also conducts inclusive education research. It received HK $64 million from The Hong Kong Jockey Club Charities Trust in 2006 to develop the Sign Bilingualism and Co-enrollment Education (SLCO) Programme, which benefits deaf and hearing children from kindergarten to secondary education.

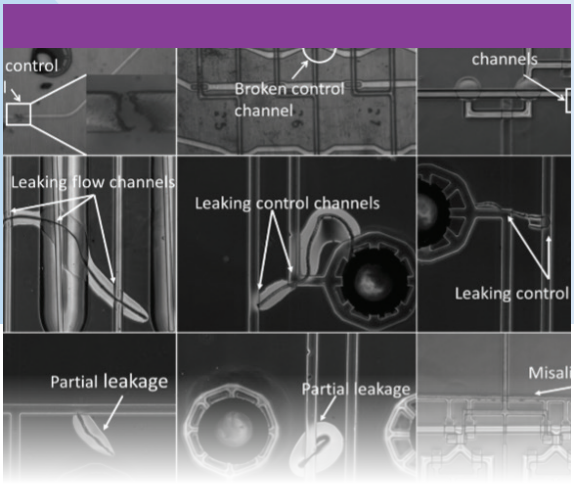
Years of effort have established CUHK as the hub for research and training in sign linguistics and deaf education in Asia. Currently, the Centre's outreach covers countries from Japan to Fiji. Its efforts to push for quality education for the deaf using the SLCO approach have also been recognised worldwide. "Occasionally, some education conferences invite us to form an independent panel to exchange CUHK's research findings with peers in the field."

Now entering its third decade of existence, the Centre continues to develop multidisciplinary projects to support deaf people in all walks of life, collaborating with researchers from the Faculties of Engineering, Law and Social Sciences in a bid to enable communication between deaf and hearing populations. Professor Sze's recent projects, such as mental health and sex education of deaf people, have drawn attention locally, and both professors are partnering with Google (Asia) to develop SignTown, a project utilising sign recognition research to promote sign language learning at a global level. "Other professors may place great emphasis on what topics are more publishable when they embark on research projects," says Professor Sze. "But our research agendas are formulated based on the needs of deaf people."

7

Global STEM Scholars

The Global STEM Professorship Scheme, launched by the Hong Kong government in January 2022, aims at helping universities in Hong Kong to recruit internationally renowned Innovation and Technology scholars and their teams to Hong Kong, hence scaling new heights in the teaching of and research in innovation and technology of local universities. As at March 2023, CUHK has recruited eight Global STEM Scholars specialising in different research areas.



Stephen Dalton

School of Biomedical Sciences

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Our goal is to develop a new generation of treatments for type 2 diabetes.

Most patients with type 2 diabetes (T2D) take some form of medication, but these have reduced efficacy over time. Moreover, insulin resistance and hyperglycemia that develops in T2D is associated with a broad range of clinical complications that are not addressed with current treatments. To tackle this major health problem, Professor Dalton and his team are using pluripotent stem cells to develop a new generation of therapies including the development of new drugs and novel cell therapy approaches.

Ho Tsung-yi

Department of Computer Science and Engineering

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I hope to gather a vibrant community of electronic design automation (EDA), making CUHK an iconic centre for next-generation EDA technologies and applications.

Professor Ho has made seminal contributions in several areas of computing and emerging technologies, especially in the design automation of microfluidic biochips. His work on the testing of microfluidic biochips earned the prestigious IEEE Transactions on Computer-Aided Design Donald O. Pederson Best Paper Award in 2015. A leader of the Electronic Design Automation community, Professor Ho has been invited to speak at over 100 companies, professional societies, conferences and universities worldwide. Now a Distinguished Member of the Association for Computer Machinery, he also plays vital roles in various international professional organisations.

Jin Bangti

Department of Mathematics

"

The gist of my research is to combine traditional physical models with powerful data-driven techniques to solve challenging computational problems in science and engineering.

The research interest of Professor Jin and his research group broadly lies in applied and computational mathematics, especially inverse problems and numerical analysis. They focus on developing highly effective computational techniques for direct and inverse problems in science and engineering applications, and establishing rigorous mathematical guarantees. Since he joined CUHK, one exciting line of his research has been about developing novel machine learning techniques for solving challenging problems in the area, e.g. using deep neural networks to estimate parameters in complex mathematical models (e.g. high-dimensional partial differential equations), and their rigorous mathematical analysis.

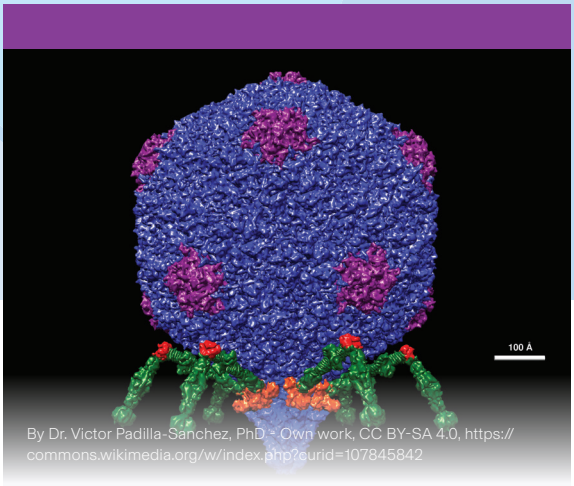
Long Yi

Department of Electronic Engineering

"

I am developing smart materials and devices for transformation towards a sustainable and healthy world.

Professor Long, who graduated from the University of Cambridge, is a Fellow of the Royal Society of Chemistry. Her career started with successful Lab-to-Fab technology transfer to industries including Seagate Technology. Her recent work won the Falling Walls Science Breakthroughs of the Year 2022, TOP3 in the "Energy" category of the 2022 Green Awards, and the 2016 TechConnect Innovation Award. Her research in CUHK focuses on the diverse applications of smart materials, including energy saving, soft electronics and functional devices.



By Dr. Victor Padilla-Sanchez, PhD - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=107845842

Mao Chuanbin

Department of Biomedical Engineering

"My research is to engineer nature's tools into precision medicine to fight against challenging diseases such as cancer.

Professor Mao's research focuses on genetic engineering of phages to develop novel strategies for biomaterials, nanobiotechnology, nanomedicine, and regenerative medicine. He has genetically engineered phages for seeking cell-/tissue-targeting peptides, detecting biomarkers for cancer diagnosis, inducing stem cell differentiation, promoting drug/gene delivery and tissue regeneration, and developing nano-theranostic agents. He has been elected as a fellow of various societies, such as the American Chemical Society, the American Academy of Microbiology, the Biomedical Engineering Society, the American Institute for Medical and Biological Engineering, the American Association for the Advancement of Science, and the Royal Society of Chemistry.

Sinno Jialin Pan

Department of Computer Science and Engineering

"We are developing a new generation of transfer learning by integrating high-level symbolic knowledge representation into deep learning models.

Professor Pan's research interests spans both machine learning and AI, as well as their interdisciplinary applications. Specifically, a common thread in his research has been focused on developing and applying transfer learning techniques to build adaptive information systems, where a system built on one domain can be automatically adapted to related equivalents or environments with little human supervision. A pioneer in the field of transfer learning, he has helped lay the early theoretical foundations and developed practical algorithms for transfer-learning techniques with diverse real-world applications.


Source:
ESA/Hubble & NASA

Ken Sung Wing-kin

Department of Chemical Pathology

"

We aim to develop cost-effective, time-efficient and accurate methods to identify disease-causing genomic variations of each individual.

Different individuals have different genomic variations, which make all of us unique. Importantly, some such variations cause genetic diseases. Understanding them is a major challenge given their prevalence and potential threat to quality of life. Riding on high-throughput sequencing, Professor Sung's team develop computational methods in laboratories that decode human genomes and identify disease-causing variants. For instance, they identified HBV integrations and HPV integrations that cause liver cancer and cervical cancer, respectively. In the future, the team will further improve the accuracy of their methods and integrate their solutions into clinical care to improve disease surveillance, prevention and treatment.

Yan Renbin

Department of Physics

"

My dream is to map the motion and distribution of gas in our Milky Way Galaxy to understand our galactic home and how stars are born around us.

Professor Yan is a leader (Survey Scientist) of the team who completed the largest imaging spectroscopy survey of nearby galaxies. He also led another team to produce the largest library of stellar spectra. His works have proved that warm ionised gas with a temperature of ~10,000K is prevalent in old galaxies and helped understand their origin. Recently, he and his students proposed a new spectral diagnostic method to constrain critical details of how gas in galaxies is ionised by young stars. He also developed a new instrument concept that could significantly improve the efficiency of mapping the universe.

Please scan the following for
more information about CUHK research:

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