THE TIME IS NOW

WHICH IS WHY DR OLULEYE IS PROVIDING THE EXPERTISE INDUSTRY NEEDS TO MAKE NET ZERO COST NEUTRAL

Dr Gbemi Oluleye
Assistant Professor, Centre for Environmental Policy

Imperial/51

THE MAGAZINE FOR THE IMPERIAL COMMUNITY

WINTER 2021/22

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WHICH IS WHY DR PEARCE IS PROVIDING DATA AND MODELLING ON GREEN TRANSPORT TO BRIDGE THE GAP BETWEEN POLICY AND BEHAVIOUR

Dr Drew Pearce
(MSc Physics 2014, PhD 2019),
Research Associate,
Department of Physics

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Dr Joeri Rogelj
Director of Research and Reader in Climate Science and Policy, Grantham Institute and Centre for Environmental Policy

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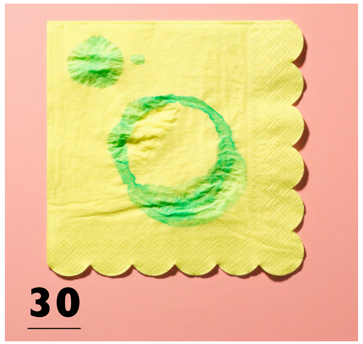

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Imperial/51

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DIGEST

NUCLEAR FUSION

Ignition marks major milestone

Imperial physicists are helping to analyse data from a unique new experiment, the first time nuclear 'ignition' has been triggered in a lab.

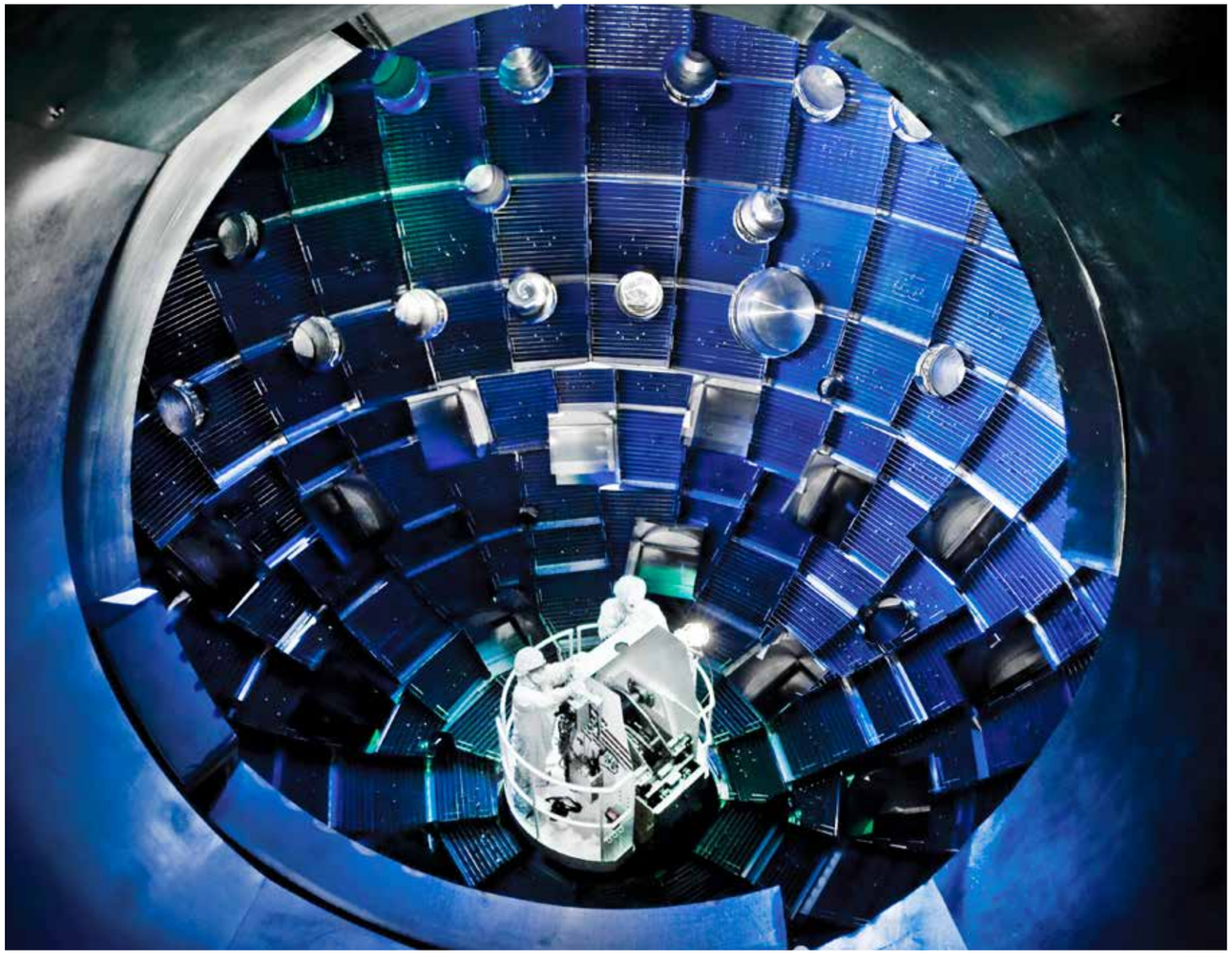
Scientists at the National Ignition Facility at Lawrence Livermore National Laboratory in the US recreated the process of ignition, amplifying the energy output from nuclear fusion. It produced more energy than any previous inertial confinement fusion experiment, and proves ignition is possible, paving the way for more efficient, controlled fusion reactions with implications for clean energy.

The Imperial team at the Centre for Inertial Fusion Studies (CIFS) are now analysing the outputs of the experiment, using diagnostic methods they have created to understand what is happening in such extreme conditions.

The hotter we get, the closer we get to the very first state of the universe

Dr Aidan Crilly, Research Associate at the CIFS, says: "Reproducing the conditions at the centre of the Sun will allow us to study states of matter we've never been able to create in the lab before, including those found in stars and supernovae.

"We could also gain insights into quantum states of matter and even conditions closer and closer to the beginning of the Big Bang – the hotter we get, the closer we get to the very first state of the universe." ◆



Below: Inside the National Ignition Facility at Lawrence Livermore National Laboratory, a service system lift allows technicians to access the target chamber interior for inspection and maintenance.

PHOTO LEFT: LAWRENCE LIVERMORE NATIONAL LABORATORY. ILLUSTRATION ABOVE RIGHT: MIKE LEMANSKI

Letters

WRITE TO US

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Due to COVID-19, we are working remotely and unable to receive correspondence by post. Please mark your message 'For publication'. Messages may be edited for length.

More memories of Jezebel

I refer to the letter from Fred Cox (Memories of Jezebel, *Imperial* 50). I can state that the 1916 Dennis Fire Engine (afterwards Jezebel – the Scarlet Woman) was collected from Joseph Crosfield by members of the RCS Union in 1956. I was an early member of the RCS Motor Club set up to maintain the vehicle.

I think your correspondent's confusion may have arisen in that the City and Guilds Union had a 1904 James and Brown car (Boanerges – 'Bo') as a mascot, which was acquired many years before (around 1930?).
Alan Redman (BSc Chemistry 1955, PhD 1958)

A puzzling challenge

I enjoy *Imperial* magazine's puzzles – good entertainment and often useful to me as a maths teacher in setting a bit of a challenge to classes.

Puzzle 2 in issue 50 was of particular interest as it's a revised version of a challenge I have previously set for students. It's an excellent puzzle as it can be approached without any particular mathematical tools, but also can be extended to a bit of a stretch question for Upper 6th if one also asks: 'What is the equation of the (optimal) path? followed by the escapee'. I put a solution to this on my website: mathsmodels.co.uk/2020/07/15/cat-and-mouse.

Thanks again for the excellent, entertaining and informative magazine.
Andrew Wilkinson (BSc Mathematics 1981)

ON OUR RADAR

It's been great to see our alumni keeping in touch and getting together in person and virtually around the world – from an online cocktail party hosted by the alumni network in Taiwan to laser tag in the UAE, virtual reunions and real-life drinks in Munich. You can share details of your meetups and events, or find out what's happening near you, on Imperial Plexus at *plexus.imperial.ac.uk*

> *Keep up with the latest news from the College as it happens, and share your thoughts and news on our Imperial alumni Facebook page and LinkedIn group.*
facebook.com/alumni.imperialcollegelondon
www.linkedin.com/groups/87488

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COVERING FOUR CLIMATE CHAMPIONS

Tackling climate change requires insight from across the board. To recognise the scope of the challenge, this edition of *Imperial* magazine has one of four possible covers, featuring different aspects of our work. Turn to page 12 to find out how our academics' real-world solutions are helping to secure the future of the planet.

FROM THE PRESIDENT / PROFESSOR ALICE GAST

Navigating successful change through research, education and innovation

As the philosopher Heraclitus noted: "Change is the only constant in life." Every generation has faced and adapted to change, and the pandemic changed our lives and the world in which we live. Imperial College London navigated these difficult times with strength, courage and a tremendous amount of teamwork, and we are inspired by the accomplishments, fortitude and resilience of our community.

One thing we know now is that, when we have to, we can change rapidly. When we had to move our work online, our highest priority was to provide our students with an excellent education. Our colleagues went above and beyond to ensure that learning outcomes were met and experiences – online, at home and on campus when possible – were the best they could be. Our students registered their satisfaction and appreciation in their responses to the National Student Survey.

Our research and innovation also pivoted to doing everything possible to understand and mitigate the disease. From epidemic modelling and making hand sanitiser to new tests, treatments and vaccine platforms, Imperial has been there for the community, the UK and the world. For this, we were named University of the Year 2022 by *The Times* and *The Sunday Times* Good University Guide.

In these pages you will see the ways we are navigating the changes ahead and how we contribute to society.

Our Professor of Digital Strategy and Innovation, Christopher Tucci, forecasts significant change: "There's no type of business that will be untouched by digital transformation," he says. He counsels looking at the big picture and planning ahead. While "no one likes change", we can and must adapt to technology for the future.

Perhaps the biggest challenge we face is climate change. In the wake of COP26, we hear from a diverse group of researchers affiliated with Imperial's Grantham Institute about their work to decarbonise society. Changing the way we make things, changing how we work, use resources and integrate our efforts across systems such as waste, supply, climate processes and infrastructure are all necessary if we are to succeed. Technological advances need to go hand in hand with societal changes. As Drew Pearce points out, there is a need to marry engineering novelty with the real on-the-ground approach of how people will use it.

I'm confident that Imperial will continue to improve the world for everyone

Changing how we design materials and medical devices is improving the quality of life for patients. Notice our inspiring alumna making devices to stabilise the hands of Parkinson's patients. Read about the human touch Aldo Faisal, Mirko Kovac, Thrishantha Nanayakkara and their colleagues are bringing to soft robotics. Changing the paradigm for the way humans and machines interact is transforming medical interventions and education.

Medics and engineers collaborate here at Imperial with great results. The Sir Michael Uren Hub in our White City Campus brings these communities together better than ever. The pandemic accelerated the rate of invention and innovation as you will see in Professors Charles Coombes' and Christofer Toumazou's optimism about their ability to "interrogate the blood" of breast cancer patients and deliver the most effective treatment.

Finally, for a bit of inspiration about how brilliant ideas are borne out of thinking, discussing, reading and collaborating, be sure to savour the compelling story of Professor Sir Martin Hairer and his breakthrough in stochastic partial differential equations.

Change is upon us whether we like it or not. As an optimist, I look positively towards the future. Everyday stories like those in this magazine buoy my spirits. A heartwarming story of outreach to our community, an accolade for a younger colleague, a transformational research discovery, an exciting entrepreneur with a good idea or an inspiring student design project making a difference to the world: these all make me confident that Imperial College London will continue to improve the world for everyone.

A major change will occur next summer when my successor, Professor Hugh Brady, takes on the role of President. It is a privilege to lead Imperial and I am pleased to be handing over an inspiring and excellent institution to a leader of his calibre.

In the meantime, we have opportunities to seize and changes to adapt to. I know that we will navigate those changes ahead with the collaborative spirit that makes us so successful. ◆

> ***Professor Alice Gast** is President of Imperial College London and is an internationally renowned academic leader and researcher.*

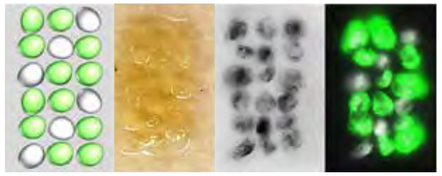
IMMUNOLOGY

Tackling long COVID

Imperial researchers are working to mitigate the effects of long COVID, and plan to identify biomarkers from people displaying the symptoms.

Almost two years on from the start of the pandemic, the lasting effects of the virus have yet to be fully understood, with scientists admitting they are operating in "uncharted territory". The emerging pattern of the condition, however, features a list of symptoms, from fatigue, breathlessness and brain fog to aching joints and depression.

Researchers from the Department of Infectious Disease and Department of Immunology and Inflammation aim to study its effect on the immune response. *Visit bit.ly/imperial-51-longcovid to hear Professor Danny Altmann from the Department of Immunology and Inflammation on the Imperial Podcast.*



PHOTOGRAPHY OPPOSITE PAGE: IMPERIAL COLLEGE LONDON/THOMAS ANGUS. IMAGE THIS PAGE: CARO-ASTORGA ET AL., 2021

BIOENGINEERING

Self-healing 'living materials' created

Imperial researchers have created 3D building blocks that can heal themselves in response to damage.

The engineered living materials could lead to the creation of real-world materials that detect and heal their own damage, such as fixing a crack in a windshield, a tear in the fuselage of an aircraft or a pothole in the road.

According to Dr Joaquin Caro-Astorga in the Department of Bioengineering: "Our discovery opens a new approach where grown materials can be used as modules with different functions, in construction for example."

Above: Bacterial cellulose spheroids as building blocks for 3D and patterned living materials, and for regeneration.

42

The Hitchhiker's Guide to the Galaxy says 42 is the answer. But what is the question? For Professor Christopher Tucci it is: how can business embrace, not just endure, digital transformation?

From farming to fashion, there's no type of business that will be untouched by digital transformation, says Professor Christopher Tucci, Professor of Digital Strategy and Innovation at Imperial College Business School. "It's just a matter of time. Why not think about it now, rather than when you're about to go bankrupt and it might be too late?"

The best strategy is to look at the big picture, he says. "Think about the future and say: 'What can we do now so that we're not struggling in ten years' time?'" And then start small. "The most advanced companies don't say: 'Stop everything, we're going to do a complete digital transformation!' They do little things all the time, building skills and confidence. You might automate one process, like expense reports, and go from there."

While large companies typically plan far in advance and startups have digital solutions built into their business model, small-to-medium enterprises that have been in business for a long time are often the slowest to innovate. "But they have one big advantage – they have fewer moving parts, so can make changes more quickly once they decide to."

Potential rewards include cutting costs, improving efficiency and increasing profits, but getting everyone on board can be a challenge. "No one likes change. Senior management has to be convinced it's necessary and you might need to address employees' fears that they're going to automate themselves out of a job."

The pandemic exacerbated existing gaps in digital competence. "It was a shock to the system. Restaurants that were cash-only, for example, had to scramble to take orders electronically." But it's not only about serving customers. "Companies that had some collaborative online work processes were able to be more competitive because they'd at least made a start."

No company can prepare for every possible macro-economic trend, but staying on top of technological developments can only help. "If you do, the chances are you'll be more resilient, more future-proof and survive longer."

> *Professor Tucci is Professor of Digital Strategy and Innovation at Imperial College Business School and Director of Education at Imperial-X.*

Right: Lucy Jung, co-founder of Charco Neurotech.
Below: CUE1, a small, non-invasive device worn on the body to administer specialised vibratory stimulation.

From that moment, I thought all I wanted to do was bring smiles back to people with Parkinson's

IMPERIAL INNOVATES

Smooth operator

Lucy Jung *(Innovation Design Engineering, 2014)* overcame a brain tumour to develop a revolutionary device for people with Parkinson's.

Interview: **Lucy Jolin** / Photography: **Hannah Maule-ffinch**

Back in 2014, I was doing an Innovation Design Engineering Master's (jointly run by Imperial and the Royal College of Art). I was working on a med-tech project and met a gentleman with Parkinson's. He explained that he was very happy to meet us, but he always looked angry, as the condition had made his face too stiff to smile. From that moment, I thought: "Bringing smiles back to people with Parkinson's is what I want to do."

We talked to a lot of people with Parkinson's to find out what helped them in their daily lives, and many mentioned vibration. So, we designed and created a vibrating pen. But before I could do anything more on the project, I was diagnosed with a brain tumour. It turned out that I was allergic to the medication used to treat it, so I had to have surgery and take time off.

Meanwhile, our pen project went viral – it was reported on around the world. Suddenly, I was being inundated with messages from people with Parkinson's. I had to tell them that, unfortunately, it was just a project. I did hope that a medical device company would offer to pick it up, but that didn't happen! So when I was in the hospital, my co-founder, Floyd Pierres, and I promised ourselves that if I ever got out, we would do everything we could to take the idea forward.

I did recover, and we started again from scratch. We reached out and talked to as many people with Parkinson's as we could find. We approached Imperial experts who generously shared their knowledge, and buried ourselves in all the available literature. I was fascinated to discover that Jean-Martin Charcot, known as the father of neurology, had already realised the benefits of vibration back in the 19th century. Hence the name of our company: Charco Neurotech.

Combining all our research and user testing, we developed the CUE1. It's a small, non-invasive device worn on the body to administer specialised vibratory stimulation, which relieves the movement symptoms of Parkinson's. It can also be used in conjunction with our app to set medication alerts, customise the stimulation, and track symptoms through games.

We've had incredible support from Imperial. The project started there, after which we connected with the Enterprise Lab, where we found out about the Imperial White City Innovators Programme, which taught me how to run a startup. It was also there that we met Govind Pindoria, Executive Director of Imperial College Innovations, who has been a fantastic mentor to us – he is now one of our directors. The Imperial-led MedTech SuperConnector and Innovation RCA gave us pre-seed money. We had mentorship from the Imperial Venture Mentoring Service, and we were the first investment from the Imperial College Innovation Fund.

Right now, it's a very exciting time as we are now closing our next round of funding and are currently preparing for mass production. We have 5,000 people on the waiting list in preparation for a feasibility study in multiple sites, and a big clinical trial. It's been an incredible journey so far. And Imperial has always been there – in fact, we feel like we are still there. ◆

IN BRIEF

Next President announced
Professor Hugh Brady has been confirmed as President-designate of Imperial, and will succeed Professor Alice Gast when her term ends next August. A global leader in science, engineering, medicine and business, and currently Vice-Chancellor and President of the University of Bristol, Professor Brady is the first medic to lead Imperial.
bit.ly/imperial-51-president

University of the Year award
The Times and *The Sunday Times* Good University Guide has named Imperial as University of the Year 2022. It follows the College's highest scores for student satisfaction in the National Student Survey and a further Good University Guide award as University of the Year for Student Experience 2022.
bit.ly/imperial-51-award

Mars's changing habitability recorded
An international team led by Imperial has found evidence of ancient dunes on Mars that could help explain how the planet's climate evolved from an environment that potentially harboured microbial life to an uninhabitable one. It forms the latest part of Imperial researchers' partnership work on various studies of Mars.
bit.ly/imperial-51-mars

OVERHEARD ON CAMPUS

Petrol-derived lead: *Imperial research has found that airborne particles in London are still highly lead-enriched compared to natural background levels – even despite the dramatic drops that resulted from the banning of leaded petrol in 1999.*

Magic mushrooms: *Psilocybin, the active compound in magic mushrooms, may be at least as effective as a leading antidepressant medication in a therapeutic setting, according to early trials carried out by the Centre for Psychedelic Research.*

Plasmodium: *Altering mosquitos' gut genes to make them spread antimalarial genes to the next generation of their species, impairing the development of the Plasmodium parasite that causes malaria, shows promise for curbing the disease.*

EDUCATION: PROFESSOR ALAN SPIVEY, PROFESSOR OF SYNTHETIC CHEMISTRY, FACULTY OF NATURAL SCIENCES, DEPARTMENT OF CHEMISTRY

The Chemical Kitchen: where students swap lab coats for aprons and gain practical skills

It began as an off-the-cuff remark. My colleague (and Professor of Surgical Education and Engagement Science) Roger Kneebone and I were discussing our chemistry students and their lack of hands-on experience. Finding students who are academically able and also good practically is hard. But we noted that those in other fields, chefs, for example, spend hours teaching practical techniques to their apprentices. This was a moment of insight that resulted in the Chemical Kitchen.

Our project introduces students to the mindset and fundamental skills needed in a laboratory setting through the non-threatening parallel of cooking. Just as a chef will prep ingredients in advance, line up utensils and keep a clear workspace – the process of *mise en place*, or 'everything in its place' – chemists must prepare for complex experiments and schedules: taking a solution out of a fridge ten minutes before it's required, and so on. Rather than a gimmick, it's an effective way for students to learn professionalism, safety and accuracy. We're teaching them why processes matter in practice, not just in theory.

Our students are more used to competing against each other than working together. In a lab, no one wants to look stupid when faced with unfamiliar equipment and procedures, but put them in a kitchen and their inhibitions disappear amid the fun – and mistakes don't matter. If a yolk turns out as tough as a bullet, you just chuck it away and try again. We teach them to cook as a team and, as chemists, they become pretty good at it.

Students wear aprons rather than lab coats, the funnels and scales are slightly cheaper, and there are stainless steel work surfaces in the bespoke space we have created. But the skills and discipline are the same. Three intensive days in the 'kitchen' stretches their accuracy – half a degree of temperature difference or a matter of seconds can be make or break for that yolk. By documenting their work with photos, video and data, they learn to take lab notes – and then they learn reproducibility, how to measure, observe, record, calculate yields and use apparatus, as well as a little basic chemistry.

Students flourish on their final assignment, which is a plated, nouvelle cuisine-style display. There'll be weird colours and flavours, 'glitterball' suspended sugar crystals created by spherification, or 'lighter than air' foam garnishes. Creativity shines through – no two plates are the same – and nothing is 'wrong'. All observations in any lab are valid. After all, it was only by noticing a mould had checked the growth of Staphylococci in his petri dish that Dr Alexander Fleming discovered penicillin.

But, of course, there's one big difference – students can pretty much consume anything they prepare in the kitchen, from tofu cheese to xanthan gum garnishes.

This will be the third year we have offered the Chemical Kitchen as a core course for first-year undergraduates, and so now we have results for our own experiment. Participating chemists say they feel far better prepared to embark upon 'proper' lab work. In the pipeline are further kitchen courses tailored to meet the hands-on skills required of engineering and medical students.

> **Students flourish – there'll be weird colours and flavours but creativity shines through and nothing is 'wrong'**

We very much hope that the focus on practical doing will help students set aside an emphasis on classical science and think about more practical delivery. And, hopefully, have some fun along the way. ◆

Let there be music, and art, and...

Imperial's Blyth Centre for Music and Visual Arts provides a vital creative outlet for staff and students, says its Director, Oliver Gooch.

Words: **Clare Thorp**

I always revel in the idea that people seem surprised Imperial has this artistic expertise

Oliver Gooch

A neglected piano, covered with picture frames and gathering dust in his parents' front room, was what did it for Oliver Gooch. "I was seven or eight," he says. "I opened the piano lid, discovered the keys and found a world that I loved."

Which is how he hopes students and staff feel about visiting the Blyth Centre, Imperial's dedicated space for music and the arts. Home to ten practice rooms, an art studio and a gallery, it is open to all staff and students to learn, practise or simply enjoy one of the free lunchtime concerts.

And this year, it will celebrate its 20th anniversary. The Blyth is the result of a legacy gift from Neville Blyth, a former Imperial lecturer and senior tutor at the Royal School of Mines. Two decades on, and on any given day, you might hear one of the College's orchestras practising, a chamber choir in full song, a jazz band rehearsing, an art workshop or, if you're lucky, The Techtonics, the university's multi-award-winning a cappella group (and just one of many a cappella groups that practise there).

Not that you have to be world-class to enjoy the facilities. "We don't examine, and there is no pressure on anyone to fulfil anything aside from what they want to achieve – that might be half an hour unwinding: playing the piano or creating a doodle," says Gooch. "There is no expectation, and you can just be yourself. It makes a space to explore your creativity and a holistic safe haven away from the rigours of university life."

"It really is an extraordinary place," adds Gooch, who became Director of the Blyth in 2018. "I always revel in the idea that people seem surprised that Imperial, a world-leading STEM university, has this artistic expertise. They're astounded by the depth and breadth of talent that we have."

Gooch, who conducts the Imperial College Symphony Orchestra, says he has had to rethink how he talks about music when confronted with 80 of the brightest science, maths and business minds. "I can't be too wishy-washy. I admire their precision and search for perfection but, in turn, this can also lead to being afraid of making mistakes. I like to impress on them that a mistake might lead to something else far more interesting."

That relationship between science and the arts lies at the heart of the programme of events planned to celebrate Blyth's anniversary. The celebrations, which run from until next year, include a 14-hour music and art 'intervention' in the main entrance of Imperial, a lecture-recital with mathematician Marcus du Sautoy and pianist Charles Owen, and live performances, Jazz on the Mezz, at the Hammersmith Campus.

Gooch has found compiling the celebrations a joy. "I love bringing projects and people together to create something interesting," he says. "As a conductor, you're enabling things to happen musically, but this job is much broader and richer. It's enabling many more things to happen that can enrich lives in a potent way. I feel lucky to be part of an institution that values the place of culture in our lives." ◆

PRIVATE VIEW PHOTO: JOSEPH O'CONNELL-DANES. OTHER PHOTOS: MINDY LEE, HEAD OF ART IN THE BLYTH CENTRE

Far left: Oliver Gooch conducts a Cadogan Hall concert in March 2020. **This page:** Some of the wide range of creative activities available at the Blyth Centre for Music and Visual Arts.

RIGHT HERE, RIGHT NOW

POST-COP26, IT'S CLEAR THE TIME IS NOW. WE SPEAK TO THE PEOPLE PROVIDING REAL-WORLD SOLUTIONS TO CLIMATE CHANGE.

Words: **Kat Brown** / Photography: **Dan Burn-Forti**

At Imperial, everyone working on climate change has one not-so-humble aim in mind: to stave off global disaster. So says Alyssa Gilbert, Director of Policy and Translation at Imperial's Grantham Institute – Climate Change and the Environment. The College is a hive of research and innovation. "But we're greater than the sum of our parts," says Gilbert. "Our overall objective is to find uses for that raw knowledge to bring about a net-zero, climate resilient world."

The Grantham Institute's five focus areas are: new research; cross-curricular teaching (including an oversubscribed MSc in Climate Change, Management and Finance); innovation (including an accelerator programme, now part of the new Centre for Climate Change Innovation, nurturing more than 130 green businesses in ten years); informing climate change discussions; and bridging the gap between Imperial researchers and decision-makers. "How does public awareness, innovation, funding and policy come together to change the world?" Gilbert asks. "That's where our work at the Grantham Institute – building relationships, networks and dialogue – can make a difference."

And so, as the world prepared for the 26th UN Climate Change Conference, we asked some of the Grantham Institute's key researchers to share their latest work and thinking.

DR GBEMI OLULEYE

Assistant Professor, Centre for Environmental Policy

My vision is to make decarbonisation of hard-to-abate sectors like industry cost-effective for government, industry and society. Imagine a pen – if the entire process of manufacturing that pen is decarbonised, releasing no greenhouse gas emissions, my research will ensure that the increase in the pen's price would be from 99p to £1, and not £5. ▶

#1 CLIMATE SOLUTION

Exploring innovations in systems, policies and business models to achieve cost-effective decarbonisation

Dr Gbemi Olueye

I lead research activities looking at developing pathways to support integration and increased adoption of concepts such as energy and material efficiency, fuel and technology switching, and carbon capture and storage in industrial systems. These pathways combine technologies and interventions via policies and business models to show how costs reduction can be achieved until a technology is market driven, with the timelines required.

To accelerate the transition to net zero, industry, systems, policy and business model innovation (i.e. the innovation trilemma) is important. Systems innovation is defined as marrying multiple industrial decarbonisation concepts hierarchically. A hierarchical ordering of concepts for any site beginning with material and energy efficiency can reduce the associated costs by at least 20 per cent. The innovation trilemma is important to accelerate adoption of these industrial decarbonisation concepts, and at the same time, maintaining industrial competitiveness.

DR DREW PEARCE *(MSc Physics 2014, PhD 2019),*
Research Associate, Department of Physics

My background is in computational physics, using computer simulations to predict and understand how materials behave. More recently, I've turned to look at how data and computer modelling can more directly address climate change.

There's often a disconnect between blue sky research and direct application-focused research, but because of the drastic and difficult situation we face with climate change there is a need to bring these two together – although the timeframe is the biggest challenge. Take an intervention like decarbonising the transport sector: you have to marry novel engineering systems with an on-the-ground understanding of how people will use them. That's where data and modelling can add huge value; even with technological advancements, large amounts of mitigation will still need to come from behaviour change.

We know every car on the road needs to be electric, but we also need far fewer cars, and the intersection between research and policy is key to this challenge. When researching my latest report, I was surprised how difficult it was to find granular data linking human behaviours and motivations at the systemic level of how many emissions they incur. From a policy perspective, you need to look from the top down and identify the behaviours that are causing those emissions in order to meaningfully address them and meet net zero.

DR MIRABELLE MUÛLS
Assistant Professor in Economics,
Imperial College Business School

I'm working with a team of researchers to understand how economic decisions are made that lead us to a zero-carbon society, with a particular expertise in carbon markets. Our recent research found that firms that work with strategic energy consumption targets are more likely to respond positively to carbon pricing. The EU carbon market has so far not affected employment or profitability, so it's a positive outlook that we hope can encourage other countries to think innovatively.

We're also interested in understanding how willing people are to shift the time of day that they use electricity or gas, as there are times when the carbon content is different. We've implemented a framework called POWBAL, where we look at what type of incentives make people flexible and ready to consume electricity at another part of the day. That involves giving people in our trials smart plugs that might turn off at certain times, and rewarding them for their flexibility. In a future energy system, they would contribute to a more low-carbon energy system. ▶

#2 CLIMATE SOLUTION:

Using data and modelling to design successful interventions to maximise potential of carbon abatement

Dr Drew Pearce

#3 CLIMATE SOLUTION:

Using research to develop key economic factors that drive behaviour, to lead to a zero-carbon society

Dr Mirabelle Muûls

#4 CLIMATE SOLUTION:

Translating complex scientific insights about our planet into simple concepts to drive better policy decisions

Dr Joeri Rogelj

Nurture tomorrow's great minds by leaving a gift in your will.

When she was an undergraduate in Lagos, Nigeria, Dr Jean Alero Thomas won a scholarship to continue her studies in England. She went on to hold a clinical research post in immunopathology at Imperial's Cancer Research Fund Laboratory and became Senior Clinical Lecturer at St Mary's Hospital.

Dr Alero Thomas sadly died in 2015 but left a gift in her will to establish the Dr Jean Alero Thomas Scholarships. Her legacy lives on with these scholarships supporting postgraduates studying cell and molecular biology within the Faculty of Medicine at Imperial.

Imperial student, Charlotte, was awarded the Dr Jean Alero Thomas Scholarship for her MSc in Genes, Drugs and Stem Cells – Novel Therapies after completing her undergraduate course at the College.

"Receiving this scholarship was a huge surprise and honour for me. In all honesty, given the governmental system for postgraduate financial support, I would not have been able to afford to pay for the tuition fees and living costs (especially in London!) required to complete my MSc at Imperial College London. Being able to continue my studies at my chosen university without having to worry about this challenge is such a relief. The honour has motivated me to put everything I have into this MSc and take every opportunity I am given this year to improve myself both professionally and personally. It really makes a difference knowing that somebody (or some people) out there believe in your ability and see potential in you."

> This scholarship was a huge honour for me. **It really makes a difference knowing that somebody out there believes in your ability.**

Charlotte, MSc in Genes, Drugs and Stem Cells – Novel Therapies
Recipient of the Dr Jean Alero Thomas Scholarship

The importance of gifts in wills at Imperial

By leaving a gift in your will to Imperial, however small or large, you can help to nurture tomorrow's great minds. You can help future generations of the brightest students come to Imperial and thrive, and support some of the world's best researchers to tackle our biggest global challenges.

The power of your legacy gift

Gifts in wills provide a solid foundation that allows our researchers, staff and students to adapt to whatever the world throws at them. No young person with the talent and aspiration to study at Imperial should be deterred by financial worries.

Your legacy gift could enable future great minds at Imperial to better understand and tackle our changing global challenges, creating a brighter tomorrow for us all. You can support researchers of tomorrow to work across disciplines, and further our understanding in critical areas in engineering, medicine, natural sciences and business.

If you would like to discuss how you can leave a gift to Imperial in your will, please call Anna Wall, Head of Regular Giving and Legacy Giving on **+44 (0)20 7594 3801** or email **a.wall@imperial.ac.uk**.

The question is, are people more willing to participate in this experiment if they are made aware that they are contributing to the public good, or because of economic incentives? And what is the degree of tolerance to having appliances switched off? Am I more likely to keep participating if the switch-off is less frequent but longer? It seems a precise exercise but it is crucial. Technology alone is not sufficient – it needs to be adopted, and behavioural change incentivised.

DR JOERI ROGELJ
Director of Research and Reader in Climate Science and Policy, Grantham Institute and Centre for Environmental Policy

My research explores how societies can transform towards more sustainable futures by connecting Earth system sciences to the study of societal change and policy.

For example, if we want to limit global warming to any level, what do we need to do? That might seem a difficult question but, ultimately, the many different factors boil down to a couple of simple messages. Every tonne of carbon dioxide adds to global warming, and if we bring emissions down to net zero, we won't see further warming. That means that we have a total carbon budget within which we have to keep our carbon dioxide emissions.

Even once these broad physical principles are understood, research continues – to understand exactly how much we can still emit to keep warming to specific levels such as those included in the 2015 Paris Agreement on climate change, or how to distribute this global budget fairly among individual countries.

A last important step is to translate these carbon budgets in pathways that describe how our society could transform while keeping global warming in check. Here, I have always been interested in describing how we can reduce emissions as deeply as possible.

Climate risks are already accumulating today, and we are not prepared. Even with drastic emissions cuts in the next decade, the projected climate impacts are dire, and so we need to get on with it, and start preparing to clean up afterwards through sustainable removal of carbon dioxide from the atmosphere.

DR ANA MIJIC *(PhD Earth Science and Engineering 2013)*, Reader in Water Systems Integration and Director of the Centre for Systems Engineering and Innovation

My research is in water management: how we can develop land, manage flooding and – the biggest challenge – improve water quality. We develop simulation models that capture historical behaviour, but we can also simulate future scenarios which helps us decide the way forward, and how that information can be used by water utilities, governments and citizens. We use water quality in rivers as the key information to understand key land use pressures and where we need to intervene.

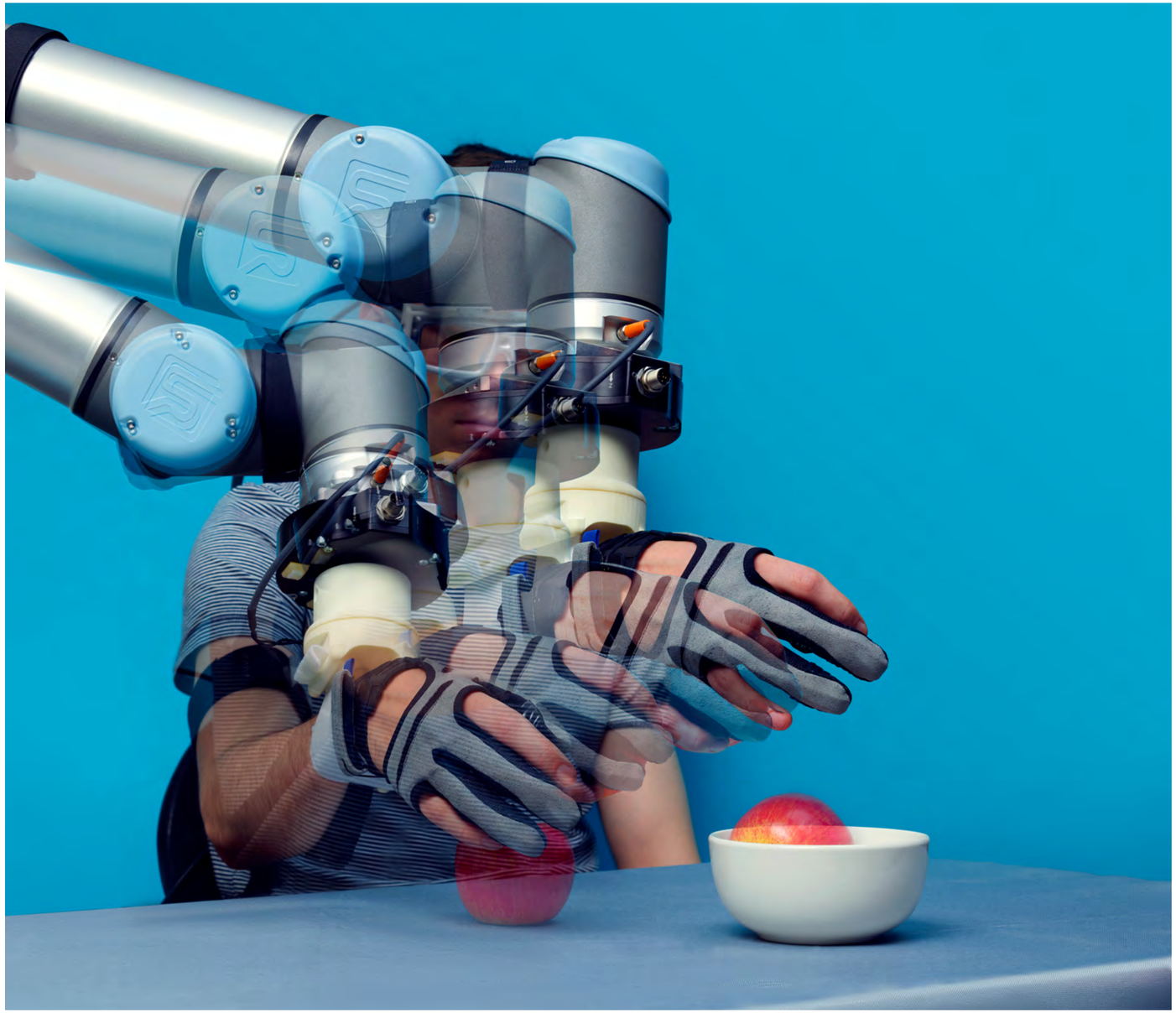
The major work we're doing right now is linked with the CAMELLIA (Community Water Management for a Liveable London) project, looking at integrated water management with different components and technologies, such as rainwater harvesting. We can model the whole water cycle of London and incorporate the role of green spaces and sustainable systems and other natural ways of protecting the environment.

Climate change is one factor in understanding the future, but there are also issues of policy, decisions, behaviour and infrastructure. An interesting element of how water engineering links to climate change is in how we have learnt to deal with systems – wastewater, supply, climate processes, infrastructure – as separate things. The problems we are currently experiencing are really problems of how all these interact, and it inspired us to think of the whole, integrated model. ◆

#5 CLIMATE SOLUTION:
Integrated water management and collaborative decisions using simulation models
Dr Ana Mijic

> *If you'd like to hear more from Imperial academics explaining why their research matters when it comes to tackling global issues like climate change, check out our 'Imperial voices on climate and environment' playlist at bit.ly/Imperial-51-voices*

HAIR & MAKE-UP: NADIRA V PERSAUD



Above:
Soft robotic glove interface developed in a joint project between Professor Aldo Faisal's Brain and Behaviour Lab and the Swedish company Bioservo, as part of the lab's intelligent assistive robotic system eNHANCE.

SOFT ROBOTICS

FORGET R2D2. FORGET MOUNTED ROBOTIC ARMS. FORGET LARGE HYDRAULIC MOTORS AND RIGID SEGMENTED JOINTS – AND SAY HELLO TO THE FLEX, BEND AND WIGGLE.

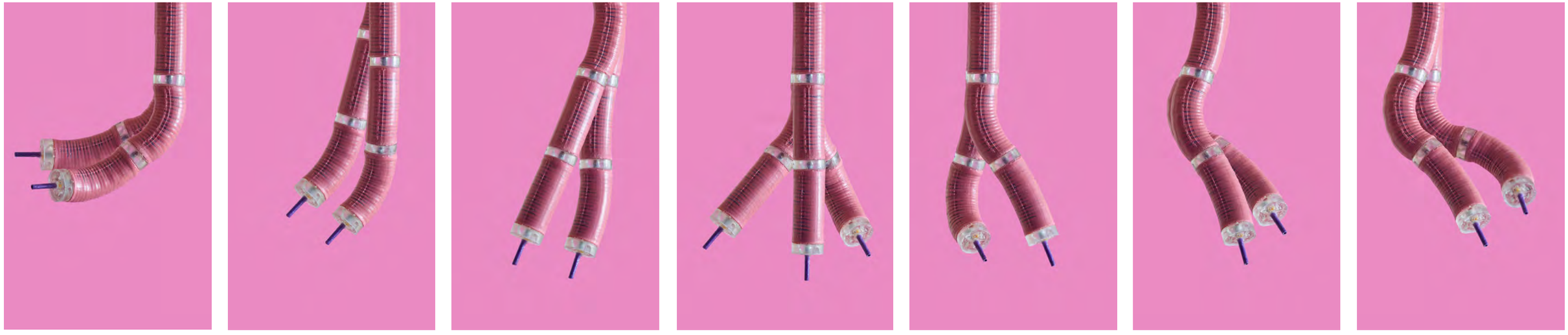
Words: **Lucy Jolin** / Photography: **Wilson Hennessy**

There might have been just the slightest squeeze, but it was enough to reduce everyone in Dr Aldo Faisal's lab to tears. Testing out a robotic arm and bespoke glove that enabled a paralysed patient to decode eye movements should not have been so emotional. "Why are you crying?" asked the patient, paralysed from a serious spinal cord injury. "It's the first time in 20 years that you've squeezed my hand," his wife replied. "It made me realise the power of human touch," says Faisal, Professor of AI and Neuroscience at the Department of Computing and the Department of Bioengineering. "Such a small thing. But so important."

Welcome to the world of soft robotics, where movement is all about the flex, wriggle, bend, deformation and transformation made in response to environment. ("Humans are soft robots," says Faisal. "My hand is a soft robot.") Why do we need them? Traditional 'hard' robots are, after all, great at many things: building cars, stirring radioactive waste, neutralising explosives and so on. But they're not so great at accurately replicating human actions, such as performing surgery. ▶

Dr Aldo Faisal
Professor of AI and Neuroscience at the Department of Computing and the Department of Bioengineering.

Dr Ali Shafti
Research Associate in the Brain and Behaviour Lab at the Department of Bioengineering.



Above:
Soft continuum manipulator prototype for minimally invasive surgery by Dr Enrico Franco and his team.

"Conventional robots have important drawbacks because of their stiffness and rigidity, meaning that they could pose a risk to a patient in close interaction," says Dr Enrico Franco, Research Associate at the Department of Mechanical Engineering. Likewise, they aren't capable of what Faisal's patient's wife found so moving – the subtlety of spontaneous human touch. And they don't like transitions or interactions, points out Mirko Kovac, Professor in Aerial Robotics at the Department of Aeronautics, which houses the Brahmal Vasudevan Aerial Robotics Lab. Today's drones are quite happy in the air above the sea, but they're in trouble when they plunge into the ocean. And while they can take pictures of, say, a problematic component on an oil rig, they can't mend it.

In contrast, soft robotics take inspiration from the ordinary biological structures and processes of everyday life: an outstretched hand, or a seabird diving into the water. Or, indeed, a dead fish 'swimming' upstream. This, it turns out, is a perfect demonstration of soft robotic principles: a system where the compliance of the structure is similar to that of the environment. "In the right conditions of turbulence and forces in a river, the fish's softness is tuned to harness that energy so it can drive itself forward," says Dr Thrishantha Nanayakkara, Professor in Robotics at the Dyson School of Design Engineering. "Likewise, there are kinds of seaweed which can hold certain structures to survive different frequencies and forces of currents. Despite all the turbulence, they bend, twist and survive. Cephalopods don't have skeletons, but they can make their body behave like a skeletal body and create solid 'limbs' to pull prey to their mouth."

As Nanayakkara points out, after four decades of robotics, we're still waiting for the rigid robot you'd trust to hold a live hamster. And that's because our whole approach has been back to front, he says. "We frame it thus: the hamster is the problem; therefore, the robot is the solution. But that problem definition itself is wrong. We have separated the environment and the embodiment of the robot. Now think of the hamster and the robot as one single system. If there is no separation between the hamster, then the hamster is part of the solution. Soft robotics can make use of the shape of the object or the movement of the object to solve the problem. For example, if I am holding a hamster in my hand, I relax my fingers. Then the hamster relaxes, too. It is the right embodiment to match the hamster's softness."

Soft robotics take inspiration from everyday life: an outstretched hand; a seabird – or a dead fish

Soft robotics requires a completely new way of thinking about problems: circular rather than linear. Faisal calls it a virtuous cycle of understanding. "On one side, we use the language of engineering to study how the brain controls and generates behaviour. On the other side, we're using that biological understanding to improve technology – for example, to restore movement to people who are paralysed or have lost limbs. This way gives them agency. They are not just teleoperating something. They are using their own body."

The traditional development path is: sketch a concept; develop a controller; simulate with that controller; choose the components; and test in the field. But nature doesn't work like that, says Kovac. "It grows. And as it grows, it evolves capabilities. The controller, materials, actuators and sensors evolve. It adapts computationally and physically. This physical artificial intelligence approach is about combining sensing, actuation materials, controllers, aerodynamics and autonomy into one coherent system. It is a co-evolution of control, materials, structures, design and learning – a new methodology which is circular rather than linear." ▶

Dr Enrico Franco
Research Associate at the Department of Mechanical Engineering.

Dr Mirko Kovac
Professor in Aerial Robotics at the Department of Aeronautics.

Dr Huai-Ti Lin
Lecturer at the Department of Bioengineering.

Using something that works with its environment, rather than attempting to transform it, is key

In Kovac's lab – which aims to develop a new generation of biologically inspired flying robots – his circular approach might start with structure. A model of a seabird wing with a control system for folding and spreading, for example, is put in a wind tunnel and studied to see how it behaves, and why it behaves like that. "And this is an integration of control, environmental interactions, materials properties and structural behaviour. None of this can be decoupled."

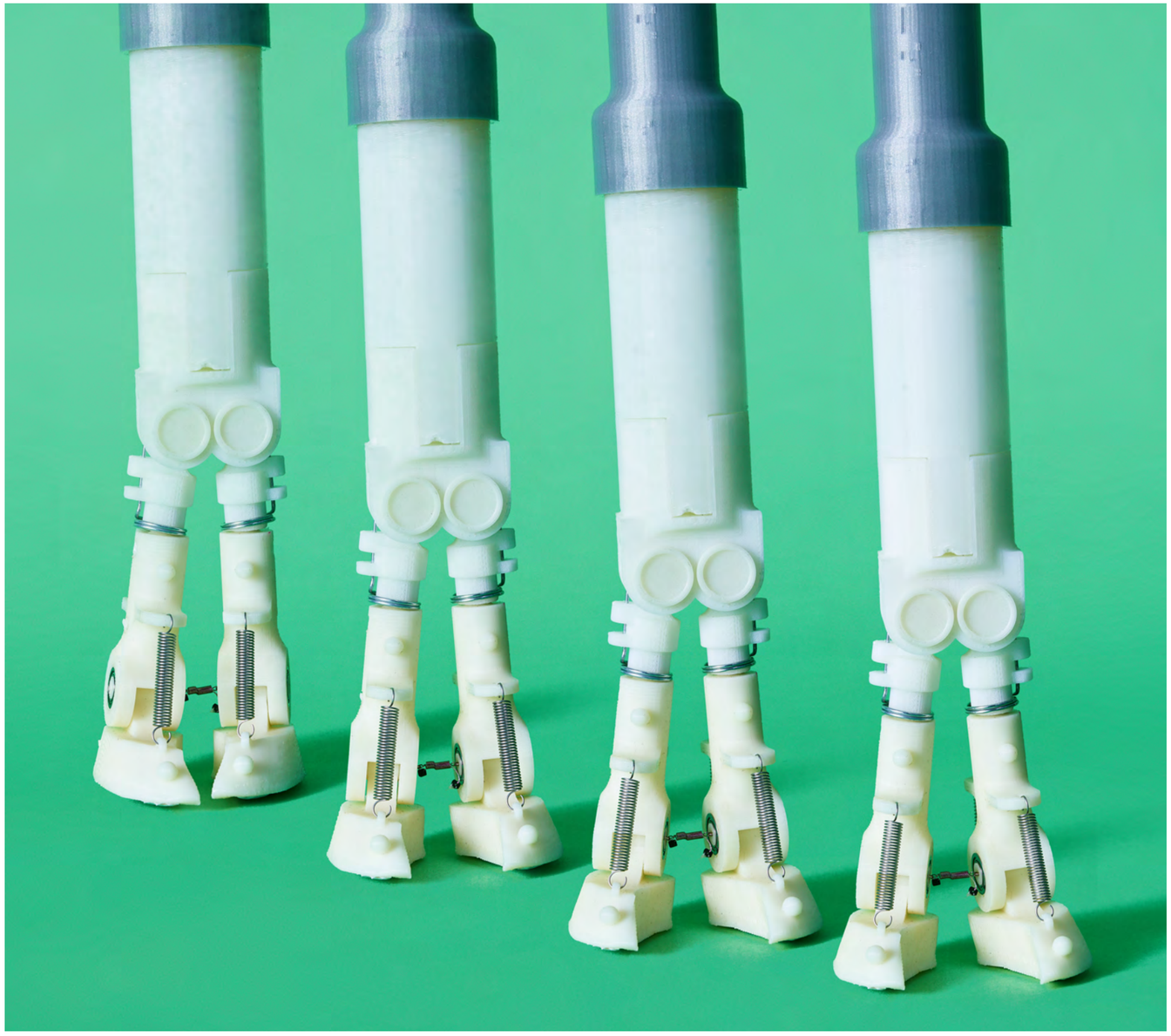
Dr Huai-Ti Lin, lecturer in the Department of Bioengineering, is also developing soft robotic principles to improve flight: in this case, studying the biomechanics and the sensory system of a dragonfly's highly deformable wings to investigate the idea of 'fly-by-feel'. Today's aircraft flight controllers are designed around steady states. When turbulence hits, pilots must use their personal experience to cope with this new, unsteady state. But flying animals, Lin points out, are very good at managing unsteady states by controlling their compliant wings. "And the secret for that is they use a collection of airflow and strain sensors on the wing itself. A dragonfly's wingblade alone contains nearly a thousand sensors. The wing can 'feel' any problems before the body. By learning the fly-by-feel approach from biology, we can enhance the flight control of future flying systems."

Using something that works with its environment – rather than attempting to transform the environment to suit the object – is key to using soft robotics in healthcare, says Franco, who works on soft robotics for minimally invasive surgery. He has a very personal connection to his work: his grandparents both died of colorectal cancer. Colonoscopies, used to diagnose this type of cancer, have a sub-optimal uptake, he points out. "This is because existing colonoscopies can dislodge the bands of the intestines, creating discomfort and pain."

His vision: a soft robot made of silicon rubber, inflated with pressurised fluid, controlled with a joystick, but semi-autonomous. The surgeon will direct the robot where to go, but the robot will find, by itself, the easiest way of getting there. An energy-based control approach will harness the friction between the surface of the robot and the internal organs, allowing movement to be either forward or backwards. Unlike the rigid colonoscopies, this approach works with the structure of the body. And again, unlike conventional robotics, it is cheaper to produce and could be operated in a surgery or local hospital, making it ideal for use in developing countries.

And soft robotics can also help to train doctors: Nanayakkara's lab is currently running trials of RoboPatient, the universal patient. "Medical students have no control over the patients they are assigned to practise on," he explains. "And the patients they meet might not be representative of how conditions and pain present differently in people of different genders and ethnicities. But RoboPatient allows conditions and pain to be replicated. It has a face, too, which shows pain. That means a student can experience a patient with a multitude of different conditions and pain responses, distilling years of experience into a few hours."

The expression on a face, the flap of a wing, the wriggle of a hamster: who knows where a true understanding of the processes behind these could take us? Small things, indeed. But vital. ◆



Dr Thrishantha Nanayakkara
Professor in Robotics at the Dyson School of Design Engineering.

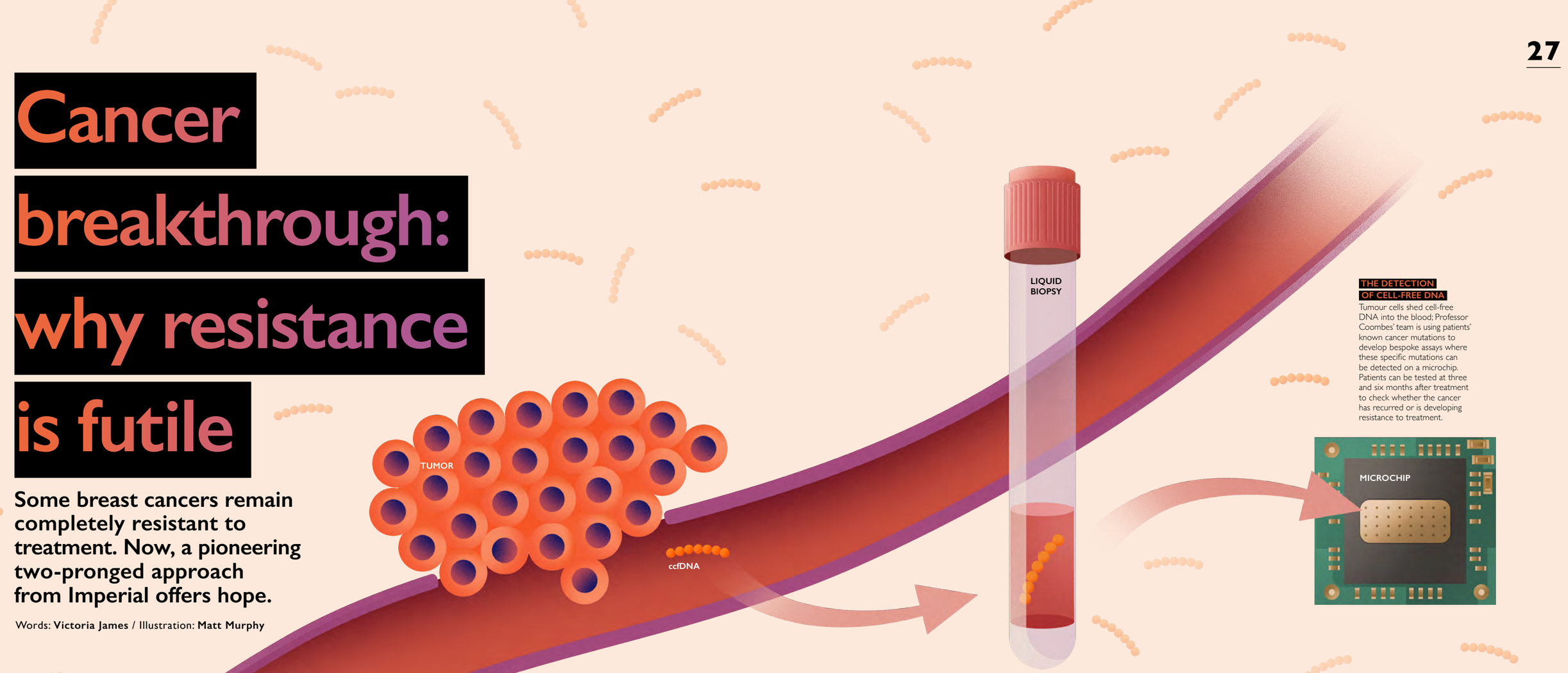
Sara Adela Abad Guamán
Designed the goat hoof (left) as part of a PhD in Design Engineering at the Dyson School of Design Engineering in 2019.

Above:
Robotic goat hoof designed by Sara Adela Abad Gaumán as part of research focused on how to simplify the locomotion system of robots for uneven terrain conditions.

Cancer breakthrough: why resistance is futile

Some breast cancers remain completely resistant to treatment. Now, a pioneering two-pronged approach from Imperial offers hope.

Words: **Victoria James** / Illustration: **Matt Murphy**



THE DETECTION OF CELL-FREE DNA
Tumour cells shed cell-free DNA into the blood; Professor Coombes' team is using patients' known cancer mutations to develop bespoke assays where these specific mutations can be detected on a microchip. Patients can be tested at three and six months after treatment to check whether the cancer has recurred or is developing resistance to treatment.

Professor Charles Coombes has been running breast cancer clinics for 40 years. But he is still always moved by the effect of the disease on his patients. "You witness their anxiety as they come to see you, how they're hoping for their test results to be negative. Everything we're doing is about reducing that anxiety; we want to save many more lives."

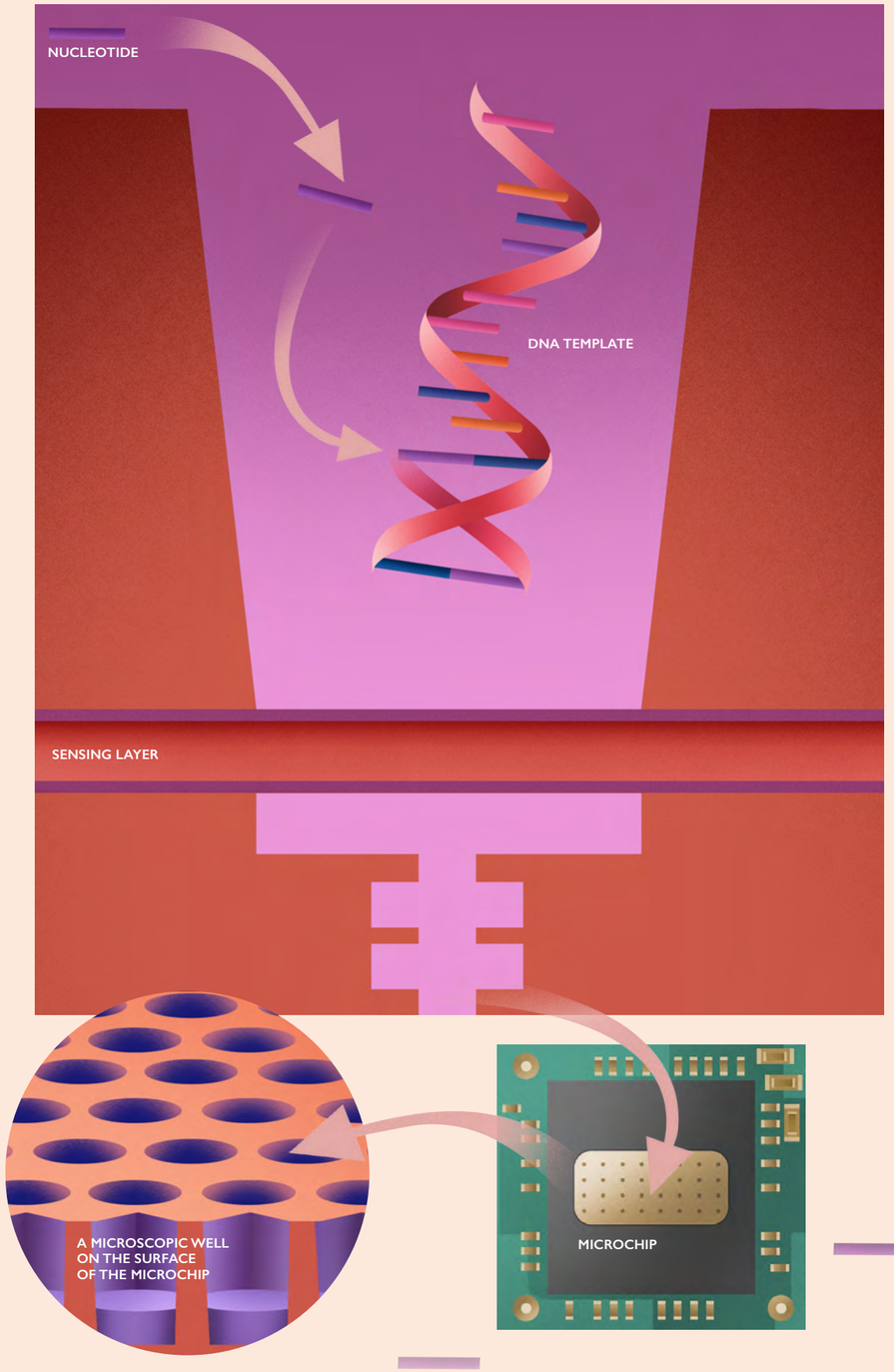
One in seven women will develop breast cancer in their lifetime, and at a least a quarter of those will face a further frightening challenge – their cancer will become resistant to drug treatment. But now a group of Imperial scientists headed by Coombes, Professor of Medical Oncology, and their collaborators at the University of Leicester, are pioneering novel approaches that promise new hope for patients with drug-resistant breast cancer. They are harnessing gene-sequencing technology to usher in a future of wholly individualised treatment.

Treatment for breast cancer used to be – and still can be – gruelling. "In the old days, we used to give chemo, and women would experience sickness, hair loss and bone-marrow failure," says Coombes. Today, a vast array of targeted drug therapies is available to tackle variant forms of the disease, made possible by both the scale and the ever-evolving tools of cancer research.

Nonetheless, for that unlucky quarter of breast cancer patients, their disease will develop resistance to the prescribed therapy. "There are multiple mechanisms of resistance," says Coombes. "One common cause is mutation of receptors. These receptors bind oestrogen, inducing gene expression in breast cancer cells that cause them to proliferate." Most current treatments work by lowering or blocking oestrogen, so one mechanism of resistance to treatment is when a mutation arises that causes the receptor to be active even in the absence of oestrogen.

The best outcome from treatment is that the cancerous lump is successfully removed, and endocrine therapy kills any cancer cells left in the body. "But there is still a proportion of cases where disease evades treatment," says Coombes. "Over time, more aberrations occur in cancer cells and it becomes more difficult to control them. That's why metastatic disease, where you see the cancer widespread elsewhere in the body, is incurable. The cancer has developed so many aberrations you just can't control them all."

With funding help from Cancer Research UK and Innovate UK, the approach of Coombes and his collaborators has been twofold. First, detecting micrometastatic disease 'on the move' – that is, catching spreading cancer early. "We had ▶



CHIP-BASED SEQUENCING

Professors Coombes and Toumazou are collaborating to develop a new chip-based sequencing test designed to detect potential mutations that may be present. This approach enables new mutations to also be detected as the disease progresses and, if necessary, different treatment decisions can be made. Chip-based sequencing uses the patient's cell-free DNA to first create a template which is then bound to a microscopic well on the surface of the microchip. A complementary strand of DNA is generated against the template by adding different nucleotides, one by one. The incorporation of each nucleotide in the complementary DNA generates an electrical signal that is detected by the chip, indicating which nucleotide is next in the sequence, and thus the full DNA sequence of the template is revealed.

Professor Charles Coombes Professor of Medical Oncology.

Professor Christofer Toumazou Regius Professor of Engineering.

Early detection means early intervention – vital with a disease whose progression can feel like a race against the clock

to develop a test that could tell us whether cells are beginning to divide and activate. It's taken many years, but we've done that now. If you take a blood test at regular intervals following surgery and after accessing treatment, you can detect cell-free DNA – that's fragments of DNA just floating around the blood, which has been excreted when cells die."

Coombes and his team "interrogate the blood", looking for mutated cancer DNA variants. Working with colleagues in the US, his team and the Leicester group devised a test that uses detectors individualised for each patient. "You monitor at three months and six months, and in the case of relapse you can see a change in the amount of variant in the blood. We can now detect women becoming resistant to endocrine therapy early and predict when they're going to relapse. We obviously then want to introduce alternative treatments to prevent that from happening."

Those tests, of course, can be the source of more anxiety for patients, like those Coombes still sees regularly. Which is where Professor Christofer Toumazou, who is Regius Professor of Engineering at Imperial, and his postdoc Melina Kalofonou (MSc Bioengineering 2009, PhD 2013) come in. "Charles is the most forward-looking oncologist I've had the pleasure to meet," says Toumazou, who is also founder of innovative medical device spinout companies DNA Electronics, or DNAe, and DnaNudge Ltd. "The field we're involved with is miniaturisation," he says. "We're trying to get everything out of the lab and onto a chip."

Kalofonou, a research fellow and the Cancer Technology Lead for Imperial's Centre for Bio-inspired Technology, works with patients whose mutations are known, planting reagents for those mutations on a chip, so that when the patients are screened you can identify if that mutation is there. "The principle is exactly equivalent to what we're doing with PCR testing for COVID-19," says Toumazou, "where you know what the genes of the virus are and so can screen people to see if they've got it." Just as with the Delta and Lambda variants, breast-cancer screening may require detection of multiple known mutations, which requires multiple reagents. But it can all be done on that one chip. "The only 'lab' bit is taking a blood sample. You can do it in a GP surgery, with results within an hour while the patient is waiting."

Early detection means early intervention – which is vital when dealing with a disease whose progression can feel like a race against the clock. But Toumazou's second collaboration with Coombes promises to revolutionise that timeframe. That's because it gets ahead of the detection of known mutations either by significant multiplexing (DnaNudge) or to the discovery of as-yet unknown mutations (DNAe). "This technology is the sequencing of mutations. Cells mutate differently in different people," he says. "So, if you just use a testing panel, you will miss something new. But with sequencing you won't miss it; you're discovering those mutations in real time."

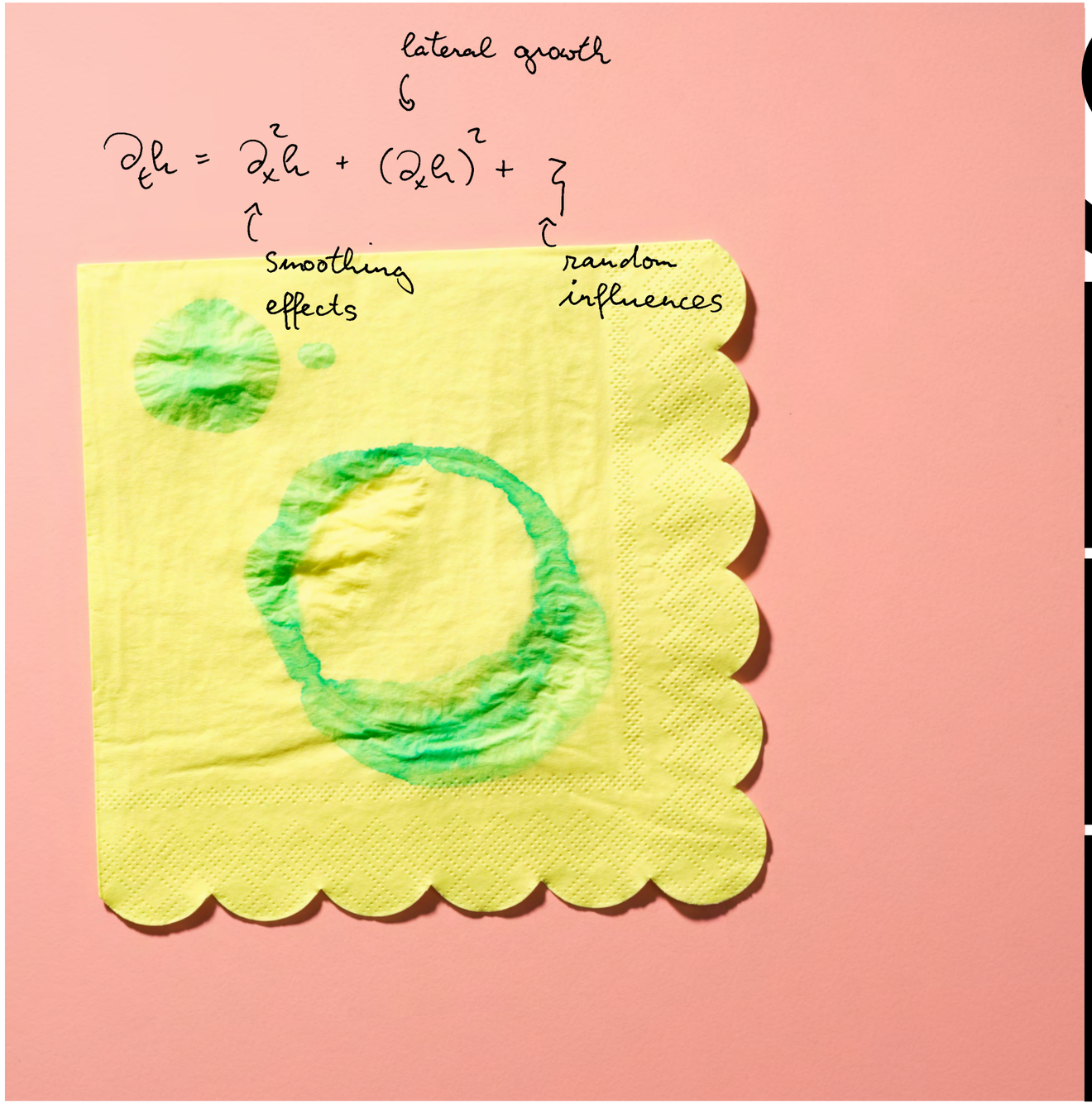
The pandemic has accelerated the timeframe within which the group's work should reach patients. "COVID-19 has opened the door for decentralisation of these technologies," says Toumazou. "Before, to even think we could run something like this in a GP surgery or through nurses – or even a venue such as health spa, for example – would have seemed fanciful. This discovery and detection was seen as the work of pathologists in laboratories, of centralised labs. But the pandemic has driven decentralisation."

Toumazou is optimistic about swift adoption. "Before COVID, I would have said it'd take eight to ten years to get this technology out there. But now? A couple of years, maybe less. Charles has the data – he has the key! The constraint now isn't the platform or the technology, because the technology is here. The constraint is the timeframe for clinical trials."

Those trials are now getting under way. The pharma companies that have drugs to target many of the cancer proliferation pathways – including AstraZeneca – are working with Coombes and his colleagues, including Professor Jacqui Shaw at the University of Leicester. But Coombes warns that the path ahead isn't straightforward. "If a woman's blood test reveals a resistance and you have a drug to target that, you'd think surely you're going to save that woman. But, sadly, that isn't always the case. These trials will be very complex, because there are so many different mechanisms that cancer uses to overcome drug treatments – at least a hundred that we know of."

Despite the challenges ahead, Coombes and Toumazou are confident that the moment has come for their work to break through. "The timing for Charles's work is being driven by the new wave of decentralisation due to COVID," says Toumazou. Indeed, Coombes notes that the recent innovations in genomic sequencing couldn't have changed the game for cancer treatment had they arrived any earlier, because of the scarcity of effective endocrine therapies. "But in the past ten years there has been an explosion of new drugs to target all the different resistance pathways. There are still a few with no decent drug attached, but mostly we're there.

"One without the other would have been pointless. But right now, it's a fortunate coming-together of these two strands of research." Those one in seven women – and the millions more people who love them – will be profoundly grateful for that good timing. ◆



Professor Sir Martin Fairer
Chair in Probability and Stochastic Analysis at the Department of Mathematics.

Right:
Karder-Parisi-Zhang (KPZ) equation, a non-linear stochastic partial differential equation that describes the temporal change of a height field with spatial and time coordinates.

SPDE

PROFESSOR MARTIN HAIRER DEALS IN THE INEFFABLE AND CALCULATES THE IMPROBABLE

Words: **Victoria James**
Photography: **Victoria Ling**
Styling: **Elena Horn**

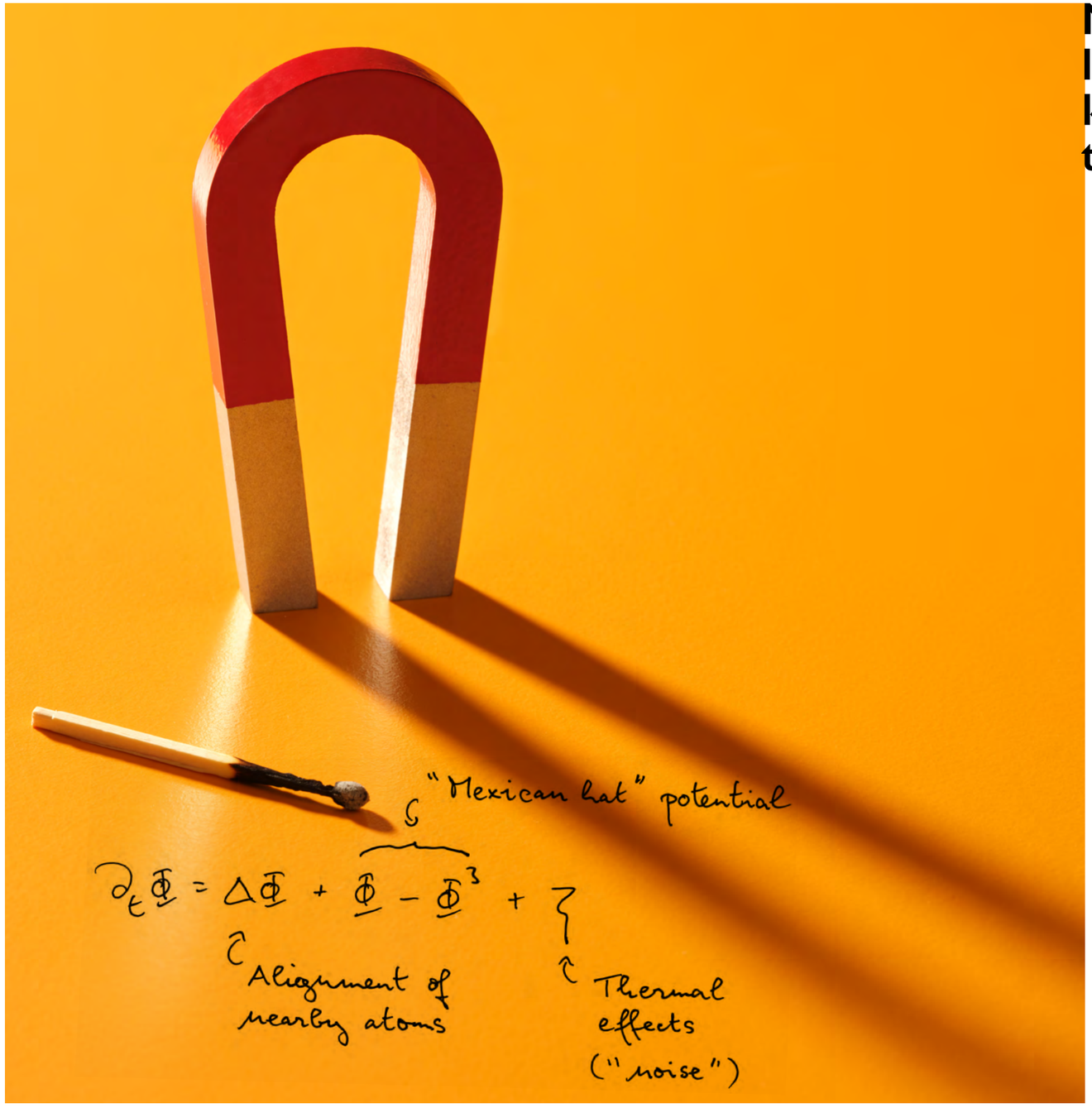
Legendary poet and musician Leonard Cohen sang, "There is a crack, a crack in everything / That's how the light gets in." According to Breakthrough Prize-winner Professor Sir Martin Hairer, Chair in Probability and Stochastic Analysis, the process is much the same for mathematicians. "For every solution, you need a starting point, somewhere into which to drive a wedge. You must find a crack, then try and break it. To find it, you think endlessly about a problem – while going for a walk, having a shower, even before falling asleep. Once you've located the crack, you have to convince yourself the argument could work. I visualise things. A blackboard is useful; I also scribble on bits of paper. The formulas get too big to hold in your head."

Indeed, the formulas for which Hairer has become famous are so big they fill 180 pages. That's the length of his modestly titled paper, 'A theory of regularity structures', first submitted for publication in March 2013. Full of elegant formulas and occasionally wry accompanying remarks ("this is really an abuse of terminology…" notes one; "there can be no scope for confusion…" admonishes another), the paper sent excitement rippling through the mathematical world and revolutionised the field of stochastic partial differential equations.

The paper was pivotal to Hairer's 2014 Fields Medal – the so-called Nobel of Mathematics and awarded every four years to researchers under the age of 40. One admiring colleague likened Hairer's work to *The Lord of the Rings* trilogy because it created a whole world. Another declared it so brilliant it must have been downloaded into his brain by a more intelligent alien race. *The Guardian* – reporting on his win last year of the $3m Breakthrough Prize – described his achievement as "taming a nightmarish family of equations that behave so badly they made no sense".

The equations in question are stochastic partial differential equations (SPDEs). But what exactly are they and why are they so complex? "'Stochastic' means that a thing is random," says Hairer. "So stochastic equations are those that involve a random term. A differential equation is a general type of equation that describes the evolution of a system over time – for example, if you throw a ball into the air and want to predict its trajectory. But if you throw the ball into the air and there are unpredictable gusts of wind, it might be reasonable to model those with a random term, so your differential equation becomes a stochastic differential equation.

"Partial differential equations describe systems that change with respect to more than one variable, for example not just time, but also position in space. So, if you have water in a pool, for every point in space there is a velocity of water in that location, a direction in which it moves. And if there were then random, unpredictable terms introduced into this scenario, the PDE would become a stochastic partial differential equation." ▶



Right: Stochastic Allen-Cahn equation, a reaction-diffusion equation of mathematical physics that describes the process of phase separation in multi-component alloy systems.

Mathematics is like a hydra. You kill one head and three more grow

Physicists and other applied scientists have long been familiar with natural phenomena that are governed by non-linear PDEs. (That is, ones which don't operate by simple proportions, such as those which rise exponentially.) But mathematically, these phenomena are staggeringly difficult to unpack because they involve nonlinear interactions between 'distributions' – for example, the distribution describing how the edge of a water droplet soaking through a napkin changes in time, and the distribution mapping how it changes in space. "Physicists are able to hold two models simultaneously in their head, one approximate and the other which knows that model is only approximate," says Hairer. "But as a mathematician, you want to understand what is actually going on."

As a researcher, Hairer "stumbled into this area" of SPDEs with a senior collaborator, Andrew Stuart, about 15 years ago. "We had a joint project in which we knew there was an equation we wanted to write down, but we didn't quite know what the equation was. If we closed our eyes, it popped out, then we could look at it and think, 'What does this actually mean?' That was sort of the starting point for my later work. For a while I had these ideas in the back of my head, but it wasn't really going anywhere. I couldn't find any cracks."

Progress came in 2009, when Hairer had insights into how ideas put forward by peers Terry Lyons and Massimiliano Gubinelli might be applied to SPDEs. "They worked well where space is one-dimensional, where the interface is just a line. I had to figure out how it could apply to two- and three-dimensional situations." Then in 2012 came a "very special" week-long workshop at the famed Oberwolfach Institute, set in the green hills of southern Germany, where Hairer presented his ideas to fellow experts. The initial crack had turned into a breach and, finally, a breakthrough.

"If you build some big, unusual structure, you use scaffolding to construct it. But eventually you take the scaffolding away and it stands on its own," Hairer says of the effect of unveiling his final workings on SPDEs after years of exploration. "If that's the first time another person sees the finished object, they might wonder how on Earth it got made, how it supports itself. It might seem a bit incredible. But the scaffolding is what makes it possible."

Hairer's work has been credited with opening the way to understanding the 'principle of universality', described by Hairer thus: "If you take different physical systems that somehow describe the same kind of situation, then at large scale they are described by the same laws." He cites the example of a liquid crystal that has two phases, one stable and one metastable. If a line is zapped along the crystal with a laser, the energy converts it from the metastable to the stable phase. "The border of that line starts out straight," says Hairer, "but it starts fluctuating as the stable phase invades the metastable. Some parts will convert faster, others slower.

"If you want to describe the law of these fluctuations, it shouldn't depend on the fact that this is a liquid crystal. You could set a piece of paper burning and look at the motion of the smouldering front of flame, and you should see the same law. Large-scale behaviour that doesn't depend on the detail of the underlying system – that's the principle of universality."

Time will tell whether Hairer's SPDE breakthrough provides a key to unlocking this principle. But it will certainly have applications beyond its initial formulation. "Maths problems are not always super-specific," says Hairer. "Take the tools that Andrew Wiles developed to prove Fermat's Last Theorem. They are original, powerful – and very useful for other things as well. Once you've developed the tools to do something specific, it is rare that that will be its only application. Whenever a new technique arises, it expands the list of possibilities that had previously been considered not doable.

"Mathematics is like a hydra," he says with a grin. "You kill one head and three more grow. You solve one problem and realise it might now be possible to tackle many others. Mathematicians never run out of questions." ◆

From cubs to virtual reality

THE HISTORY OF MEDICAL EDUCATION AT IMPERIAL SPANS MORE THAN 300 YEARS OF CHANGE AND DEVELOPMENT.

Words: **Sarah Woodward**

1823
Opening of Charing Cross Hospital Medical School at Chandos Place

1834
Set-up of what was to become the Westminster Hospital Medical School

1854
St Mary's Hospital Medical School is founded

1893
Imperial Institute opened by Queen Victoria

1884
Augustus Waller discovers the electrical reactions of the human heart (a discovery that led to the ECG)

1907
Signing of the charter forming Imperial College London. Above, the Dissecting Room

1913
Dr John Alcindor: the first pan-African physician, who has his surgery in Paddington

1924
Edith Summerskill: The first female student at Charing Cross Hospital Medical School

1935
The British Postgraduate Medical School opens as a school of the University of London at Hammersmith

1928
Scottish physician Alexander Fleming discovers penicillin

When Martin Lupton, Vice-Dean (Education) for the Faculty of Medicine, addresses first-year medics, he doesn't pull his punches. "The one constant that defines medical training through the ages is that it is long and arduous," he tells them. "But I would hope that the doctor of the past would recognise the modern doctor, even if they did not understand their treatments. So much of what is at the core of medical education is passed down through the generations."

"Before the eighteenth century, most medical care was carried out through monasteries and other religious institutions," explains Dr Jennifer Wallis, Medical Humanities Teaching Fellow at Imperial. "In many places there might also be an informal apprenticeship system, with prospective doctors training with either surgeons or apothecaries. These student doctors relied on local connections within the powerful guilds of surgeons to get their position."

Wallis points to the turn of the eighteenth century as a pivotal moment in medical education. "In the aftermath of the French Revolution, hospitals in France came under centralised control and the 'Paris School' of medicine evolved, emphasising the teaching of anatomy and introducing pathology. Dead bodies were made more central in medical education through routine autopsies. To qualify, medical students were required to identify disease from a study of the body." The origins of Westminster Hospital Medical School can be traced back to this time, when the students, known as 'cubs', were appointed three to a surgeon.

It was not until 1815 that the Apothecaries Act formalised medical training in the UK, with the study of anatomy and a minimum of six months on the wards needed to qualify, while the Medical Registration Act of 1858 followed this up with more stringent requirements of would-be doctors. And plenty were needed – the first half of the century saw the opening of the London hospitals upon which the Imperial College London School of Medicine is founded.

Celebrating its 25th anniversary in 2022, Imperial's medical school was formed as a result of a series of mergers of the leading London teaching hospitals. In 1984, Charing Cross Hospital Medical School amalgamated with the Westminster Hospital Medical School. Then, in 1997, Charing Cross and Westminster Medical School merged with St Mary's Hospital Medical School to create the Imperial College School of Medicine. A decade later, Imperial College Healthcare NHS Trust was formed by merging St Mary's NHS Trust and Hammersmith Hospitals NHS Trust and integrating with the Faculty of Medicine to create the UK's first Academic Health Science Centre (AHSC).

The teaching of medicine at Imperial draws on a long history of education in a clinical setting. Charing Cross Hospital, originally known as the West London Infirmary, was established in 1823, and 1834 saw the formal set up of Westminster Hospital Medical School. St Mary's Hospital, the youngest of the constituent schools that make up the School of Medicine today, was first proposed in 1841 by the surgeon and anatomist Samuel Lane. The foundation stone was laid by Prince Albert in 1845 and, as was Lane's original intention, the hospital was formally recognised as a school of medicine in 1854.

Until the late nineteenth century, medical education remained a largely male preserve, with the role of women largely confined to nursing and midwifery. Much has changed since, but Mary Morrell, Professor of Sleep and Respiratory Physiology and Director of Phase One (Years 1 to 3) MBBS Course, began her own training as a nurse at St Mary's Hospital in the 1980s, before the amalgamation with Imperial.

"It was a wonderful apprenticeship, but we are so much better at widening participation now. It has always been the ▶

central premise for a medical education at Imperial that students will both develop an understanding of evidence-based medicine as well as a sound base of science and research skills. We hope they will develop the research pathways and directives of the future, as well as become good doctors."

By the time Queen Victoria opened the Imperial Institute in 1893, fulfilling Prince Albert's dream of a centre of science in the centre of London, Wallis explains that although there were an increasing number of London teaching hospitals, they were still dealing with a varied system of hospital provision. "Specialist hospitals such as Moorfields also sprang up, and the Royal College of Physicians began to express concern that if the specialist cases did not reach the larger teaching hospitals, then students would receive a less grounded education. At every point, the concern was that students should receive enough bedside experience."

In 1913, the Royal Commission on Higher Education in London suggested an amalgamation of teaching hospitals. And in 1921, the Athlone Committee followed up by suggesting the creation of a postgraduate medical school. Then, in 1935, the British Postgraduate Medical School opened as a school of the University of London at Hammersmith Hospital (later, in 1997, joining Imperial).

This was a time of great advances in medical science, says Wallis. "Photography entered medicine almost as soon as film could be developed, and from the first X-ray in 1895 the available technology began to expand. Then, in the first half of the twentieth century, developments in anaesthetics and antibiotics promised to expand the range of interventions that could be attempted. Alongside these exciting developments, though, we could argue that there were worries that students would stop listening to the patient narrative in making their diagnosis and rely instead too much on their instruments."

These historical concerns have not gone away, Lupton stresses. "Today's technical advances are so widespread and fast-changing that the student curriculum could expand ad infinitum. Our great challenge, as the technical skills required multiply week to week, is to continue to teach what it is to be a doctor. The duty to put the care of your patient first, confidentiality, professional attitudes and behaviours – these date back to the School of Hippocrates. It is worth remembering that complaints about doctors are almost always about behaviour, rather than skillsets."

Professor Amir Sam (PhD Medicine 2011), Head of the School of Medicine, agrees. "We must not overlook the fact that people need doctors when they are potentially at their most vulnerable. We need to produce doctors with human abilities. But Imperial is a science-based university, and we are also nurturing the future clinical scientists."

Dr Niamh Martin (PhD Medicine 2003), Honorary Consultant in Diabetes and Endocrinology and Head of Year 1 of the School of Medicine's BSc in Medical Biosciences, sees greater accountability than in her day. "We now have staff-student liaison groups, with the students championing change. Our principle is 'you said, we did'."

During the pandemic, Lupton points out, students continued their clinical placements. "It is a very long course, but it is not just about knowledge. It is impossible to teach professional preparedness remotely." One of the recent changes is the introduction of a form of apprenticeship in Year 6, launched in March 2021. "This allows them to practice being a doctor under the watchful eye of a junior (and occasionally a senior doctor)."

In many ways it is a system that looks back to the original cubs of the nineteenth century. But as Professor Sam says, the doctors of tomorrow are being taught with new technology, using new methods, the impacts of which are still being studied. "Through the pandemic, the medical school was able to continue with face-to-face teaching through a lot of hard work and goodwill. The machines have not taken over, but once again medical education is at a critical turning point.

"Imperial is pioneering in the medical school by studying the utility of innovative teaching and assessment methods in the same way as we investigate new treatments in clinical medicine. Just because we have been surfing the wave of teaching or assessing students in one way for the past few decades does not necessarily mean it is the best way." ◆

MOST IMAGES SUPPLIED BY IMPERIAL COLLEGE ARCHIVES & IMPERIAL COLLEGE HEALTHCARE NHS TRUST: IMAGE 1997: ELLYW EVANS IMAGE 2007: DAVE GUTTRIDGE. IMAGE 2021: ALLIES & MORRISON

MEDICAL EDUCATION – THE FUTURE

Imperial's pioneering work in the field of medical education includes a series of innovative partnerships and collaborations.

For example, the Lee Kong Chian School of Medicine in Singapore is a joint Imperial-Nanyang Technical University medical school training the next generation of doctors, and the Leica and Imperial Imaging Hub, based at the White City and South Kensington Campuses, will provide advanced, biomedical imaging.

Development is also progressing well on the transformative new School of Public Health, a multidisciplinary building that will provide collaborative, flexible and interactive spaces for academics, collaborators, students and the local community.

> *If you'd like to find out more about the £100m campaign for the School of Public Health, visit www.imperial.ac.uk/giving/campaign-for-the-school-of-public-health*

1984
Merger of the Westminster Hospital Medical School with Charing Cross Hospital and Westminster Medical School

1988
Imperial merges with St Mary's Hospital Medical School

1995
Merger with the National Heart and Lung Institute at Royal Brompton

1997
Imperial School of Medicine formed

1998
New building by Foster and Partners for the Imperial School of Medicine

2001
Faculty structure introduced in May

2007
Imperial College Academic Health Science Centre created

2013
First students enrol at the Lee Kong Chian School of Medicine in Singapore

2021
Ground broken for new School of Public Health building at White City Campus

2022
Imperial School of Medicine celebrates its 25th anniversary

So much of medical education is passed down through the generations

DATASET / DR MARCO BRANCACCIO, DEPARTMENT OF BRAIN SCIENCES

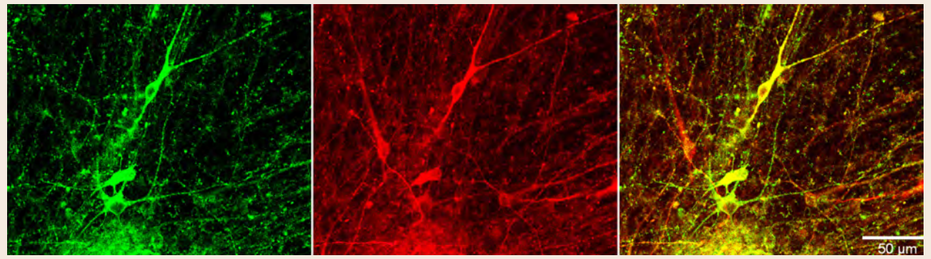
Breakthrough research links dementia risk to the body clock

Context One in 14 of over-65s in the UK has dementia. That's 850,000 people – and by 2040, according to the Alzheimer's Society, 1.5 million people of all ages will be living with this cruellest of diseases. Which is why Imperial researchers are investigating what makes someone genetically predisposed to dementia – and whether action might be taken from birth.

Background "Alzheimer's is a very difficult disease to track, as it develops over decades," says Dr Marco Brancaccio, Lecturer in Dementia Research at Imperial's Department of Brain Sciences. "But in recent years, we have discovered that many chronic pathologies are connected with disruption of circadian rhythms or, as it is also called, the body clock. We wanted to establish whether there's a link between a disrupted clock and neuro-degenerative diseases such as Alzheimer's."

Methodology Brancaccio and his team took biopsies from healthy patients and those with dementia, working on cells in a dish that exactly mirrored the body clock of the cells still in the patient. They then used innovative stem-cell and live-imaging techniques that enabled them to track, in real time, the circadian rhythms in the removed cells. "You can't take a brain out," says Brancaccio, "but this model gives you a very similar molecular and cellular perspective to the actual person." He is not aware of anyone else doing such circadian rhythm research on cells from Alzheimer's patients.

Findings "We went in with an open mind but were surprised and excited to discover the speed of the clock was different – slower – in those patients with dementia," says Brancaccio. "By isolating the cells from the patient, we reversed them back into an embryonic-like stem cell. That 'wipes them clean', as if the patient had just been born, with no memory of the disease. Because they have become brand new cells with no memory and no effects of ageing, if they then still display disruptive circadian rhythms, that might suggest there are genetic features connected to the body clock that make those cells more at risk of developing the disease.''



Above: Neurons in a dish derived from Alzheimer's patients, labelled with fluorescent tags to detect circadian variations of neuronal activity (red) and neurotransmitter release (green) respectively, in real time.

Outcomes The excitement is not just the possibility of detecting a link, says Brancaccio, it's the potential that it might be preventable. "We want to understand the genetic mechanism behind the disruption of the clock, because there are no obvious reasons why this should be the case. Once we do, the next challenge is to see if we can interfere with those genes and, much further down the line, design drugs that counteract these effects. This is a marker – in principle we could use this as a way to infer people's risk of developing the disease. It's still a little bit of chicken and egg – is the disruption of your clock, which you can identify at birth, indicating you're more at risk, or is the clock one of the very first mechanisms impacted by the initiation of Alzheimer's? We still need to answer that question. What we do know now is that if you have a weaker body clock, there is an exponentially greater risk of developing dementia, so there must be something there." ◆

> ***Professor Marco Brancaccio** is a Lecturer in Dementia Research and UK Dementia Research Institute Fellow.*

WORDS: PETER TAYLOR-WHIFFEN

SOCIETY

Imperial College Boat Club

Blade runner

Far from just messing about on the river, the Boat Club's success is down to putting in the hard yards.

Words: **Jo Caird** / Photography: **Hannah Maule-ffinch**

"New members often say we're a bit different," says Men's Captain of Imperial College Boat Club, Milford Killian-Dawson (MSc Mechanical Engineering, Fourth Year). "We've got a diverse and welcoming culture. Whether you've never rowed before or have years of experience, people find their home here."

That supportive, welcoming atmosphere helped to keep the Society going throughout lockdown. "The hardest thing was not being able to be with your team members," says Killian-Dawson. "That's why I love rowing so much – the team aspect."

And it's also fostered a culture of excellence. This year, Imperial rowers brought home eight medals from the BUCS Regatta, the women's team won the Cathy Cruickshank Trophy at the Henley Women's Regatta the following week, and the men's team made it to the final of the Henley Temple Challenge Cup for the first time in 20 years.

It's just the latest in the Club's long history of success. Decorating the walls of the Club's iconic boathouse on Putney Embankment are photos of past crews, including previous winners of the Henley Royal Regatta, Henley Women's Regatta and Head of the River Race. Founded in 1919, the Boat Club moved to its current boathouse, specially designed by the Club's founder, Charles Bristow, in 1938. And in addition to all those wins, the Club's athletes have won three Olympic gold medals and two silver medals.

"The Club definitely celebrates its history and its success," says Adam Freeman-Pask (MSc Environmental Engineering 2008), who rowed with the Club throughout his time at Imperial. "When you're down there, people will tell stories of different crews from different eras. You feel part of a strong history and want to contribute to that history of success."

Freeman-Pask went on to do just that, being selected for Team GB at the London 2012 Olympic Games and winning silver and bronze medals in European and World Rowing Championships events in 2012 and 2013. "That step up in terms of what the Boat Club offered was a really vital period in my sporting career," he says.

Melanie Wilson (Medicine 2015), who joined the Boat Club in 2009, the same year she made her GB Rowing Team debut, can relate. "To have that kind of back-up during the years when I was training full time in the national team was amazing, so I'm just really grateful," she says. And it worked. Wilson competed in the London 2012 Olympics and won a historic silver medal in Rio in 2016.

Wilson is still a member of the Club today, squeezing in training alongside the demands of her career as a GP. "It's exciting to see the students training. They visibly grow in confidence during their time at the club. The training is intense, but it becomes part of their social life as well. Committing to the training programme alongside studying is a challenge, but sets you up well for whatever you choose to move onto."

And there's always the romance of messing about on the river. "Watching the sun come up is one of those simple pleasures in life," says Freeman-Pask, "but there's something quite wonderful about doing that with a bunch of your mates in a rowing boat on the Thames. It's all tranquil and quiet, before anyone else has got up – there's a magic about it." ◆

Pulling together: Members of the Imperial College Boat Club women's and men's teams training at Putney Embankment.

Left:
Stephanie Travers, part of the Mercedes-AMG Petronas Formula One Team, with teammate Lewis Hamilton.

It was a surreal feeling to be so close to these high-speed machines

A WORKING LIFE

On track for life in the fast lane

Formula 1's Stephanie Travers *(MSc Chemical Engineering 2017)*

My weekends growing up in Zimbabwe were all about watching Formula 1 on the TV with my family. My dad had an engineering workshop, as did my grandfather, so I was always surrounded by engineering and it sparked an interest. I knew I wanted to be involved from a very young age – I just didn't know how.

I moved to the UK aged ten. I went on to work as hard as I could in the STEM subjects and started researching degree subjects that would get me into F1. Chemical engineering stood out to me, especially when I found someone in trackside fluid engineering that had taken that path. They inspired me to just work as hard I could at Imperial, to find my perfect position.

And then it happened. I was selected from more than 7,000 candidates to become a trackside fluid engineer with the Mercedes-AMG Petronas Formula One Team, and it was an incredible and surreal feeling to finally be so close to these high-speed machines. These days I work for Petronas, the title and technical partner to the team, and we provide all the fluids that go into the car. It's nerve-wracking but I'm still able to focus on the job in hand.

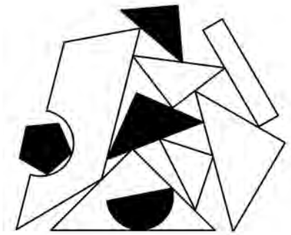
I take fluid samples for analysis in the run-up to each race weekend, using three critical pieces of equipment – a spectrometer, a gas chromatograph and a viscometer. All this ensures that we're compliant with the regulations of the FIA, the governing body for F1, as well as maintaining optimum engine performance and measuring wear on the engine and gearbox. If we have some contamination with our fuel, we can face disqualification for the race weekend. That means finishing the race with no points, and every point is so crucial.

Analysis is done before we even enter the race weekend and then at various stages, taking multiple samples each day. If there is an issue in a practice session, the team may decide that they would like to take an emergency sample. When that happens, I'm summoned on the radio and they get me into the garage as soon as possible. As soon as the car comes in from the track, I have to be as quick as possible to take that sample, seal the car's oil port back up and head into the lab and analyse it. Every single second, even in a practice session, is so important for the team to set up the car and prepare for qualifying for the race at the end of the week.

It's all about keeping an inner cool in those high-pressure situations. You have to be so precise. When the pressure's on I try to keep emotion out of it, but sometimes when there's no analysis to be done we can relax and just enjoy the race. That's when the emotions come out, and I'm back to being that young girl caught up in the thrill of it all. ◆

> *Stephanie Travers is a trackside fluid engineer with the Mercedes-AMG Petronas Formula 1 Team.*

INTERVIEW: JO CAIRD. PHOTO BY MERCEDES-AMG PETRONAS FORMULA ONE TEAM. ILLUSTRATION: MIKE LEMANSKI



PUZZLES

Test your brain power

Ready to test your little grey cells? Imperial's best minds set the ultimate puzzle challenge.

1: HARD

In a game of chess, White's first move was 1e4 and Black's fifth move was 5...Qa5 checkmate. What was the game?

2: VERY HARD

What is the least number of times you have to hit the ball over the net in order to win a set of tennis at Wimbledon?

3: FIENDISH

What is the smallest number of tricks one side must win in order to win a rubber of bridge without ever holding an ace or a trump?

All puzzles set by Professor Jonathan Mestel, Professor of Applied Mathematics, Department of Mathematics.

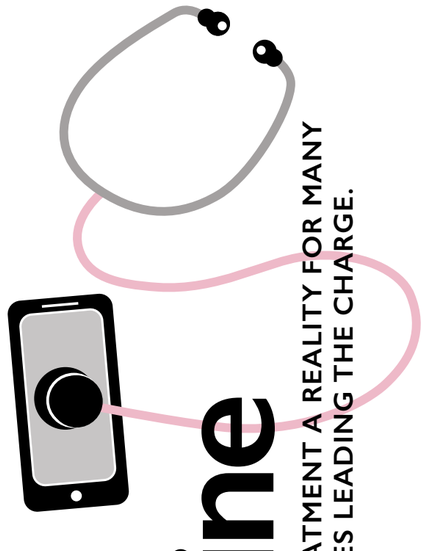
HOW TO ENTER:

The first ten readers to send the correct solutions for two or more of the puzzles will be entered into a prize draw to win a book voucher for the value of £10. Winners' names will be printed in Imperial 52 in May 2022, and solutions published at *www.imperial.ac.uk/be-inspired/magazine/issue-51/brain-power.* Entries close on 31 January 2022.
To enter, please email **imperialmagazine@imperial.ac.uk**

FOR ISSUE 50 SOLUTIONS:

www.imperial.ac.uk/be-inspired/magazine/issue-50/brain-power
The names of our winners for issue 50 are published with the solutions on our website.

Due to the pandemic, the team at Imperial have been working remotely, which has caused some delays in sending prizes to previous puzzle winners. We are working hard to get prizes to all our winners, but please send us an email if you'd like any further information about your prize.



OUR IMPERIAL

Better online

DIGITAL HEALTHCARE MAKES ACCESS TO TREATMENT A REALITY FOR MANY MORE PEOPLE. MEET THE IMPERIAL GRADUATES LEADING THE CHARGE.

DR ABDULLAH ALBEYATTI

(MBBS Medicine 2011)
CEO,
Medicalchain and MyClinic

How has digital transformed your work?
I have been a massive advocate for digital solutions in healthcare ever since I started thinking about becoming a doctor. As part of my training, I did a stint at Leeds General Infirmary and was shocked by the pages of notes a patient accumulated before discharge. I set up a template for discharge letters to the GP and Medicalchain grew out of it. We use blockchain technology to securely store health records and maintain a single version of the truth. It is important that we are morally and ethically transparent when it comes to patient records, and that patients own their history. Patients come on a journey with us and choose to be a data donor. And through MyClinic we provide an easy-to-use telemedicine platform that allows patients to connect with their doctors on video wherever they are in the world.

What lessons from Imperial have stuck with you?
The sense that you can always do more. I was intimidated by the level of excellence, and I struggled academically in my early years. But joining the medical football team changed things for me. I mixed with a range of people, and ending up thinking: "If these guys can do it, so can I." The ethos at Imperial is that problems are there to be solved. Now I say that to my patients: "As your doctor, I am here to provide solutions."

What are your ambitions?
I would like Medicalchain to become the 'Google of healthcare', the starting point for all medical consultations and the place where you go automatically to look up your health records. And through MyClinic, I want everyone to have access to specialist treatment linked to their health passport. Imperial taught me that pressure is a privilege, and you are always at the base of the mountain with a long way to climb! When I graduated, I thought I was going to tread water as a doctor for a few years, but I quickly realised that Imperial had set the bar so high that I was in a really good place to succeed at whatever I chose to do next. ◆

> *Winner of the Emerging Alumni Leader Award in 2021, Abdullah still practises as a locum GP as well as running his businesses.*

MARGARET MUTUMBA

(Master of Public Health 2010)
Founder and CEO,
MedAtlas

When did you decide to work in public health for women?
I studied pharmacology as an undergraduate but by the time I got to Imperial, I was sure my future work lay in public health. I didn't want to narrow it down to a specialisation, however, so during my course I did research on addressing bilharzia, an infection from parasitic worms most commonly found in fresh water across Africa, in young children. After graduating, my work addressed malaria prevention, young people living with HIV and maternal mortality in sub-Saharan Africa. As a result of that work, I realised that I loved engaging with women and children. It bothered me as a woman that there was limited understanding of fertility as a biomedical condition. For a child to be born healthy, it starts with the mother, and some women need fertility treatment to be able to have a child.

Is fertility treatment difficult to get in Africa?
It's a huge unspoken issue. There are 54 countries on the African continent and only about 20 of them have fertility centres of any sort. Women face great stigma if they don't produce children and it is difficult to get men to acknowledge that fertility is a two-person issue. One of the great advantages of providing advice online is that it can be done remotely, in the privacy of the home. And at MedAtlas, we provide access to qualified, licensed specialists that our already vulnerable patients would not otherwise be able to reach.

As a student, did you see yourself as a tech entrepreneur?
Not at all – it's certainly been a journey! My father is a physician who worked in public health and my mother is an entrepreneur, so I suppose it is in the genes. I am passionate about providing affordable access to specialist treatment in Africa, not just for fertility but for many other health conditions. And most people have at least a smartphone to get online. ◆

> *After working in fertility clinics in Tanzania, Uganda, Zambia and Rwanda, Margaret founded MedAtlas in November 2020 to provide a specialist telemedicine platform in Africa, initially for fertility treatment.*

DR MALA MAWKIN

(MBBS Medicine 2019)
Head of Market Development,
Leva Clinic

How did you get into digital healthcare?
In my first year at Imperial, I signed up to take part in a telephone campaign, calling alumni to ask if they would make a gift to Imperial. One of the alumni I contacted had founded Touch Surgery. I wrote back thanking him for the donation and cheekily included my email in case there were any internships going. I ended up working there in my summer holidays. One of my key messages to students now is to benefit from the alumni network – don't lose that email address! And stay involved. I recently helped on the Clinical Research and Innovation Course for Year 2 Students, and had 22 students come to work with me at Leva Clinic, the UK's first online clinic for pain management.

How has the technology changed?
I started med school at an interesting stage. In 2013, telehealth had only just really started, there were no Zoom consultations, and medical education was not tech-enabled. During my time at Imperial, the course evolved to become much more tech-friendly and in my third year we were all given iPads for use on ward rounds. I now enjoy being involved in innovation in healthcare, and helping the NHS embrace new solutions to the challenges it's facing.

How do you see the future for e-medicine?
At Leva Clinic, we give those living with chronic pain access to an entire clinical team, from nurses and doctors to psychologists and physiotherapists, all in one place onscreen, wherever you are based. The whole process is transparent to the patient. I always stress we are providing healthcare, not 'online' care. The online bit is just the means of delivery. I am passionate about patient access, and we can widen that access through technology, whether it is in Malawi (where I worked in an e-health research centre) or rural England. ◆

> *Recently recognised as one of the UK's most influential people in digital and tech in the 2021 BIMA 100 list, Mala is Head of Market Development at Leva Clinic, which launched the UK's first online chronic pain clinic.*

POLICY AGENDA: PROFESSOR MICHELLE ROGAN,
DIRECTOR OF MSC INNOVATION, ENTREPRENEURSHIP AND MANAGEMENT

A change for the better: the value of teaching social and environmental issues

THE LANDSCAPE

Making a positive impact – whether on society or the environment – is no longer an optional extra. Over the past decade, consumers and citizens have begun to actively reject organisations and leaders who don't have such values at the heart of their thinking. "Years ago, you'd be able to get a good student debate going around what role business had in concern for society," says Professor Michelle Rogan, Director of MSc Innovation, Entrepreneurship and Management. "That's impossible now – it's no longer about whether we should address social issues, it's about which ones we should be working on." The challenge for educators is therefore to give their students – the innovators and business leaders of the future – the tools and skills to put their values into practice and, in the process, change the world for the better.

THE CHALLENGE

Rogan's MSc students have been set a challenge: specifically, to make fast fashion circular and waste-free. "We wanted a few golden threads to run through everything they learn, that connect what they're learning to their own personal innovation development," exp[lains Rogan. "We already had wonderful core course content on understanding innovation strategy, technology and business models, thinking about how they're going to create value in the world.

"But then we developed a module called 'personal innovation development', not as an add-on but to run through and underpin the whole course. In three terms, students work on understanding what their strengths are as a leader of innovation, how they connect to others and what social capital they need to be an effective innovator. Then they focus on how to bring that to the wider world."

THE COLLABORATION

"Teaching social and environmental issues isn't about teaching students what to think. It's giving them the tools and skills to think for themselves,"

> **Innovation in corporate social entrepreneurship is becoming more central**

says Rogan, "and a huge part of that is encouraging them to embrace different perspectives."

The fast-fashion challenge was set in conjunction with Open IDEO, an open innovation collaboration that brings together people in design thinking from all over the world to solve global problems. "One of our initial student discussions was about how they felt about using vintage secondhand clothes," recalls Rogan. "Some immediately reacted negatively, others had a very different reaction. It's one thing to sit in London and talk in the abstract about pollution created through the production process of, say, dyeing fabrics, but if you have someone in the classroom who's actually grown up in one of the countries where there's labour exploitation or pollution caused by fashion, it makes the problem real. It's important to maximise that advantage – to make the most of your diverse cohort so everyone can learn from each other."

THE COMMITMENT

While individual modules can teach skills in innovative, environmentally impactful entrepreneurship, that learning will be most effective where the institution's ethos is based in the same values – as it is at Imperial. "Imperial's fundamental pillars include working toward a sustainable society, and that's reflected everywhere you look. The excitement around environmental and social innovation is within our MSc but it's also in Imperial's design school, engineering school, business school, and our alumni community, who are doing fantastic work. Effective education around sustainability and positive social impact needs to be based on a community all working together in the same direction naturally, and that happens everywhere you look at Imperial," says Rogan.

THE FUTURE

"Innovation in corporate social entrepreneurship is becoming more central to leadership in business, government and NGOs," says Rogan. "You want to give students not just the education for now, but the skills to pick up those golden threads and take them forward, to help them lead innovation in an organisation or their own startup. That's how they will be able to change the world." ◆

> ***Professor Michelle Rogan** is Director of MSc Innovation, Entrepreneurship and Management at Imperial College Business School.*

INTERVIEW: PETER TAYLOR-WHIFFEN

ALUMNI LIFE

Support every step of the way

The Imperial community is ready to help your career achieve lift off.

Words: **Lucy Jolin**
Illustration: **Antonio Sortino**

Starting a career is always challenging – now, more than ever. Luckily, the Imperial community is here for you. Whether you're looking for early-career coaching, mentoring or informal networking, our generous network of expert Imperial alumni and free programmes can help you take those first crucial steps.

The Coffee & Coach online programme offers coaching-style sessions to early-career alumni who are seeking career-related support. Recent graduates are paired with experienced and trained alumni coaches and can schedule five one-hour sessions per month, focusing on career transitions, confidence, influence and impact in the workplace, and leadership and management. "The whole experience was great," said one recent graduate. "My coach was extremely knowledgeable and had a wealth of experience to offer, and I met every single one of my coaching objectives."

Pour yourself another cup for Coffee Roulette, an Imperial Plexus programme where recent graduates can meet online and enjoy a friendly conversation. Or if you're after practical tips and advice, sign up for our free webinars and Alumni Masterclasses for recent graduates to help you in your career. Recent events have included how to hone your leadership skills, switch sectors or succeed in a virtual workplace. There's also the Alumni Insights series, where a panel of alumni experts in a particular industry gather to share their own experiences, tips and insights into their sector.

None of this would be possible without the support of the alumni community, so check out our website and newsletters to find out what's on offer, including our monthly top picks of events, benefits and volunteering opportunities. And don't forget Imperial Plexus, either, where you can access jobs listings, find project collaborations or search the global map of 15,000 alumni. ◆

> *Are you a recent graduate? If so, you can find out more at bit.ly/recent_grads. Or if you'd like to volunteer to share your time and experience, visit bit.ly/alumni_volunteer*

Top deck:
Cai Linton on the 8am Uber Boat by Thames Clippers from Putney Pier.

MY IMPERIAL

On the crest of a wave

Cai Linton *(Molecular Bioengineering, Second Year)* and his love of the Thames via boat.

Interview: **Diane Shipley** / Photography: **Joe McGorty**

The Uber Boat by Thames Clippers is the best way to get around the city without getting too caught up in the hustle and bustle. You go past the Houses of Parliament and the London Eye, and even though you only catch a glimpse of St Paul's Cathedral, it's fun to try to peek inside. There's often such an interesting mix of stalls and pop-up shops at the South Bank, but my favourite part is going under Tower Bridge, and seeing a perspective you could never get on land!

My first experience of the boat was a couple of years before I started at Imperial, when I came to London for the day. I'm from a rural part of North Wales, so it was quite a contrast for me, but I loved being able to see so many major landmarks without going on the Tube or walking around, catching one bus after another. Now when my family and friends come to visit we always travel by boat, so they can relax as they take in the sights.

Imperial can be intense, with lectures, project work and preparing for exams; I also have a sustainable food startup through the Enterprise Lab, which is very demanding. I de-stress by cycling from Imperial through Hyde Park and St James's Park to Westminster and take the boat east. If you time it right, you catch some stunning views over Greenwich as the sun sets, and then going back past Canary Wharf you see all the lights twinkling on the water. Some of my favourite memories of being onboard are from lockdown, when we could only socialise outside. It was strange seeing London so quiet, but it was also the perfect way to spend time with friends, have a good conversation and get away from everything.

When it gets colder, you can enjoy the experience from the boat's cabin, but as long as the weather's good, you'll find me out on the deck. Travelling in from west London, it's usually quiet and calm in Putney, then gets busier as you head into central London. That's when I usually find myself surrounded by tourists, but I don't think of that as a downside. It's exciting to see London from their perspective, especially when everyone is in awe of all the different views. It makes me feel proud to live in such a special place. ◆

Get Connected

Be inspired by science as we share the wonder of what we do. Our programme of online events and activities is available on a range of platforms, so you can connect with us from anywhere in the world. www.imperial.ac.uk/whats-on

Sign up to receive updates about our monthly programme of events and online activities:
www.imperial.ac.uk/whats-on/events-signup

The Athena Lecture 2021

2 December 2021

The Annual Athena Lecture, this year given by Dr Magdalena Skipper, Editor in Chief of *Nature* magazine.

Online and in-person

Imperial Lates: Tiny Science

6–9 December 2021

Be inspired and enjoy some after-hours science at Imperial Lates, returning for a new season from December. Get hands-on at creative workshops, discover the incredible world of small science and hear about the latest cutting-edge Imperial research at these fun, adults-only evening events.

Online and in-person

Imperial Inaugurals

Professor Marina Galand
15 December 2021

Professor Marina Galand, Department of Physics, discusses her research in planetary science and the deposition of particles in our solar system.

Online and in-person

Professor Oscar Ces
12 January 2022

Professor Oscar Ces, Head of the Department of Chemistry, talks about his research in the field of chemical biology and soft condensed matter.

Online and in-person

Professor Mirko Kovac
19 January 2022

Professor Mirko Kovac discusses his work as Director of our Aerial Robotics Lab and the development of biologically-inspired flying robots.

Online and in-person

Professor Ioanna Tzoulaki
23 February 2022

Professor Ioanna Tzoulaki discusses epidemiology, prediction models and her work in the School of Public Health.

Online and in-person

Professor Michael Templeton
16 March 2022

Professor Michael Templeton discusses addressing public health challenges related to water supply and sanitation.

Online and in-person

Professor Wouter Buytaert
16 March 2022

Professor in Hydrology and Water Resources, Wouter Buytaert, takes us through his research on the impact of environmental change on the water cycle.

Online and in-person

Professor Christos Markides
23 March 2022

Professor Christos Markides presents his work on the development of clean energy technologies.

Online and in-person

Professor Ioanna Tzoulaki

Keep in touch wherever you are
Visit imperial.ac.uk/alumni/events or sign up to our newsletter at alumni@imperial.ac.uk ➜

Professor José-Luis Peydró
25 May 2022

Explore systemic risk, FinTech and the globalisation of finance with Professor José-Luis Peydró.

Online and in-person

The Schrödinger Lecture 2022

1 February 2022

The Annual Lecture of the Faculty of Natural Sciences, with Dr. Rajiv Shah, President of the Rockerfeller Foundation.

Online and in-person

President's Address 2022

22 June 2022

Imperial's President, Professor Alice Gast, delivers her eighth annual address to the College and friends.

Online and in-person

Current and Future Women Luminaries

Hear from some of Imperial's leading lights in a number of candid and enlightening conversations.

bit.ly/Imperial-Luminaries

Great Exhibition Road Festival

The Festival is back in summer 2022 for another annual celebration of science and the arts in South Kensington. Join us for free events for all ages from Imperial and South Kensington's museums and culture organisations.

greatexhibitionroadfestival.co.uk