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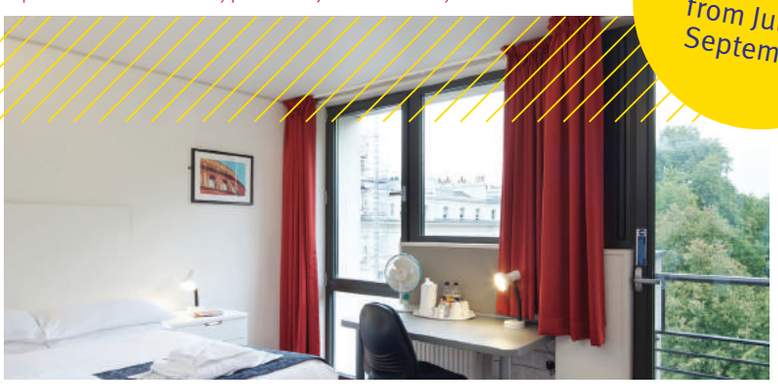

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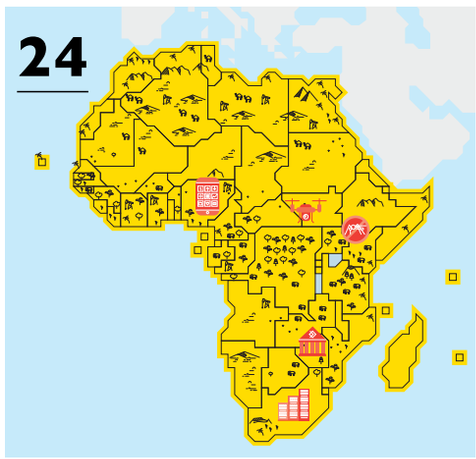

Regulars

Features

Imperial/46

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The wonder of science

It was fascinating to read about the work of Imperial's Science Communication Unit (The Wonder of Science, *Imperial 45*) and the need to counteract the misconception that science is concerned only with certainty and facts.

As an applied mathematician, I realise that my initial interest in maths and science arose from my desire for certainty, but my life has been more fulfilling by not getting it!

The arts have a huge role to play in bringing science to the public's attention, illuminating difficult concepts that arise from beyond the realms of everyday activity, discussing the ethical questions of 'what ifs', as well as demonstrating that we are not 'unweaving the rainbow' but providing an appropriate sense of awe.

Poetry wasn't mentioned in the article, but I would place it at the top of any list of endeavours, for revealing what science really means to us as humans on this pale blue dot.
Martin Zarrop,
(PhD Computing and Control 1975)

In praise of collaboration

Studying at Imperial was probably one of the hardest yet most important periods of my life. I learned so much.

The opportunity to study at one of the world's best institutions has taught me so many skills that I still apply to this very day.

One of the first skills I learned was collaboration. Scientists, clinicians, bioinformaticians, medicinal chemists and others all coming together is something I'll always remember. Seeing how different minds can combine and drive research success was an amazing experience.

I am now at Havas Lynx Group, one of the world's leading healthcare communications agencies, working with the biggest pharmaceutical companies. My role as a writer in medical and scientific services provides a knowledge base for all other disciplines within the agency.

Thank you, Imperial, for providing me with the skills to excel at what I do. I will always continue supporting and donating every month to support future students.
Lewis Wong
(MRes Surgery and Cancer 2015)

Inspirational read

I was most impressed with the latest issue (*Imperial 45*), thinking back to my days at Imperial (1962-65) when there were only three ladies on the three-year chemical engineering undergraduate course.

The current situation of real female opportunity through the College's education was beautifully illustrated by many of the articles, such as Clean Reaction, highlighting the work of Dr Florence Gschwend.

I felt the magazine was highly inspirational. It made me think that it should be brought to the attention of schoolgirls and boys thinking about their futures. Certainly, my copy will be passed on to those at the comprehensive where my daughter teaches. Perhaps we can encourage multiple use by others doing likewise?
John F Porter
(Chemical Engineering and Chemical Technology 1965)

Editor's response: Our student recruitment, outreach and engagement teams regularly share Imperial *magazine with schools and local community organisations.*

Planet wise

Many of you have been in touch to praise our move to the recyclable, compostable, potato-starch film that *Imperial* magazine now comes in.

Colin Hodgson (Mineral Resources Engineering 1985) commented on Facebook that it is a "great step forward", and Elizabeth So (Charing Cross and Westminster Medical School 1993) was just one of many to write in with congratulations, saying it's "much more environmentally friendly than Cambridge's alumni magazine that came out on the same day and which I noticed was covering my neighbour's post!"

Peter Smith (MSc Computing 1999) continues the debate: "I can see that your magazine is printed on paper that comes from 'sustainable sources', but as representatives of one of the most respected scientific institutions in the world, I really would urge you to consider how every small-seeming activity scales up with regard to its impact on climate change. With the magazine available online, is this, on balance, far more environmentally friendly than the overall hard-copy distribution operation."

"I think moving to a potato starch wrapper for *Imperial* is a great move," writes Rob McCarthy (MSc Biology 1996), "but how about going one step further and 'going naked'? IEMA's *Transform* magazine is now being delivered without any packaging at all, eliminating the waste issue completely."

> *Are you receiving the alumni e-newsletters, containing information on the latest alumni benefits, events and how to get the most out of your Imperial connection? If not, it might be because we do not have your current email address. Visit www.imperial.ac.uk/alumni or use the form enclosed with this magazine to update your information.*

DIGEST

THIS PAGE ILLUSTRATION: JOE WALDRON. OPPOSITE PAGE ILLUSTRATION: MIKE LEMANSKI

FESTIVAL

Great Exhibition Road Festival

Imperial will team up with some of the world's most iconic institutions this summer, when it presents the Great Exhibition Road Festival. This unique 'exploration of the extraordinary' fuses art, science, technology and curiosity, and represents a partnership between Imperial and the Natural History Museum, the Science Museum, the V&A, the Royal Albert Hall and 15 other leading organisations.

"Since the first Great Exhibition brought us here in 1851, this road is where engineers, artists, educators and scientists have reimagined the future, with curiosity as their common spark," says Vicky Brightman, Head of Public Engagement at Imperial.

"The organisations involved share much more than geography and history: they are united by a common mission to generate and share knowledge and ideas, to explore and find answers to the big challenges facing the globe for the benefit of all, and to inspire the next generation of designers, engineers, scientists and artists."

A series of free events across the last weekend of June mark the bicentenary of the births of Queen Victoria and Prince Albert, and take inspiration from the Prince's vision for the area as a dedicated centre for research, learning and creativity.

More than 100,000 people are set to attend, with researchers, staff, volunteers and visiting speakers presenting hundreds of hands-on demos, interactive experiments, workshops and live performances. *The Great Exhibition Road Festival takes place on 28, 29 and 30 June, coinciding with Imperial's Alumni Weekend. For more information, visit www.greatexhibitionroadfestival.co.uk*

The Great Exhibition Road Festival will be a celebration of the shared identity and value of the world's first planned cultural district.

FROM THE PRESIDENT / PROFESSOR ALICE GAST

“Prince Albert had the vision for Imperial – he’d be pleased with how far we’ve come”

In this bicentennial anniversary of Queen Victoria and the Prince Consort’s birth, we have a wonderful opportunity to celebrate their contributions to our heritage.

The Imperial Festival this year will take place as part of The Great Exhibition Road Festival, a three-day celebration during the last weekend in June. It coincides with Alumni Weekend, and we invite friends and alumni to join us.

It was Prince Albert’s vision and wisdom that led to our great university. As you read about the wonders of quantum technology (p34) or the modern day race to eliminate or mitigate malaria (p12) in this issue, you can imagine how pleased he would be.

I think Prince Albert’s legacy gave us three three things: the land that became our wonderful campus; the encouragement to work across disciplines and across nations; and the great example of philanthropy that is so important to Imperial today.

After the historic 1851 Great Exhibition, The Royal Commission had a surplus of about £200,000. According to a memorandum signed by the Prince, £50,000 of the surplus was to support the purchase of “25 to 30 acres of land ... called Kensington Gore”. Albert said: “I would buy that ground and place on it four institutions, corresponding to... Raw Material, Machinery, Manufactures and Plastic Art. I would devote these institutions to the furtherance of the industrial pursuits of all Nations in these four divisions.”

I think that Imperial has fulfilled, and perhaps exceeded his vision. We arguably have done some of the best academic work in these areas and more. This started with the 1845 creation of the Royal College of Chemistry (RCC). The threads of Imperial are interwoven by the RCC merger with the Royal School of Mines and the move to South Kensington in 1872. The addition of the Royal College of Science (RCS) and the Central Institution (later called City and Guilds College) provided the foundation.

We signed the Charter combining these institutions into Imperial in 1907, and added Medicine in 1997 to fulfil an important national need. It is fitting that our first academic building in White City is the Molecular Sciences Research Hub, a direct descendent of the RCC and Central Institution.

> His legacy gave us three things – land, the encouragement to work across disciplines and a great example of philanthropy

We have since built 2.5 million square feet of research and teaching space on 14.5 acres from the Royal Commission purchase. We now have a university of 17,000 students and 8,000 staff, and our turnover is slightly more than £1bn. This is quite a legacy from Prince Albert’s vision and investment of £50,000.

Prince Albert proposed that this land and the institutions he foresaw should be interdisciplinary and international. He said: “We should ensure that ... the different industrial pursuits of mankind, Arts and Sciences should not again relapse into a state of comparative isolation from each other... and that the different nations would remain in that immediate relation of mutual assistance by which these pursuits are incalculably advanced...”

Today, Imperial is recognised as the most innovative university in the UK with multitudes of cross-disciplinary research and teaching programmes. Our most recent efforts in bioengineering and design engineering bring this cross-fertilisation to the forefront.

We are also the UK’s most international university, with students and staff from 130 countries and research collaborations with around 190 other countries. I thank Prince Albert for paving the way for such openness, and his ingenious approach to financing the exhibition. He raised donations from notable figures and from everyday people. The Royal Commission oversaw the establishment of more than 300 local committees which gathered subscriptions from their regions.

This legacy of philanthropy at all levels is a critical element of our progress. Today we are very grateful to our donors who are following in Albert’s footsteps. We owe a lot to the courage and foresight that the Prince Consort brought to the huge undertaking of the Great Exhibition, and the legacy he left for us. ◆

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

RESEARCH

New centre for blood cancer research established

A new centre for blood cancer research is to be established at Imperial, thanks to a recent £10m donation.

The new Hugh and Josseline Langmuir Centre for Myeloma Research, named in honour of the Centre's benefactors, will support pioneering research into the causes, mechanisms and treatment of myeloma, a type of blood cancer that develops in plasma cells, affecting the bones, kidneys and immune system.

Based at the Hammersmith Campus, the Centre's proximity to Imperial's White City Campus, with its mix of academics, global companies and emerging businesses, will help achieve its aim of driving collaborations with researchers in fields such as genomics, bioinformatics and drug discovery. It also hopes to work with multidisciplinary groups, start-up companies and corporate partners.

As Professor Alice Gast, President of Imperial College London, explains: "Donations such as this are truly transformative, allowing us to bring together talented people, unleash potential and surmount some of the greatest challenges facing society.

"We are profoundly grateful to Hugh and Josseline Langmuir for their generosity and foresight in supporting this critical work. Patients and their families will reap the benefits for generations to come."

The centre will support pioneering research into the causes, mechanisms and treatment of myeloma, a blood cancer that develops in plasma cells and affects the bones, kidneys and immune system

PHOTOGRAPHY: IMPERIAL COLLEGE LONDON/THOMAS ANGUS. ILLUSTRATION: MIKE LEMANSKI

A working life

Dr Henrietta Bowden-Jones OBE has dedicated her life to understanding and preventing addictive behaviour, and says the best part of her work is being able to make a real difference.

My very first role model was Lucy, a character in the Charlie Brown *Peanuts* cartoons who takes it upon herself to ensure the wellbeing of others sharing her life in the playground. When I saw her standing with the sign saying, 'Psychiatric Help, 5 cents,' I wanted to sit behind that booth.

Today, that desire to help is as strong as ever, and I'm now juggling around 30 simultaneous projects, mostly covering research and clinical work around gambling disorder and gaming disorder addiction. The behavioural addictions field is one that I first became fascinated with during my medical doctorate work. Then, in 2008, I opened the National Problem Gambling Clinic, the UK's first, and currently only, NHS national clinic for gambling addiction. Initially no one expected it to be busy, but we've been inundated since we opened. There are now half a million confirmed problem gamblers across the country but only 8,800 people in treatment. The new NHS five-year plan will be announced soon and I am hopeful that an expansion of services will be addressed.

It's also been a most rewarding experience for me, understanding an illness from a neuroscience perspective and then translating that into clinical work. The best thing about the job is the ability to make a difference, not just at an individual level but at a population level, by working on projects that emphasise the right strategies to reduce harm.

My need to keep up to date is constant: as addictions evolve, we have to understand what people are finding compulsive, what new products are harmful and how we can tailor our treatment. When I started, people were gambling in bookmakers, now nearly everyone is online and the financial harms they are experiencing are different. Every week something happens to surprise me. For most of the population, new technological advances are great, but my patients are going to find a way of harming themselves, so I need to try at every turn to counteract things that can be harmful to the most vulnerable.

I feel my duty now is also at a preventive level, sharing information about important issues: what can we do to block things that are harmful? Our current focus is on advertising, making sure decision makers understand why we feel it is harmful for young people to see gambling adverts. We are also focusing on new technological advances, what banks can do to stop people wasting money on gambling and what we can do to protect young people. On a very serious note, problem gambling is a significant cause of suicidal ideation and intent in young people, so we need to understand who's doing it and whether some types of gambling are more likely to cause people to become suicidal than others. We need to have this conversation at a higher level nationally, so the next year is all about these big issues. We will be busy!

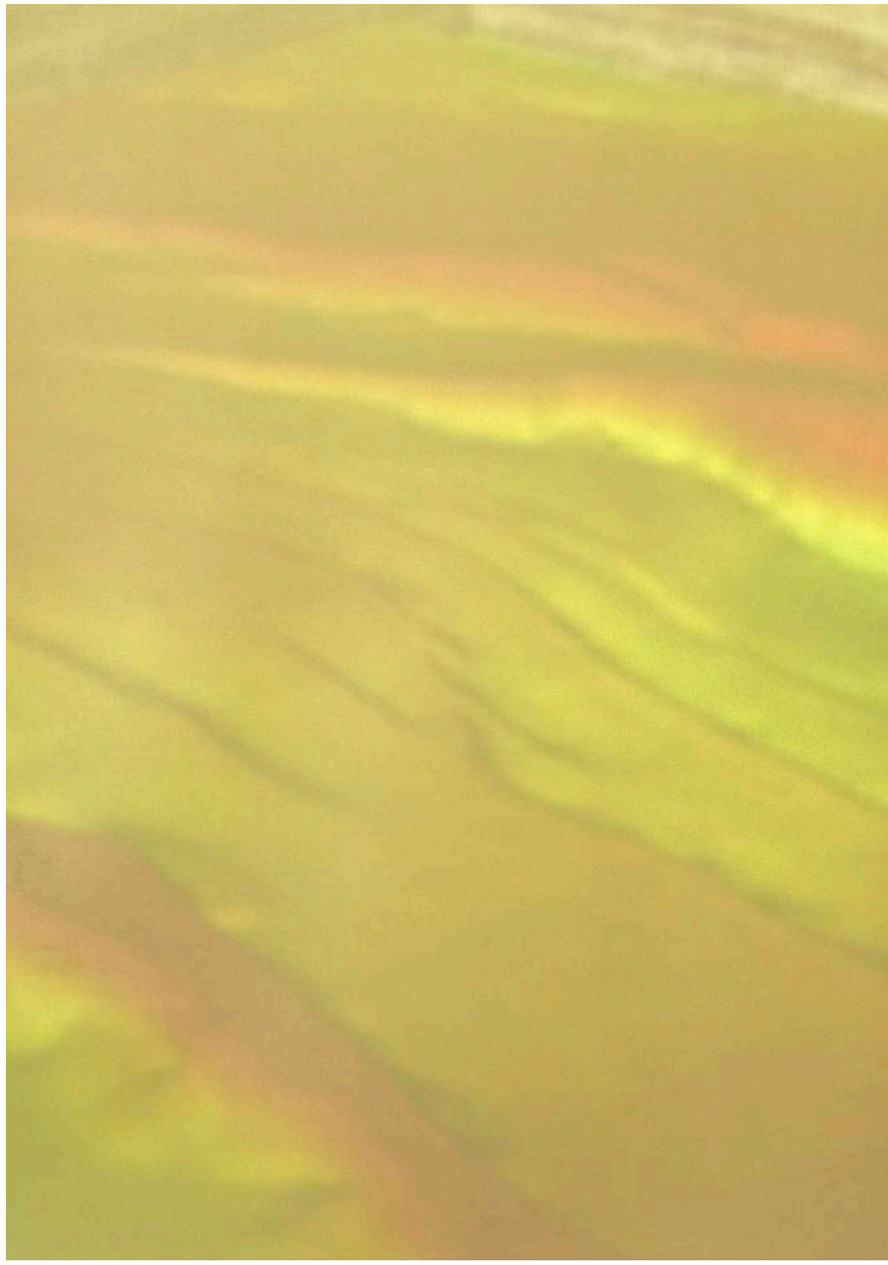
> *Dr Henrietta Bowden-Jones OBE (MD Neuroscience and Mental Health 2005) is director and founder of the National Problem Gambling Clinic in London. She is Honorary Clinical Senior Lecturer in the Faculty of Medicine at Imperial and is the current President of the Medical Women's Federation.*

ADVENTURES IN...

Rift basins

How did life on Earth begin? Professor Chris Jackson says the answer is right beneath our feet.

Words: **Radhika Holmström** / Photography: **Angela Moore**



On paper, Professor Chris Jackson specialises in the analysis of sedimentary basins. In practice, the range of his work is so broad it takes in the very fabric of the planet, including how the Earth's crust forms and is deformed – and how it may change in millennia to come. No wonder he says that spending just five minutes with a geologist can tell you a lot about the rich geological history of where you are standing and how our landscapes came into existence.

"I want to know things like: how do mountains form? What processes stretch the Earth's crust? How do the rocks and sediment contained in different environments – rivers, beaches, deserts and so on – record the evolution of the Earth over millions of years?" It's a huge, overarching topic and, unlike many colleagues in the field, Jackson takes a big-picture approach, enabling him to work in several seemingly diverse but, on closer inspection, interlinked areas of geoscience.

The social impact of the research motivates Jackson and his colleagues, and his work has a distinctly commercial application. "Once you know how the Earth evolved, you're more likely to know where to drill for hydrocarbons," he says.

Those investigations are focused far below the surface of the Earth and access astonishingly detailed information. "We use seismic reflection data to essentially x-ray the earth deep beneath our feet, even in areas currently under several kilometres of water. To do this, we create a massive underwater bubble that sends sound waves down into the

Professor Chris Jackson and a projection of seismic reflection data showing the subsurface structure of offshore NW Australia.

rocks below: by doing this we can image down to 20km and cover areas hundreds of square kilometres wide. We can interpret these large-scale, relatively low-resolution data, along with small physical samples of the rocks and fossils obtained from boreholes; by integrating across scales, we can build a picture of the incremental changes that have happened in that particular part of the earth, and distil the information that's of interest to the hydrocarbon industry."

Sometimes data is sent back to Jackson at his Imperial office – he and his colleagues are currently looking at data from offshore New Zealand and Australia – but he also goes into the field, to examine what can be gleaned from the surface. He and his team have worked across South America, Africa and northern Europe, mapping and analysing the landscape around them, but, he says, the local landscape prompts just as much reflection.

They also work on volcanic and earthquake activity, just one aspect of their research that traces contemporary threats back to their origins. "When we look at the composition of various rocks, we're always asking ourselves: 'Is it volcanic? Is it sedimentary: did giant rivers used to flow here? Is it limestone, deposited in ancient coral reefs? When you ask those questions, you can start to reconstruct the landscape of many millions of years ago. Ancient rocks are exposed at the earth's surface still, and yet they tell you about the beginnings of life on Earth." ◆

> ***Professor Chris Jackson*** *is Professor of Basin Analysis at the Department of Earth Science and Engineering.*

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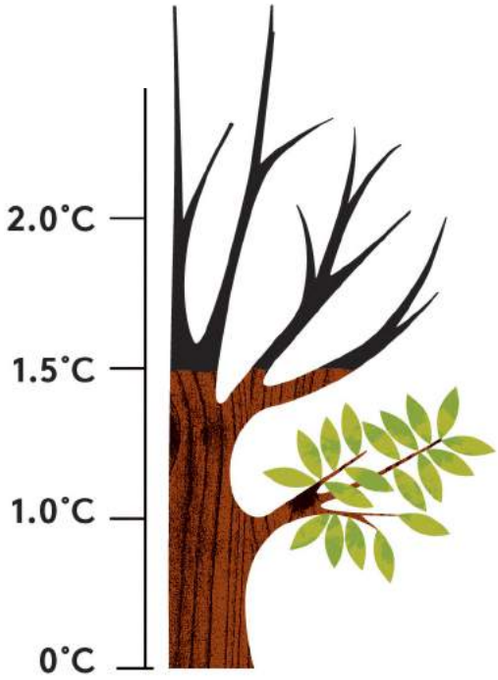


The Hitchhiker's Guide to the Galaxy declares 42 the answer. But what is the question? For Joeri Rogelj, it's all about cutting carbon emissions.

"If we don't take drastic action on climate change, the consequences for future generations will be dire," says Dr Joeri Rogelj, Lecturer in Climate Change and the Environment at the Grantham Institute.

And he should know. As one of the coordinating authors of the latest Global Warming of 1.5° Special Report by the UN Intergovernmental Panel on Climate Change, Rogelj is at the forefront of efforts to spread this message and mitigate the damage. The report concluded that the best-case scenario would be to limit global warming to 1.5°C – any higher and developing countries will be particularly badly affected. It says: "The impact of even two degrees of warming is projected to be detrimental to efforts to ensure food security and poverty eradication."

Achieving this target means that worldwide carbon emissions need to be cut to zero by mid-century. The big question driving Rogelj's research is how to do that in a holistic way. "We do not just care about climate change. For example, you can try to solve the climate problem by growing bioenergy crops or plant forests everywhere – but this could negatively impact food security or biodiversity. The challenge is to find out how these different objectives can be tackled together."

It's a daunting mission, but one he's eager to take on. "These are core aspirations of our global society so, as a scientist, I find it incredibly motivating to work towards furthering them. I hope that my research provides a small piece in the puzzle. At the same time, this challenge also provides a great opportunity to choose a more sustainable path."

He was pleased that the UN's report reinvigorated the debate around climate change, but now hopes that this will be translated into policy. "I'd like this work to inform both national and international governments to set science-based targets to achieve the most ambitious climate goals."

> *To read the full report, visit: report.ipcc.ch/sr15*

IN BRIEF

RESEARCH FACILITY The new Children's Clinical Research Facility, which aims to improve the quality of life, treatment and care for children with complex diseases, has formally opened, based at St Mary's Hospital.

PUBLIC HEALTH ONLINE DEGREE Imperial has launched the Global Master of Public Health, its first fully online degree in health.

PHD TRAINING Imperial has secured funding to help train hundreds of PhD students in engineering and physical sciences across six Imperial Centres for Doctoral Training.

> "We are at the forefront of understanding the spread of viruses – and could potentially save millions of lives"

OVERHEARD ON CAMPUS

Chemical kitchen: *A new Chemistry module for undergraduate students will train them in culinary and gastronomy techniques, to develop practical and professional skills.*

Cadget: *A new breathable, washable orthopaedic cast that won the 2019 WE Innovate final for Biomedical Sciences student Suchaya Mahuttanatan.*

ROAR: *The Centre for Rapid Online Analysis of Reactions at White City aims to speed up the synthesis of new molecules for research.*

RESEARCH FOCUS / POLICY AGENDA
DR CHRISTOPHER CHIU,
CLINICAL SENIOR LECTURER AT THE FACULTY OF MEDICINE

THE PROBLEM

There were an estimated 16,000 annual deaths associated with influenza in the UK, according to the latest figures from Public Health England, and one in six paediatric admissions to hospital were for related conditions. Each week around 30,000 of us went to our doctor with symptoms, and millions more were struck down with coughs, colds and flu, leading to millions of hours off work and placing a huge strain on NHS resources.

At the root of the more severe forms of these illnesses are two viruses – influenza virus and respiratory syncytial virus (RSV). For the former, there is a vaccine, but strains mutate constantly so vaccine components need to be regularly updated, and some years they are a poor match for circulating strains. No effective vaccine is yet available for RSV.

But Dr Chris Chiu, honorary consultant in Imperial's Department of Infectious Diseases, hopes to change that. "Although antivirals exist, the challenge is to get these into people early enough," he says. "The virus replicates so quickly, by the time most people start antiviral drugs, they already have the symptoms and it cannot be stopped. Because of this, vaccines are really the only practical way to protect most people in the world against flu and RSV."

FIGHTING BACK

Chiu's pioneering research focuses on how B and T cells – the body's naturally produced defensive cells – can be harnessed using effective vaccines. His work will have a global impact – flu and RSV-related infection causes death across the world, particularly in developing countries. But, he says, the slow speed of testing, development and delivery of these vaccines is a major problem and needs to be accelerated by an interdisciplinary approach. The Imperial Network for Vaccine Research, which launched last year and which he chairs, brings together experts from across the university to do just that. "We are at the forefront in understanding viruses, bacteria and parasites, the spread of disease, how microbes interact with the human body, through to methods to accelerate licensing and encourage take-up by a sometimes sceptical public. This network brings that all together."

VACCINE INNOVATION

Imperial has also been announced as one of three partner institutions in the UK's first Vaccines Manufacturing Innovation Centre, a £66m facility to accelerate vaccine development and enable quick manufacturing in the event of a UK or global epidemic.

"The UK has always had great inventors," says Chiu, "but there have been historic hurdles to quick and efficient vaccine manufacturing. Working with the London School of Hygiene and Tropical Medicine and the University of Oxford, we are the only group of this kind in Europe, accelerating cutting-edge vaccine research in normal times. But in the emergency of an epidemic, we can pivot to get essential medicines out quickly."

Around three million lives a year are thought to be saved by immunisation – now Imperial's work can potentially save millions more. "Our work is vital in stopping the spread of disease," says Chiu. "It's great news that policy-makers are recognising that vaccines are essential."

> ***Dr Chris Chiu*** *(PhD Investigative Science 2006) is Clinical Senior Lecturer at the Faculty of Medicine.*

PHOTOGRAPHY: IMPERIAL COLLEGE LONDON/THOMAS ANGUS.
ILLUSTRATION: MIKE LEMANSKI

ADVANCEMENT

New Vice-President (Advancement)

The advancement community at Imperial has a new face, as Michael Murphy takes up the post of Vice President of Advancement from June.

A highly successful global fundraiser with almost 30 years of experience, Michael has worked with scientists and leading educational institutions throughout his career, most recently as chief development officer at the prestigious National Academies of Sciences, Engineering and Medicine in the US. He replaces the retiring Sarah Porter Waterbury, under whom the Advancement Division has more than doubled in size and overseen major gifts which helped the College achieve a record financial year in 2018, with £59m in donations, an almost four-fold increase compared to previous annual averages.

"Michael joins us at a remarkable time," said Professor Alice Gast, President of Imperial, "as Imperial is leading in so many areas of excellence and discovery, and friends and alumni are supporting our impactful work."

TRIBUTE

Professor James Stirling 1953 – 2018

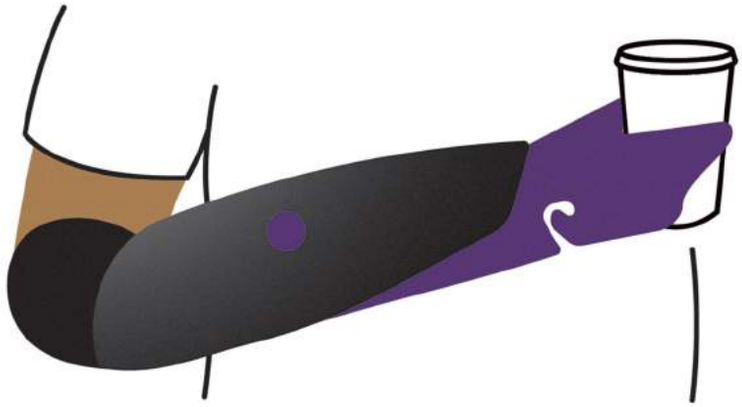
Tributes have been paid to Professor James Stirling CBE, Imperial's first Provost, who passed away in November. Professor Stirling pioneered advances in quantum chromodynamics and particle physics phenomenology, resulting in some of the most highly cited research papers of all time in the physical sciences.

Professor Michele Dougherty, Head of the Department of Physics, said: **"James believed strongly that one of the most important parts of his job was making people feel valued for their work, and he was passionate about enabling others"**, while Professor Jo Haigh, Chair of Atmospheric Physics at Imperial, said: **"James's positive, supportive, no-fuss attitude made working with him a pleasure."**

The University of Manchester's Professor Brian Cox described Professor Stirling as: **"A towering figure in theoretical physics for many years and a big influence and help to me in my career, and to a generation of particle physicists."**

Tom Wheeler (Physics 2014), a former President of Imperial College Union, said: **"He was tenacious and focused, kind and compassionate. I can say with total confidence that my time at Imperial was made better due to his leadership."**

Dr Jess Wade (MSci Physics 2012, PhD 2016), Research Associate in the Department of Physics, said: **"I don't think he'll ever really go. He transformed particle physics, he transformed Imperial and he made all of us think we could do it, too."**



Test tube

Innovate. Invent. Experiment. In this series, Imperial alumni tell us what they are working on.

WHO **BEN LAKEY**

(MRes Bioengineering 2018)

WHAT

Mitt Wearables builds affordable, functional prosthetic limbs using plastics and fabrics. Instead of having rigid sockets that clinicians have to specially fit to users, we have an adjustable interface that users can fit themselves, which makes them light, breathable and much more comfortable.

HOW

The human body is so complicated – hands in particular; we're years away from replicating them well. So instead of having an electric hand that does many things badly, we have a growing range of task-specific tools that clip in and out – for holding a pen, a kitchen knife, a table tennis bat or whatever users need.

INSPIRATION

My co-founder Nate Macabuag (MEng Mechanical Engineering, 2018) came up with the idea in the third year of his degree, after he designed a robotic hand. The quadruple amputee he asked to test it said: 'You don't need all of these electronics, I just want something that's comfortable to wear.' I was also studying high-end prosthetic hands, so a mutual friend introduced us. When Nate told me what he was working on, I loved it.

MOTIVATION

I got into prosthetics after my sister had her foot amputated and I saw the struggles she went through to have the procedure, to get a prosthetic and to have it fitted correctly. And that's in Canada, a country with great healthcare. What really excites me about our design is that, because it is easy to use and many times cheaper than the alternatives, it makes prosthetics globally accessible.

THE FUTURE

We will be the first direct-to-consumer prosthetic because we have standardised sizes, much like shoes. That opens up a world of possibility: long term, our goal is to have Mitt prosthetics in 101 countries. My grandpa always used to say that if you love what you do it will never feel like work. More than anything, I want to build a company like that.

> *Ben Lakey is co-founder and CEO of Mitt Wearables.*

ILLUSTRATION: MIKE LEMANSKI

IMPERATIVE / PROFESSOR STEPHEN CURRY,
ASSISTANT PROVOST (EQUALITY, DIVERSITY AND INCLUSION)

"Our future success depends on our strategy for equality, diversity and inclusion"

We often kid ourselves that our own experiences are universal, especially if we belong to majority groups within society; but in many respects, they are not. We are all different. As a university that aims to flourish in a world that is growing ever more diverse, we need to tap into diverse pools of talent that have previously been neglected, to increase the quality, relevance and impact of our research and education, and to build a culture that values and respects everyone. A clear strategy on equality, diversity and inclusion (EDI) is not a nice-to-have, then, it's an imperative – our future success depends on it.

Imperial's new strategy provides a toolkit for placing EDI at the centre of everything we do, and outlines our priorities and practical steps to achieve them. We will take positive action to improve the opportunities and experiences of under-represented groups, such as women, black and minority ethnic, LGBTQ+ and disabled staff and students. And we will reduce the incidence of bullying and harassment, compile and publish data to monitor our progress, collaborate internally and externally to develop good practice, and be open to dialogue and challenge on all this work.

We won't be starting from scratch. Over the past ten years, we've done a lot to try to advance gender equality, for example. Much has been centred on the Athena SWAN Charter, which aims to increase representation and progression of women in academia. Benchmarking schemes like this are important and I think it's healthy to hold ourselves to external standards, but they can become constraining if you focus too much on the requirements of the scheme rather than achieving real change on the ground.

Beyond gender equality, there are many other aspects of equality and diversity that have not necessarily received the attention they deserve in academia, and we are working to rectify this. We participate in the Stonewall Workplace Equality Index, which aims to support LGBTQ+ staff and students, and we're a Disability Confident Employer. We have also signed up for the Race Equality Charter, which is intended to improve the experiences of black, Asian and minority ethnic staff.

The creation of my role shows Imperial is serious about moving with the times. But delivering the action plan will not be my task alone. The clear message must be that it's everyone's job, from the most senior echelons of the leadership to our undergraduate community.

The challenge now is in making sure the programme is delivered effectively over the coming years. We can't shy away from having difficult conversations, and there will inevitably be some resistance. Even at a progressive institution such as Imperial, there will be people who may think this is not part of our duty – those who see it as a bolt-on or even as 'political correctness gone mad'. But this is an argument that we have to win, and that we will win.

We're very interested in reaching out to our alumni community to help us achieve our goals. We would love to welcome Imperial graduates from under-represented groups to come back to talk to our students and staff about how they overcame any barriers that they experienced. We need role models to show younger people from similar backgrounds that there are people like them who have gone on from Imperial and thrived in the outside world.

> The strategy is a chance to ensure Imperial is a place where everyone's individuality and dignity is cherished

There are great opportunities here. We can be even better at doing the things we already excel at. We can make research more relevant, and attract both staff and students who may not previously have considered Imperial as a place where they would feel comfortable. The new strategy is a call to action to everyone at Imperial – and a chance to ensure it is an institution where the dignity and individuality of everyone is respected and cherished. ◆

> ***Stephen Curry*** *(Physics 1985, PhD 1988) is Assistant Provost (Equality, Diversity and Inclusion) and Professor of Structural Biology.*

INTERVIEW: WILLIAM HAM BEVAN

MALARIA: WINNING THE FIGHT

A single mosquito strike is all it takes to become infected with malaria, a disease that kills 800,000 people every year. At Imperial's mosquito labs, researchers are using gene-drive techniques to stop infection in its tracks.

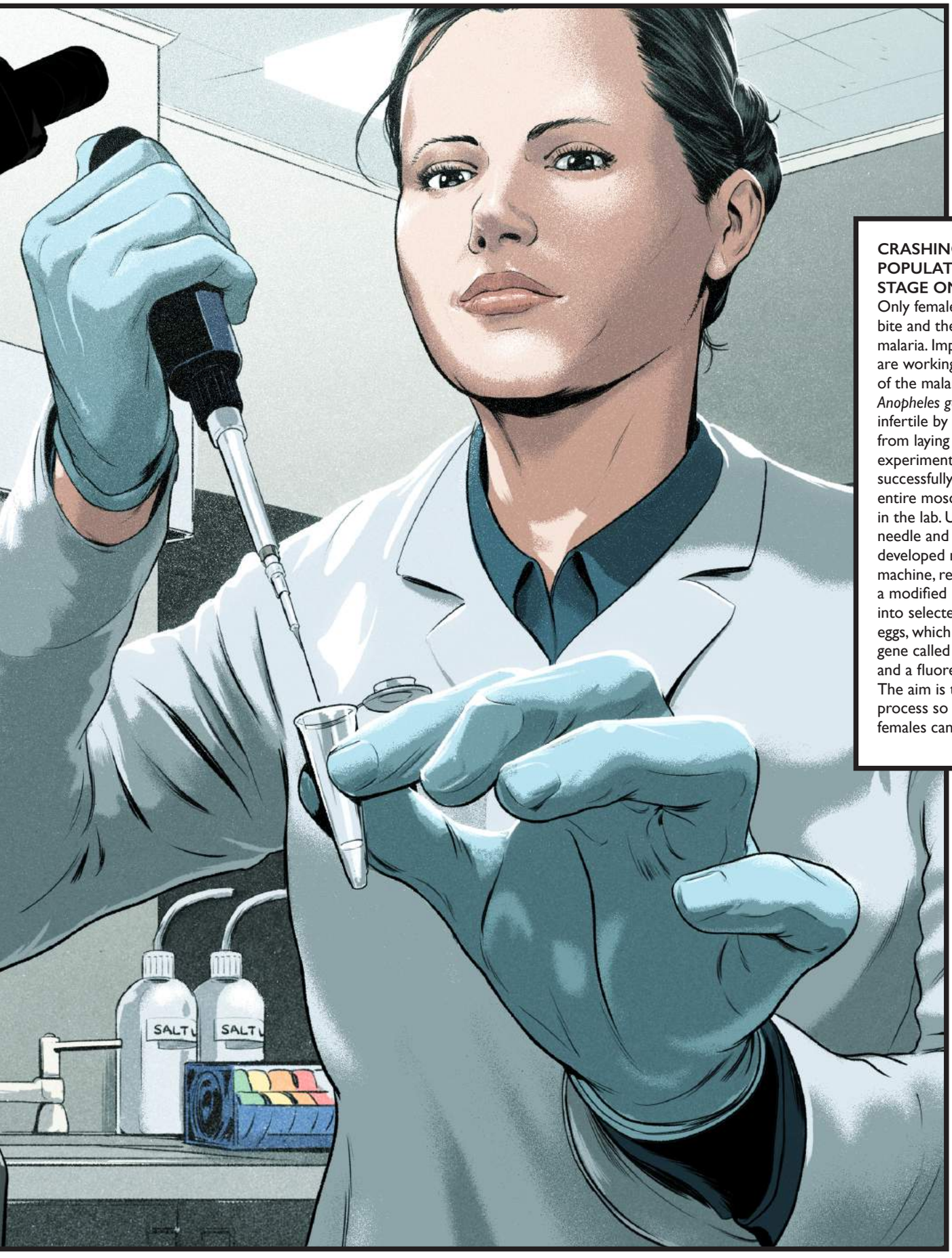
Words: **Lucy Jolin** / Illustration: **Guy Shield**

Down a violet-painted corridor and through a hefty pair of doors, the bloodsuckers are hungry. As research associate Dr Roya Haghighat-Khah splays out her hand just above a white-mesh box containing about 50 female mosquitoes, they fly up to the top and desperately hang on. It's only the females that bite humans, she points out cheerfully. "You can see their proboscis pierce the mesh."

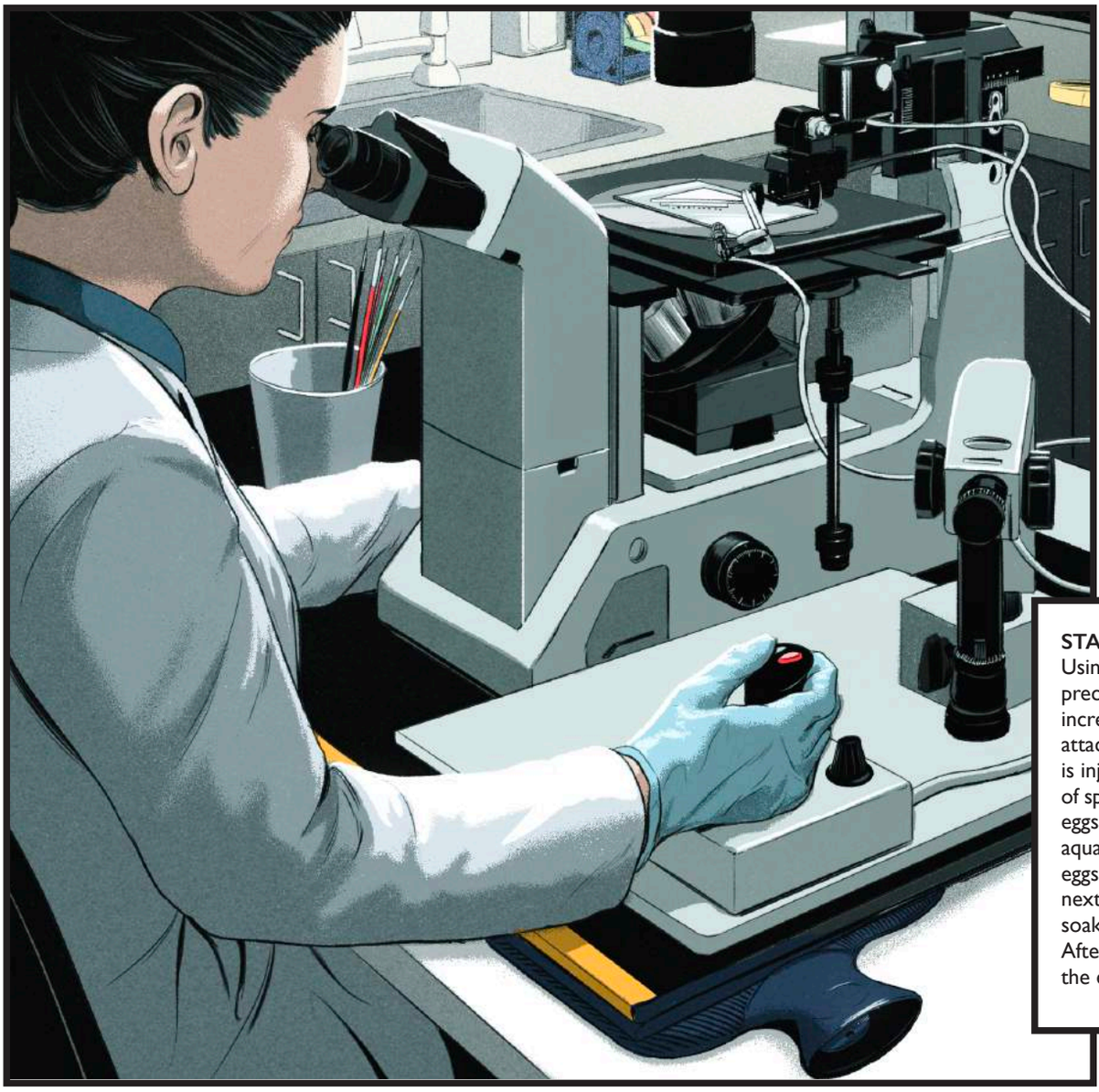
Here, deep in South Kensington's Sir Alexander Fleming Building, stainless-steel shelves hold yet more white-mesh boxes, all full of mosquitoes, while larvae and pupae wriggle away in dishes, waiting to be fed fish food pellets. In the fridge sit tasty bottles of blood meal, made from cow's blood. And on a table lies 'The Executioner', a tennis-racket-shaped electronic mosquito zapper designed to make short work of any escapees.

This lab is the site of potential game-changing discoveries in the age-old battle against one of the planet's oldest and deadliest threats – malaria. Despite antimalarials, insecticides, protective nets and a rudimentary but, as yet, unlicensed vaccine, malaria still kills 800,000 people a year, with around half a million less lethal cases annually. UNICEF estimates that a child dies from the disease every 30 seconds.

But the mosquitoes bred in the several Imperial insectaries are special – though some may also be unwittingly threatening their own species' wellbeing. Last year, Professor Andrea Crisanti and colleagues in the Department of Life Sciences became the first to successfully 'crash' a mosquito population of *Anopheles gambiae* (the main ▶



CRASHING THE POPULATION – STAGE ONE:
Only female mosquitoes bite and therefore spread malaria. Imperial scientists are working to make females of the malaria-carrying *Anopheles gambiae* species infertile by preventing them from laying eggs. In this experiment, researchers successfully wipe out an entire mosquito population in the lab. Using a super-fine needle and a specially developed micro-injection machine, researchers inject a modified DNA gene drive into selected mosquito eggs, which impacts a crucial gene called doublesex and a fluorescent marker. The aim is to disrupt the process so that fewer females can reproduce.



STAGE TWO:
Using a microscope and a precision joystick with an incredibly thin needle attached, the modified DNA is injected into the tail end of specially prepared mosquito eggs. To keep them in an aquatic environment, the eggs are placed in a glass file next to moist blotting paper soaked with salt water. After three to four days the eggs hatch into larvae.

carrier: not all mosquitoes spread malaria) in a lab, using genetically modified mosquitoes.

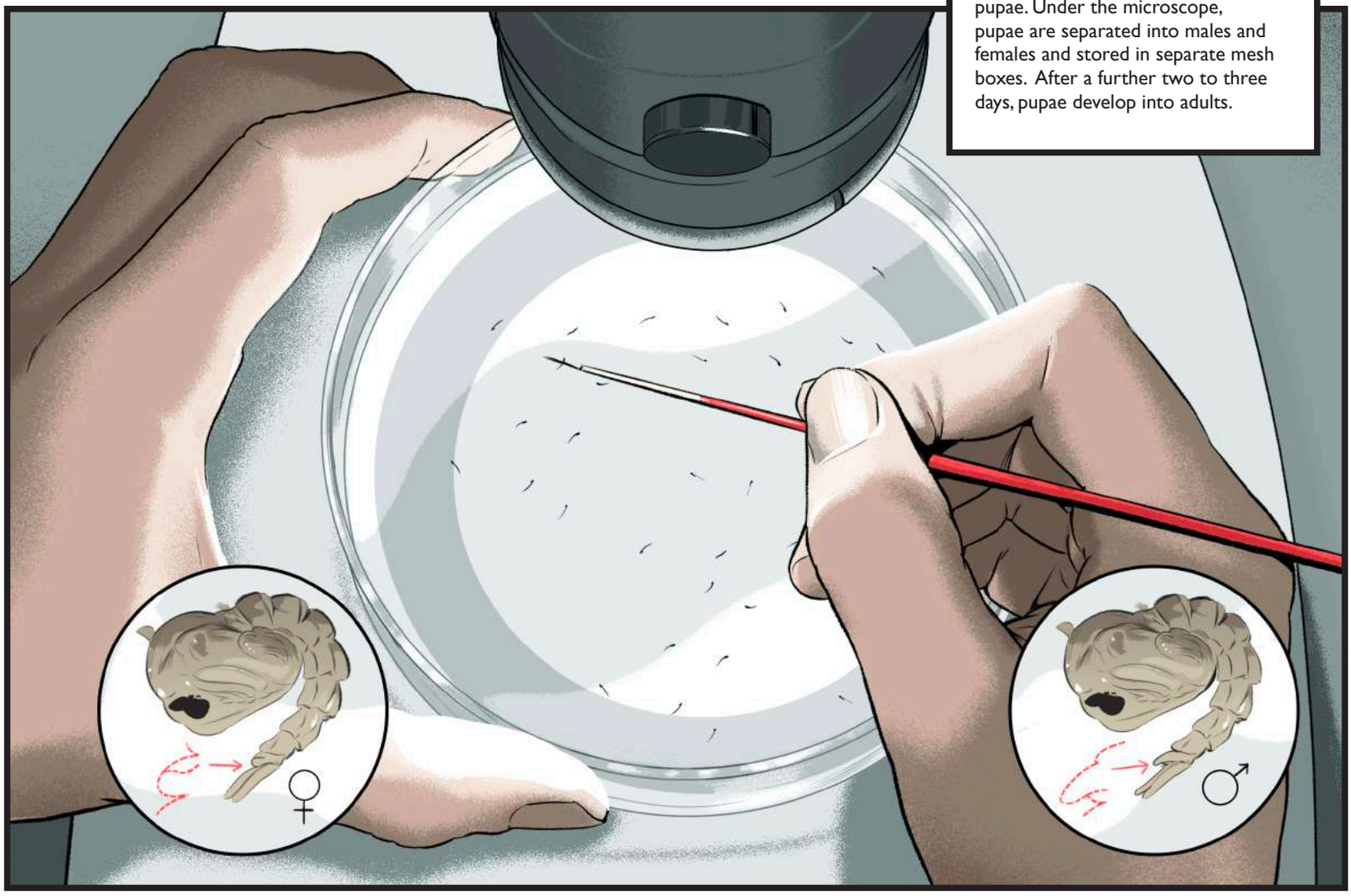
They harnessed the gene-editing molecule Crispr to develop a novel genetic tool known as a 'gene drive'. It progressively spread a genetic modification into the mosquito population designed to destroy a crucial gene called doublesex, which enables females to develop. Males that carried this modified gene didn't change, and neither did females with only one copy of the modified gene. But females that carried two copies of the modified gene showed both male and female characteristics. Because of this, they didn't display female behaviour: they didn't bite and they didn't lay eggs. It took just eight generations for the population to crash – the equivalent of three months.

This is a significant discovery for those places where malaria thrives alongside war, famine and poverty, says Crisanti, Professor of Molecular Parasitology. In principle, his genetic technology doesn't need any human intervention – it spreads by itself. Now, a new challenge awaits: convince the world.

"An entire field of social science has opened up to convince people that the technology is safe and can be utilised for the purpose for which it has been developed," says Crisanti. "The concern around destruction of a species is a consequence of our short-term perspective on nature, due to our short lifespan. Species appear and are destroyed continuously."

Another possibility, of course, is to find drugs that will stop transmission of the parasite. But this is a particularly fiendish problem, points out Jake Baum, Professor of Cell Biology and Infectious Diseases, because malaria is not a bacteria or a virus, whose ability to avoid the immune system or evolve drug resistance is limited by the small amounts of information they can access. Instead, malaria is a complex and ever-changing parasite, with thousands of genes more like one of our own cells. And if you get rid of malaria in mosquitoes, it doesn't follow that you'll also get rid of malaria in humans. It's like a relay race, he says, with humans and mosquitoes passing the parasites from us to them, them to us.

Baum's lab is working on some of the most fundamental questions surrounding the malaria parasite: how does it actually cause infection and how might understanding



STAGE THREE:
The larvae are fed on fish food pellets and, after seven days, become pupae. Under the microscope, pupae are separated into males and females and stored in separate mesh boxes. After a further two to three days, pupae develop into adults.

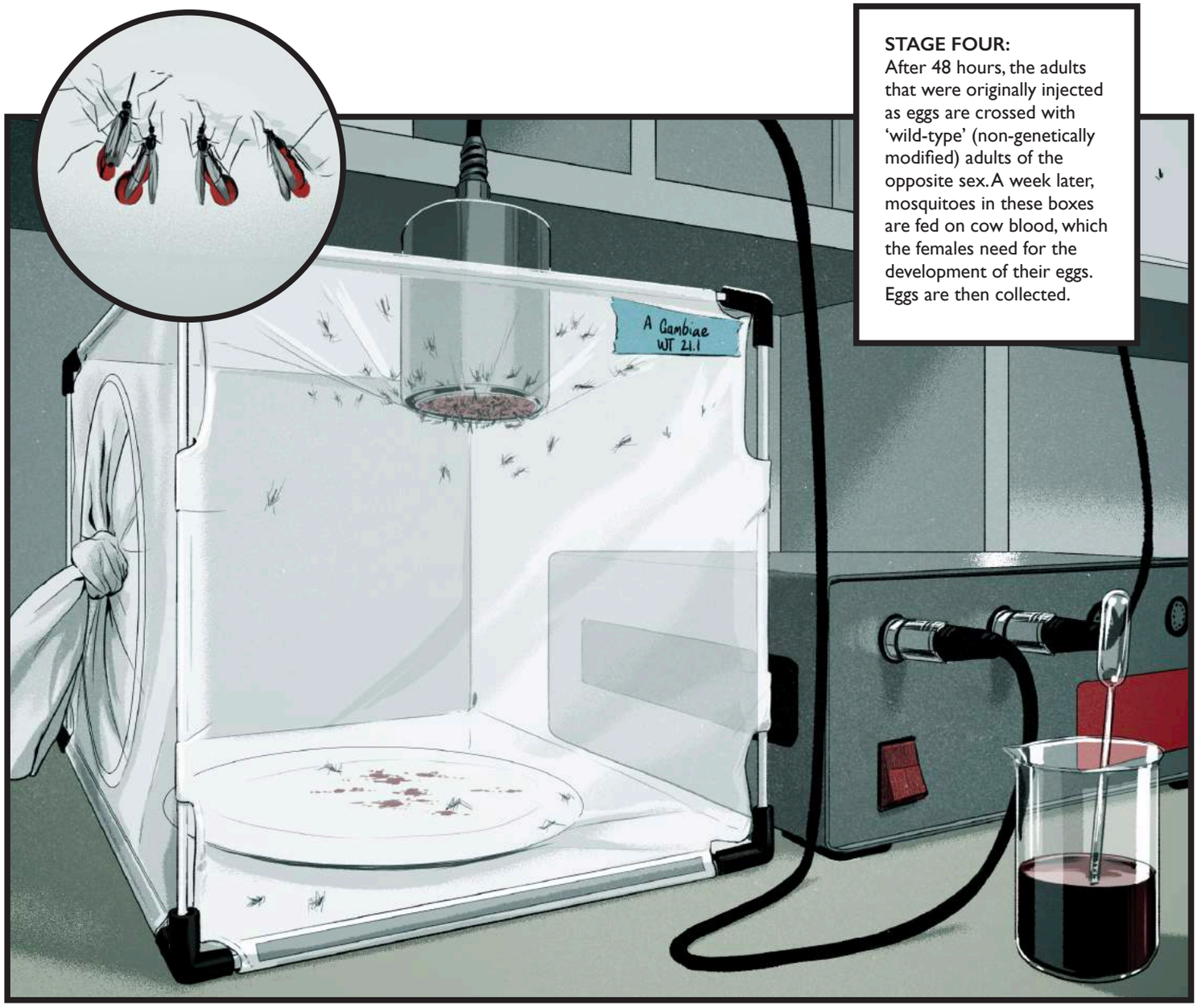
this process better lead to a vaccine? In his insectary, they breed a South Central Asian mosquito called *Anopheles stephensi*, and maintain parasite strains that have been collected over decades. He's a fan of basic fundamental science, as well the 'art of looking'.

"My mother was an abstract painter, so I was always taught to look," he says. "For example, when the parasite is taken up by the mosquito into its stomach, it becomes activated by the drop in temperature and increase in pH level. If you drop the temperature and fool the parasite into thinking it's in the mosquito, you can watch the transformation happen. And then you can train a microscope to watch it happening on a massive scale, and use this to screen for drugs that stop the activation process." His lab has recently used this technique during a project funded by the Bill and Melinda Gates Foundation to screen 70,000 drug compounds, collected by the University of Dundee, which might stop humans from transmitting malaria to mosquitoes.

Vaccines are, of course, a crucial potential weapon. But they have proved hugely difficult to find, again due to the complex nature of the parasite. One vaccine, RTS,S, has been trialled in children, but shows around only 30 per cent efficacy. "And there is nothing else as advanced as that, which leaves us really vulnerable," says research associate Dr Fiona Angrisano.

Instead, Angrisano's current work is focused around a protein called HAP2, which can be found on the surface of the reproductive cells of male malarial parasites. When these ▶

The gene drive results in population crash in just eight generations – the equivalent of three months



STAGE FOUR:
After 48 hours, the adults that were originally injected as eggs are crossed with 'wild-type' (non-genetically modified) adults of the opposite sex. A week later, mosquitoes in these boxes are fed on cow blood, which the females need for the development of their eggs. Eggs are then collected.

parasites are shot into a human by a mosquito bite, they infect first the liver, then the red blood cells. When they are bitten by another mosquito, that mosquito picks up the parasite, after which male and female reproductive cells of the parasite combine in the stomach of the host, then grow and travel to the salivary glands of the mosquito, ready to transit the malaria-causing parasite when the mosquito next bites a human. But blocking part of HAP2 disrupts that process, meaning that the mosquito won't transmit the parasite.

The team at Imperial demonstrated that blocking part of HAP2 disrupts fertilisation. Initially the team created an antibody that blocked fertilisation events in vitro by 89.7 per cent. To test if the same effect was observed in animals, the team then created and administered an HAP2 vaccine for mice infected with the malarial parasite and found that the experimental vaccine reduced malarial transmission by 58.9 per cent compared with non-vaccinated mice.

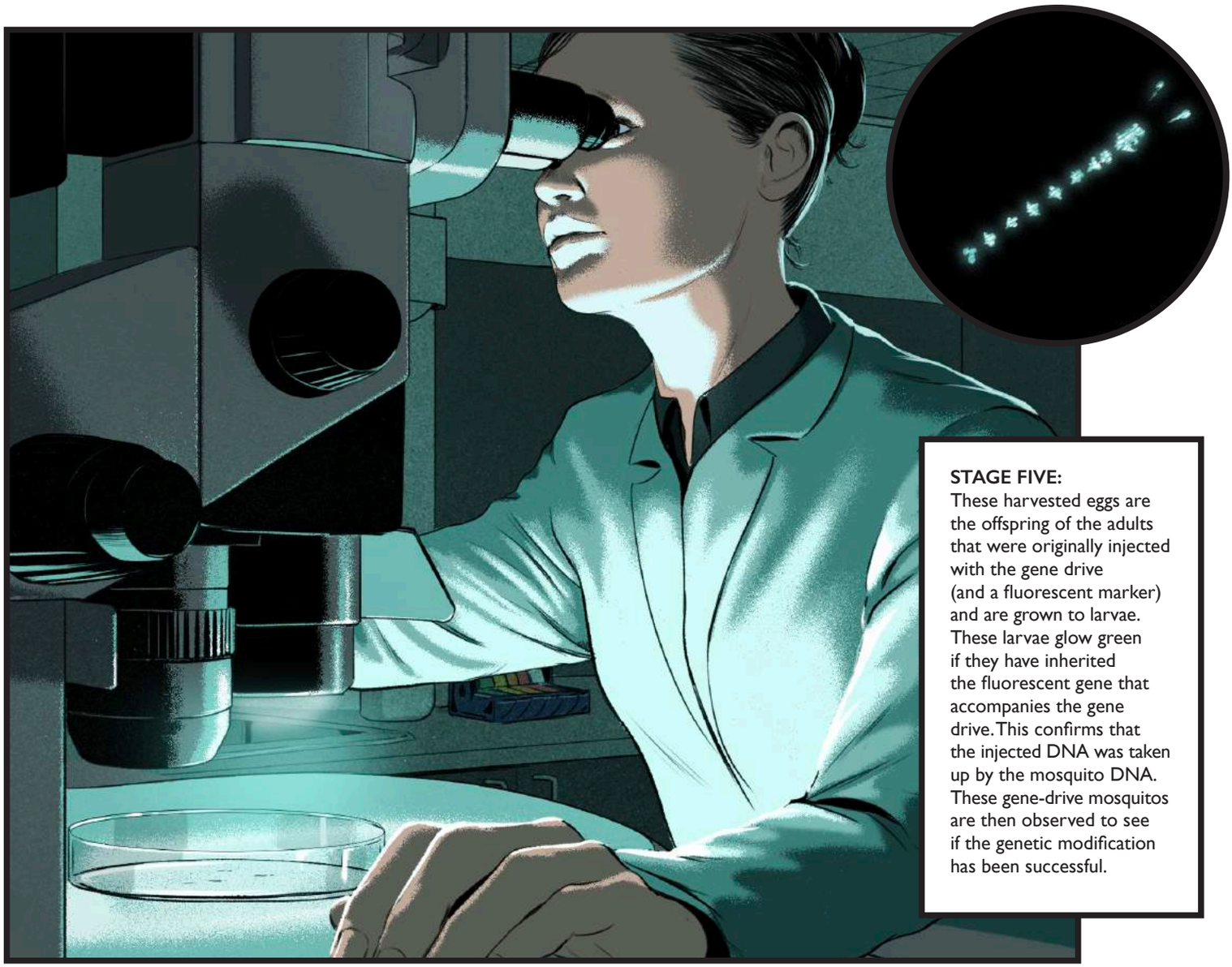
Imperial-bred mosquitoes, once again, have been vital to the success of this work: it means that Angrisano and her colleagues can look at how the transmission-blocking process works in real mosquitoes. By allowing mosquitoes to feed on vaccinated and non-vaccinated mice, they can dissect the mosquito midgut and count the number of successful fertilisation events present, thus determining the reduction in malarial transmission.

"We've shown in the lab that we can block fertilisation well, and so the aim of this research is to try to enhance the reduction in transmission we see by developing this vaccine further," says Angrisano. "The overall aim of a transmission-blocking vaccine such as HAP2 is to treat the herd. It won't necessarily stop disease burden or symptoms for an individual but, eventually, if everyone's vaccinated, we may stop the spread of malaria."

Dr Aubrey Cunnington, Clinical Senior Lecturer in the Faculty of Medicine, is coming from yet another angle: trying to understand what's actually going on inside the human body when there's a malaria infection. In particular: what makes malaria kill some people and not others?

His lab is also focusing on genes, studying all the human and parasite genes expressed in an infected blood sample. They're particularly interested in the role of genes encoding

SPECIAL THANKS TO ROYA HAGHIGHAT-KHAH WHOSE EXPERTISE WAS INVALUABLE IN THE CREATION OF THESE ILLUSTRATIONS.



STAGE FIVE:
These harvested eggs are the offspring of the adults that were originally injected with the gene drive (and a fluorescent marker) and are grown to larvae. These larvae glow green if they have inherited the fluorescent gene that accompanies the gene drive. This confirms that the injected DNA was taken up by the mosquito DNA. These gene-drive mosquitos are then observed to see if the genetic modification has been successful.

Vaccines are a crucial potential weapon, but the parasite's complex nature means they are challenging to develop

the granules inside a type of white blood cell called neutrophils. People with a high expression of these genes have been shown to be more likely to have severe malaria – but they could also be important in preventing malaria parasites getting into red blood cells, protecting against the disease.

"One of the things the neutrophils do when a bug invades your body is release these granules, which are preformed inside them," explains Cunnington. "It's like throwing hand grenades. They damage the bugs but can also damage the body's cells. They have a defence function, but if you have too much of it, it usually results in problems for your own body, too. We've identified that neutral granules seem to be pretty important and strongly associated with severe disease in humans."

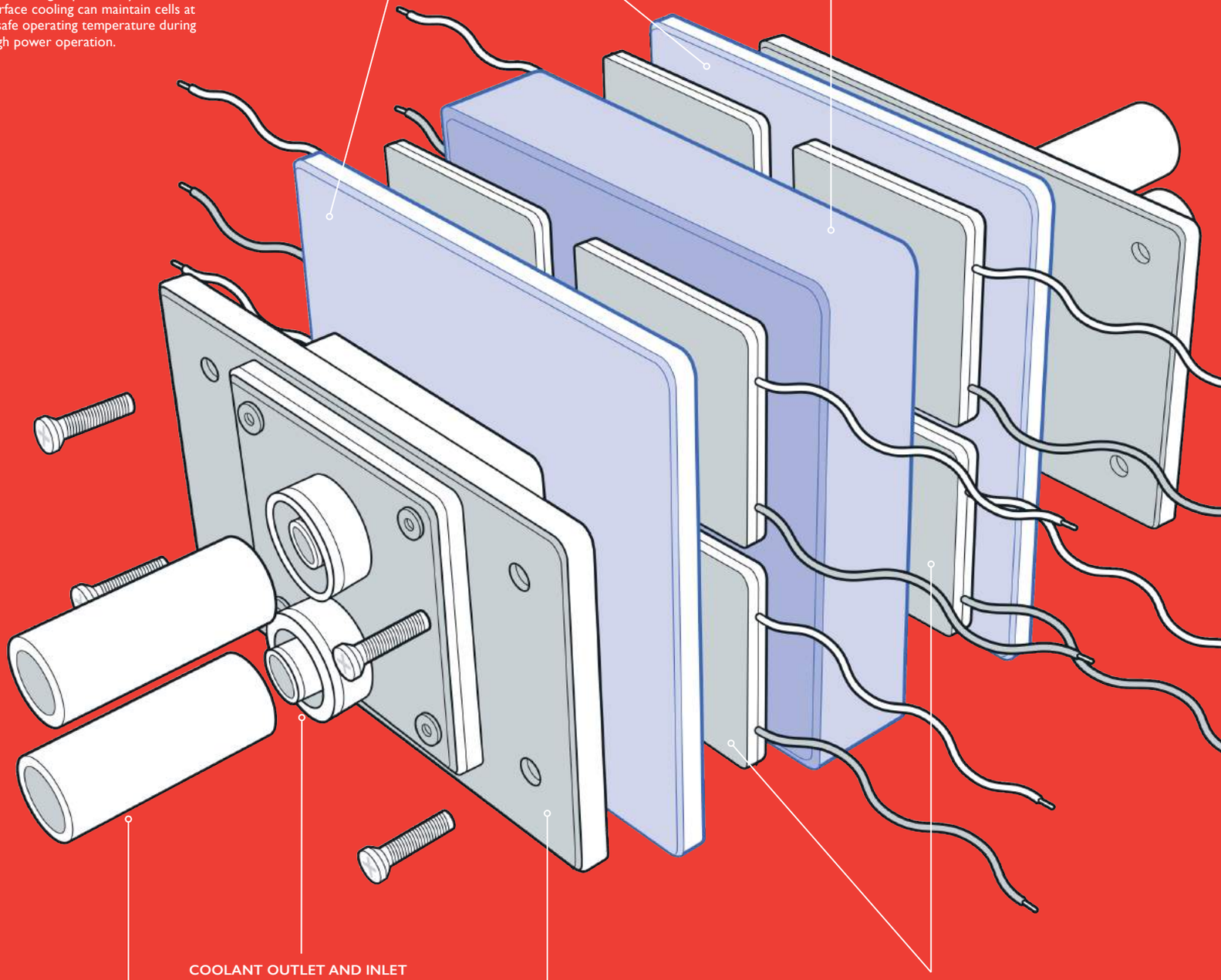
The next stage is to investigate further, which they're currently doing in mouse models.

Hard as it may be, malaria is a challenge we cannot ignore, says Baum – and it's likely that there will never be one single solution. Along with Cunnington, he founded the Network of Excellence in Malaria at Imperial, bringing together more than a hundred scientists. "Nobody owns malaria," he points out. "I see myself as a very small part of a very large jigsaw puzzle, and you have to work with all the other pieces. We need every different aspect of understanding if we are to have a hope of finally controlling this ancient foe."

In the insectary, the mosquitoes whine: perhaps this generation will enable the next breakthrough. For now, the malaria parasite lives on – but not, perhaps, forever. ◆

INSIDE THE TAB COOLING THERMAL MANAGEMENT RIG

Increasing the power from a battery pack of a given physical size can be achieved by demanding more current from each cell. As a result, the cells' temperatures increase to levels that shorten the battery life and, in the worst case, cause them to catch fire. This rig explores ways that cell-surface cooling can maintain cells at a safe operating temperature during high power operation.



COPPER PLATE
Conducts heat from peltier elements to the water cooling block

BATTERY CELL
Lithium titanate cell used for high power applications with a long cycle life

COOLANT OUTLET AND INLET
Connects water tubes to the cooling block

WATER TUBES
Cold water is pumped through the water cooling block, carrying away the unwanted heat from the battery cell and peltier elements

WATER COOLING BLOCK
A repurposed computer CPU cooler that transfers heat from the copper plate into the cooling water

PELTIER ELEMENTS X 8
Thermoelectric coolers made of semiconductor material that generate a heat flux based on an applied voltage. One surface becomes cold and is used to hold the cell at a fixed temperature. The other becomes hot as a result and must be cooled by the water block

The not-so-humble battery holds the key to the development of electric vehicles – and to the energy revolution, says Professor Greg Offer.

Illustrations: **Anthony Calvert**

The future of batteries

Batteries are ubiquitous. They've been around for more than 200 years. Even the latest lithium-ion technology, commercialised in the 1990s, can now be picked up for just a pound or two online. But while they might seem like the most ordinary of technologies, the fact is that batteries could well hold the key to an energy revolution, a new economy and minimising climate change. As a researcher working at the interface between science and engineering, it's finding solutions to real-world problems like this that's the real prize.

What do we need to do to change the world? Solve the tricky science and engineering problems posed by electric vehicle batteries. After all, using cleaner fuels, decarbonising the economy and radically redesigning transport systems don't only depend on personal choice and public policy. There are major scientific questions that we still need to answer.

Lithium-ion batteries – the last revolution in battery technology – were designed to be used in small, portable electronic devices, and putting them to new uses like powering electric vehicles generates new challenges. As part of the funding from the Faraday Challenge (see box, page 23), we are developing the modelling tools that industry will need to bridge the gap between the fundamental science and the engineering of battery systems, while researching ways to extend battery life.

For instance, two of the most crucial questions concern diagnostics and prognostics. Batteries have finite lifespans. Each time they're used they lose a little capacity, and as they age they also produce less power, so the battery eventually needs replacing. But while this is a minor inconvenience for a mobile phone or laptop, it's a major issue for an electric vehicle that's made worse because we lack the technology to diagnose a battery pack's state of health.

One of our papers showed that two similar batteries aged in different ways can show the same capacity and power fade, but one can remain safe to use for a further 1,000 cycles, while the other could explode the next time it's used. We concluded that how each battery ages makes the difference, and our aim over the next ten years is to turn this science into better battery management systems for the electric vehicle industry.

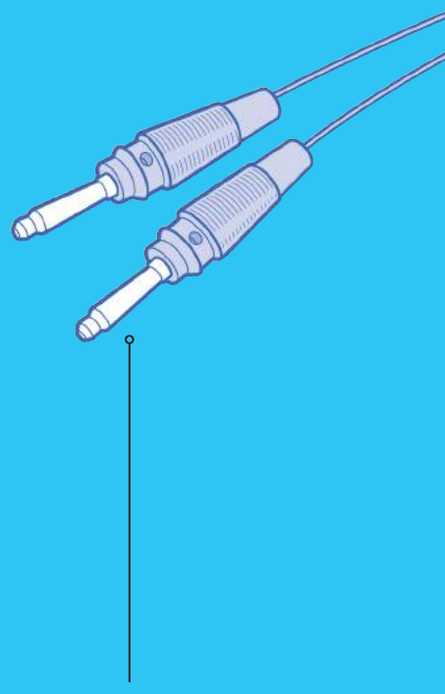
The flip side is prognostics, because alongside better diagnostics, the industry also needs to know how long a cell will last, something that's currently impossible to predict. Designers today rely on empirical models – collecting past data to predict what will happen in the future, but this is expensive as well as inaccurate. What we really need are models based on science, which means understanding the degradation mechanisms at play and using these to make more accurate models.

We're also involved in multiple projects focusing on translating our fundamental knowledge of battery life and thermal management into real-world applications that involve more than a dozen industrial partners. These include Innovate UK projects involving the likes of Rolls-Royce, Williams Advanced Engineering, Caterpillar, Delta Motorsport and Aston Martin.

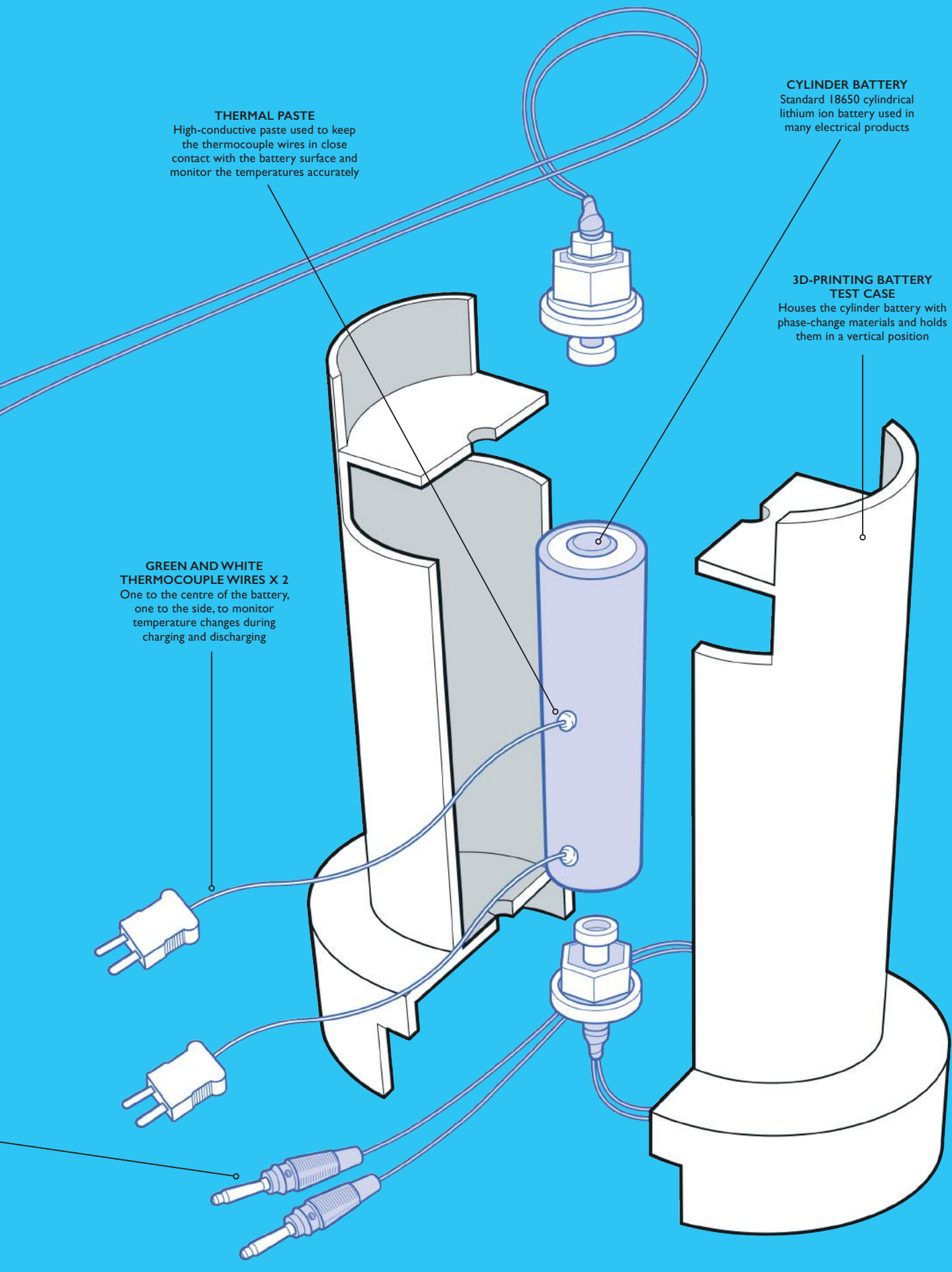
We know, for instance, that the way batteries behave – and how they degrade – depends heavily on temperature. ▶

INSIDE THE PASSIVE COOLING THERMAL MANAGEMENT RIG

Batteries generate plenty of heat during the charging and discharging process. If the heat is not dissipated quickly, it will accelerate the battery degradation, shorten its life and even cause the thermal runway. This rig employs phase-change materials of RT42 to absorb the heat with its high latent heat capacity, thus maintaining an ideal working temperature environment for the battery cell.



BATTERY CHARGING CABLES
Connect the battery cylinder to the battery testing system, and supply and measure the voltage/current during charging and discharging


THERMAL PASTE
High-conductive paste used to keep the thermocouple wires in close contact with the battery surface and monitor the temperatures accurately
CYLINDER BATTERY
Standard 18650 cylindrical lithium ion battery used in many electrical products
3D-PRINTING BATTERY TEST CASE
Houses the cylinder battery with phase-change materials and holds them in a vertical position
GREEN AND WHITE THERMOCOUPLE WIRES X 2
One to the centre of the battery, one to the side, to monitor temperature changes during charging and discharging

Alumni Weekend

29–30 June 2019

Experience the best that The Great Exhibition Road Festival has to offer, reunite with classmates and celebrate your Imperial connection at Alumni Weekend 2019.

- Escape the crowds and relax with family, guests and your fellow alumni in the private Alumni Lounge
- Get early bird access to our tour tickets
- Enjoy a preview before the Festival officially opens to the public
- Organise a class reunion (with our help)
- Celebrate with your department or faculty at a welcome back reception
- Mark your graduation milestone with special events

Tickets from £5. Classes of 2018 and 2019, and under-16s go free!

www.imperial.ac.uk/alumni-weekend

CAN'T MAKE IT TO LONDON?

Fear not – we are bringing Alumni Weekend to wherever you are in the world! Celebrate your time at Imperial with fellow alumni in your area – check the website or volunteer for an event near you.

Batteries perform best and most efficiently the hotter they get, because most desirable electrochemical processes occur faster at higher temperatures. But the same is true of processes that you don't want to happen. Degradation mechanisms get faster and more aggressive at higher temperatures, resulting in an inevitable trade-off between how a battery performs and how long it lasts.

Like the porridge-eating, fairytale character, there's a Goldilocks region. It depends on application, but for most battery cells this sweet spot is around 30°C. The trade-offs differ but the science remains the same. Whereas Formula 1 car batteries operate above 100°C and only last for a couple of races, the electric vehicle companies we work with want batteries to last ten years, so how do we keep cells at the optimum temperature?

The solution may sound simple, but it's not. Tesla cars, for example, are powered by cells roughly the size of an AA battery. Of course, they don't use just a couple, there are 5,000 to 8,000 cells packed together in the bottom of the car, and keeping thousands of small cells at the right temperature is extremely difficult. That's not the only challenge: temperature gradients are even more important. Our experiments and models show that operating most batteries at higher temperatures with smaller temperature differences between individual cells is better than lower temperatures with higher thermal gradients.

Across the world, the drive towards electric vehicles is picking up pace. In 2018, electric vehicles accounted for two per cent of new vehicle registrations in the UK. In Norway, that figure was 48 per cent. And China's massive market saw 142,000 electric vehicles sold in the first quarter of 2018 – an increase of 154 per cent over the previous year.

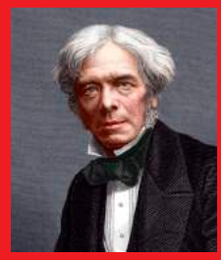
In the UK last year, sales of electric vehicles rose by 11 per cent. The government plans to end sales of new conventional diesel and petrol cars and vans by 2040, halve the number of people exposed to levels of particulate matter that breach WHO guidelines by 2025, and it's setting new long-term air quality targets for particulates.

But at the heart of everything lies the humble battery, and it's hard to overstate the excitement of being in battery research today. I always wanted to be a scientist and I always wanted to make a difference. As an undergraduate chemistry student at Imperial in the 1990s, I was fascinated by electrochemistry and started working on fuel cells before discovering batteries. By working on batteries, I thought that I could be part of one of the most exciting periods of change in transport and the automotive industry. What I didn't predict was the Faraday Challenge – it's a game changer, not just for me, but for the world.

By focusing on battery packs for electric vehicles, Imperial can support the UK's growing battery industry, bringing jobs and investment. It's the kind of opportunity that comes along once in every ten careers – having the chance to make this much impact at this stage in my career is amazing. Without it, the alternative is breathing polluted air and suffering the more extreme consequences of climate change, so it's essential for us all. ◆

> *Dr Greg Offer (MSci Chemistry 2001, PhD 2006) is a Reader in Mechanical Engineering at Imperial.*

PROFESSOR OFFER WAS INTERVIEWED BY BECKY ALLEN. IMAGE: SCIENCE PHOTO LIBRARY



BATTERY REVOLUTION: THE FARADAY CHALLENGE

The Faraday Challenge, named after Michael Faraday, who discovered electromagnetism, benzene and electrolysis in the 1820s-30s, is a £246m government investment in the UK research, innovation and scale-up of battery technology, part of the UK government's industrial strategy.

The aim is to ensure that batteries – whether in cars, aircraft or grid storage – will be a cornerstone of a low-carbon economy, through investment in three initiatives: a new UK Battery Industrialisation Centre in Coventry; a series of collaborative research and development projects led by Innovate UK; and the Faraday Institution, a new virtual research institute based in Harwell, Oxford.

Imperial was a founding institution: in 2018, it was announced that the College would lead one of the Faraday Institution's first four flagship projects, and work on a second led by the University of Cambridge researching ways to extend battery life.

The team at Imperial plays a significant role in the effort going into the Faraday Challenge. The Imperial-led Multi-Scale Modelling Fast Start project, worth £10m, brings together scientists, engineers and mathematicians – 72 researchers across eight UK universities – to make the modelling tools that industry needs to bridge the gap between the fundamental science and the engineering of battery systems.

Imperial also won a significant chunk of the research and innovation project funding, led by Innovate UK, as part of the Faraday Challenge.

The College's Electrochemical Science and Engineering group won funding for nine of the Innovate UK battery research projects, and has just won two more, in total worth more than £13.4m, that focus on battery life and thermal management, and which involve more than a dozen different industrial partners. Its ultimate aim is simple: to make better batteries.

faraday.ac.uk

With market size, demographics, and necessity providing the spur, African innovators are leapfrogging the rest of the world

Words: **Megan Welford** / Illustration: **Ian Dutnall**

AFRICA IN NUMBERS

GDP
US$1,649,000,000,000

GDP GROWTH

3.6% 2017

4.1% 2018/9 (ADB)

LABOUR PRODUCTIVITY

+2.2% 2010 2013(ADB)

POPULATION
1,061,000,000

16% OF WORLD'S POPULATION (UN 2017)

WORKING AGE POPULATION SET TO INCREASE BY 2,000,000,000 (BY 2100)

URBAN POPULATION 42.5% (UN 2015)

GROWTH RATE 2.6% (UN 2015)

LIFE EXPECTANCY 60
2016-2060 (1960 40) (WORLD BANK)
58.6 MEN 61.9 WOMEN

INFANT MORTALITY 57.2 PER 1000 LIVE BIRTHS
(UN 2013-2018) (2000-2005 80.7)

EDUCATION

PRIMARY SCHOOL ENROLMENT 97.3% (UNESCO 2016)

FINISHING PRIMARY SCHOOL 56% (UNESCO 2015)

SECONDARY SCHOOL ENROLMENT 33.5% (UNESCO 2016)

TERTIARY EDUCATION ENROLMENT 9% (UNESCO 2016) (1970 - 1.4%)

EMPLOYMENT

7.9% UNEMPLOYMENT RATE (UN)

53% DIRECT EMPLOYMENT IN AGRICULTURE (UN)

13.5% EMPLOYMENT IN INDUSTRY (UN)

33.6% EMPLOYMENT IN SERVICES AND OTHER (UN)

AGRICULTURE

REMAINS AFRICA'S LARGEST EMPLOYER

70% OF THE POPULATION EMPLOYED EITHER DIRECTLY OR INDIRECTLY

TRADE

EXPORTS $355,742m (UN 2017)

IMPORTS $480,744m (UN 2017)

OTHER

73% PEOPLE OWN A MOBILE PHONE
SMARTPHONE USE DOUBLED BETWEEN 2014 AND 2106

0.84 CO_2 EMISSIONS METRIC TONNES PER CAPITA (WORLD BANK 2014)

41% PEOPLE LIVING IN POVERTY
UNDER $1.90 / DAY (WORLD BANK 2015) (2015 59%)

23.4% SEATS HELD BY WOMEN IN NATIONAL PARLIAMENT (UN)

A huge – and growing – demographic. The ability to harness enormous tech potential. Megacities driving a youthful and entrepreneurial outlook. And now the world's second biggest continent could soon become one of its biggest drivers. The so-called 'demographic dividend' means the continent is well placed to take advantage of the 'fourth industrial revolution': an era of big data and artificial intelligence. And Imperial's alumni, research and expertise are at the heart of the knowledge explosion.

"In the past, a lot of our work with Africa was based on 'addressing African problems'," says Imperial's Vice-President (International), Professor Maggie Dallman. "But now we're developing areas of expertise and academic exchange. Bringing brilliant people here – and sending brilliant people there."

One person who understands that exchange better than most is Imperial alumna Natalie Jabangwe (MBA 2012), CEO of Africa's largest mobile-phone-based financial services company, EcoCash. "More Africans own a mobile phone than own a toothbrush," says Jabangwe. "Necessity is the mother of invention, and in mobile financial services and technology, Africa is leapfrogging the rest of the world."

Launched in 2011, EcoCash registered 31 per cent of Zimbabwe's adult population in the first 18 months of doing ▶

business, with 22 per cent of Zimbabwe's GDP passing through the platform. Seven years on, the company has eight million registered customers, banks 80 per cent of the adult population of Zimbabwe, and accounts for more than 70 per cent of the country's GDP.

"The continued growth of the African economy will depend on SMEs' access to credit," says Jabangwe. "This is where the biggest growth will come from. Sixty per cent of the world's 200 billion SMEs are in Africa, yet 75 per cent of African SMEs don't have that access."

Which is why EcoCash, alongside other mobile money services companies such as M-Pesa in Kenya, has developed a solution. "In the absence of collateral," explains Jabangwe, "we can use data – your income and expenditure, how often you top up your phone, who you communicate with, how often you move around – to get a picture of your financial circumstances and cut through traditional financial eligibility."

"I've lived in many different places," says South African Benji Meltzer (MSc Bioengineering 2014), "and the opportunity in Africa is huge. The tech talent is very strong and people are embracing technology, because they have to. Governments and the climate have done them no favours."

Uzoma Dozie (MBA 1998), who as CEO of Nigeria's Diamond Bank oversaw its recent merger with Access Bank, agrees. "The UK, for example, has been very slow to take up mobile banking solutions," he says, "and that's because people had other banking options. Getting people to change their behaviour – towards digital adoption, for example – is harder when they already have options."

He points out that there are 17 million SMEs in Nigeria that are still 'unbanked' – they don't have a bank account. "That is a huge customer base that is financially excluded because banks are not compatible with their lifestyle; they can't physically get to one, they don't have utility bills to open an account."

Diamond Bank's response has been to team up with mobile telecoms company MTN to offer a current account in response to a text. "We opened ten million bank accounts in two years," says Dozie. Customers begin by being able to send and receive small amounts of money and can access more services as their financial stability, and access to documentation, grows.

The bank also collaborated with Nigerian fintech companies to develop a banking app and then take it to market – literally. "In markets all over the country, people, particularly women, were buying and selling goods via lots of small cash transactions. A 'money man', basically an extortionist, would hold the cash for them and take a cut. They never really knew how much they had. We trained agents to go in and open bank accounts for them on their smartphones. This is something we take for granted, but which proved to be transformative. Knowing how much money they had, and being able to control it, meant people could save for their children's education or to move to a better place, or grow their business." ▶

29 million customers

The merger of Diamond Bank and Access Bank has created the largest retail bank in Africa by customer base (29m)

The Imperial connection:
Uzoma Dozie (MBA 1998),
CEO of Nigeria's Diamond Bank

£9.6bn transactions

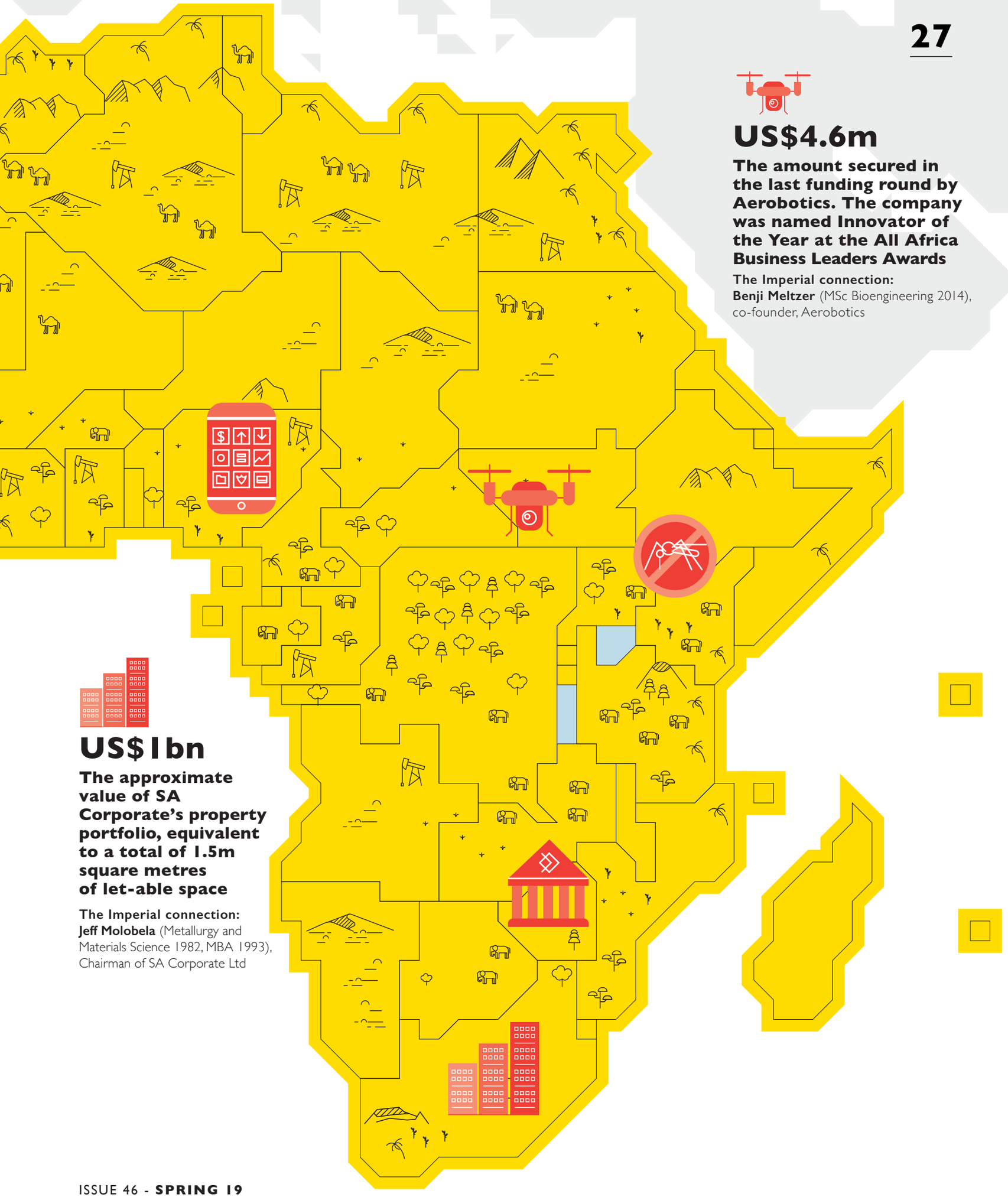
Eighty per cent of the adult population of Zimbabwe bank at EcoCash, accounting for more than 70 per cent of the country's GDP (the equivalent of £9.6bn)

The Imperial connection:
Natalie Jabangwe (MBA 2012),
CEO, EcoCash

An estimated US$3.1bn

was invested in 2017 into malaria control and elimination efforts globally by governments of malaria-endemic countries and international partners

The Imperial connection:
Dr Jalal-Eddeen Saleh (Medicine 2004),
National Professional Officer – Malaria, Communicable and Non-communicable Diseases Cluster, World Health Organization



US$4.6m

The amount secured in the last funding round by Aerobotics. The company was named Innovator of the Year at the All Africa Business Leaders Awards

The Imperial connection:
Benji Meltzer (MSc Bioengineering 2014), co-founder, Aerobotics

US$1bn

The approximate value of SA Corporate's property portfolio, equivalent to a total of 1.5m square metres of let-able space

The Imperial connection:
Jeff Molobela (Metallurgy and Materials Science 1982, MBA 1993), Chairman of SA Corporate Ltd

> “I would like to sincerely thank all of the donors for their generosity. These funds make a real difference to students’ lives in allowing us to take advantage of all experiences at Imperial without hesitation. The impact of this stays with us all throughout Imperial and much further into the future.”
>
> – Abhinaya Chandrashekar, Medicine BSc 2018, President’s Scholar

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Of course, economies can't grow when the population doesn't have access to healthcare. "Ill-health has a micro impact on household income, the success of small businesses – productivity in general," says Dr Jalal-Eddeen Saleh (Medicine 2004), National Professional Officer with the World Health Organization in Nigeria. "The macro impact is that GDP goes down. Insecurity, turmoil and war shatter health systems. Security is coming back to the continent, and, as it does, so health systems are coming back.

"We eradicated smallpox, and we're nearly there with Guinea worm and polio. Eradication is the endgame and, on the way, there is disease control and elimination." Saleh's particular area of expertise, malaria, is a massive challenge. Estimates suggest the disease retards Nigeria's GDP alone by at least 40 per cent annually, costing nearly 480 billion naira (approximately £1bn) in out-of-pocket treatments. But global efforts such as Imperial's own research (which you can read about on p12) and the Roll Back Malaria campaign (which includes providing treated malaria nets to the population) have resulted in a reduction in prevalence of the disease in Nigeria from 42 per cent to 27 per cent (according to latest figures available). This has a direct impact on economic growth.

Back in South Africa, Benji Meltzer and his company Aerobotics are using big data and machine learning to develop software for drones, which has the potential to boost food security. Agriculture remains the continent's largest industry, employing 53 per cent of Africans. "Drones can survey a huge area of land, making it possible for large-scale farmers to spot problems early, like identifying pests," explains Meltzer. "They can then target their interventions, which is more efficient than blanket-spraying a pesticide." Meltzer is currently working with large-scale farms, but once the technology is developed and adopted by more customers, the cost should come down, making it more accessible for smaller farmers. "Farmers with smartphones already have access to knowledge such as weather forecasts and pest control that they didn't before," he adds.

But, of course, data connectivity doesn't just miraculously occur, and making it happen throws up various challenges for Africa. "Data connectivity is going to be key in driving Africa's participation in the global economy," says Jeff Molobela (Metallurgy and Materials Science 1982, MBA 1993), a businessman and expert on South African telecoms and infrastructure. "Young people demand access to instant communication and information. But African telecoms companies need to pay attention to the challenges – they need to facilitate innovation at lower costs to the end user and promote inclusivity. I am involved in bringing new fibre cables into eastern and southern Africa, and I can say that connectivity needs a cross-African focus, for continued innovation."

Data and technology means the democratisation of knowledge, says Jabangwe. "People can now do Imperial MBAs online, for example," she says. "They have access to top-class institutions at a third of the cost, and access to digital learning platforms in different areas."

Finding solutions to the hardest global challenges – from health and infrastructure to nutrition and mass communications – takes inspiration, determination and partnership. But the unique environment that Imperial creates, along with the ability to harness new and emerging technology, is truly transformational. ◆

Knowing how much money you have, and being able to control it, means you can save for your child's education and grow your business

Words: **Becky Allen** / Photography: **Angela Moore**

Smart by design

User-led design has become a development cliché. But for one group of users, essential products have remained clunky, expensive and even unusable.

There had to be a better way. And now, at Imperial, there is.

Ramona Williams always knew she would be an inventor, she just didn't know when it would happen. Born with a rare eye condition that means she is sight-impaired, her eureka moment came when her nephews and nieces arrived. "Taking them out in the buggy for the first time I suddenly realised what it's like to handle a pushchair and a cane. You can't do both," she says.

"Visually impaired friends who were starting families described how hard it was to take their babies out," says Ramona. "Some said they carried their children everywhere, others used their cane in one hand and towed the baby buggy behind them with the other, and a few were so afraid of using a pushchair that they simply stayed at home. I knew there had to be a better way."

After hearing about Imperial's new enterprise and innovation partnership with the London Borough of Hammersmith and Fulham, she attended the launch event at the College's White City Campus and asked whether, together, they could build a better buggy. "I thought it would never happen," Williams says. "Getting a phone call telling me they were keen was really refreshing."

The result is the Smart Baby Buggy, a collaboration between Williams, who is the founder and director of disability training business Eyes for Success, and undergraduate students from the Department of Bioengineering. Borrowing sensor technology from self-driving cars, the buggy has the potential to change the lives of visually impaired parents, enabling them to negotiate their neighbourhoods more safely and easily. It's also the perfect example of user-led design.

The first prototype of the Smart Baby Buggy – complete with LiDAR (light detection and ranging) and ultrasound sensors – was unveiled at the 2018 Imperial Festival. Today, Williams is recruiting testers, raising funds for the next prototype and spreading the word about user-led design. "When you're disabled, you can often be an afterthought," she says. "But if you involve users from the start, you can make the best, most acceptable product."

For Dr Ian Radcliffe, a teaching fellow in the Department of Bioengineering, putting users up front and centre is what actually defines good design. And as module leader for the Department of Bioengineering student engineering design projects, it's a practice he wants to instil in young engineers.

That can mean getting involved in some pretty high-profile and ambitious projects. In the run-up to the Rio 2016 Olympic Games, Radcliffe's students teamed up with GB paralympic swimmer Andrew Mullen to design a new piece of equipment that would give him a better start in his backstroke races. ▶

Left: Paralympian and double Wheelchair Fencing World Champion Dimitri Coutya. Imperial engineering students worked with Dimitri, fencing clubs around the world and the International Wheelchair and Amputee Sports Federation to develop a new, low-cost design for a wheelchair fencing frame that could be easily replicated. It uses materials that are simple to get hold of – or which can be easily substituted – in a lightweight, compact and modular design that allows for modifications and upgrades.


adidas
QUICKIE

All backstroke events begin in the water, with swimmers holding poolside bars in order to launch backwards – presenting unique challenges for some para swimmers. Mullen has some grip with his stumps but cannot reach the bars, and the luggage straps he relied on in the past were awkward and prone to breaking. After talking to Mullen and his coaches, Imperial students designed an ingenious strap adapted from riding stirrups, strapping and climbing carabiners.

Mullen used the new strap at the 2015 International Paralympic Committee Swimming World Championships in Glasgow and at Rio 2016, winning silver in both 50m backstroke finals. "It's a beautiful piece of design, and a showpiece of what user-led design is all about. It's simple, elegant and does exactly what Andy wanted," says Radcliffe.

"The students did everything right. They began by speaking to Andy and his coaches to understand what they needed, what they currently used and the environment. They came back and did all the force calculations, sought inspiration from existing technology, produced several prototypes and trialled them. It's a process of constant user engagement – they shaped the final design and that meant Andy was really happy because it fixed all the issues he faced."

It sounds simple, but the plethora of clunky, expensive and inappropriate devices aimed at people with disabilities illustrates how often designers ignore users. Professor Aldo Faisal, Head of Imperial's Brain and Behaviour Lab, says this is an unforgivable error. "In my lab, students meet amputees and other users from day one. We also work with patient organisations, so we have the whole sociology mapped out," he explains. "It's vital to know who you're designing for."

In 2016, Faisal and a team from Imperial entered the 2016 Cybathlon, the world's first international championships where people with physical disabilities compete to carry out everyday tasks using state-of-the-art technical assistance systems. "It was the first time that assistive technology groups had competed directly against each other – not via academic papers but in technology on the ground – and it brought some startling revelations," says Faisal. "The man who won gold for upper arm amputees didn't have a bionic prosthetic, he had a mechanical device operated by his shoulder using technology that's 550 years old! It shows that when you keep the end user in mind, the solution can look very different."

For Dr Paul Bentley, Senior Lecturer at Imperial and consultant neurologist at Imperial College Healthcare NHS Trust, working with users has been essential to moving engineering ideas out of the lab and into the clinic, where he treats hundreds of stroke patients every year.

Stroke is common and disabling (around 100,000 strokes occur in the UK every year, and more than two-thirds of stroke patients leave hospital with a disability) and, as a researcher, Bentley has been teasing apart the links between physical and cognitive disability after stroke. "People have often approached the two separately," Bentley explains. "But our research showed that a lot of the physical disability arises from cognitive impairment, so we developed a method of assessing both the physical weakness and the cognitive impairment that occur after stroke."

Once he had built an assessment tool that worked well in the lab, Bentley realised that by taking a more frugal technology route, the assessment tool could be 'flipped' into a cheap and portable physiotherapy device that stroke patients could use at home. The new device – called GripAble – means patients can play arm training games using a lightweight electronic handgrip connected via Bluetooth to a tablet computer. It is simple and cheap enough to be used at home, and because it involves computer games, it helps motivate patients to engage in more regular physiotherapy. This year, GripAble won a £1.1m grant from the National Institute for Health Research to develop the world's first online social network of interactive, collaborative games, and is currently closing a second round of funding.

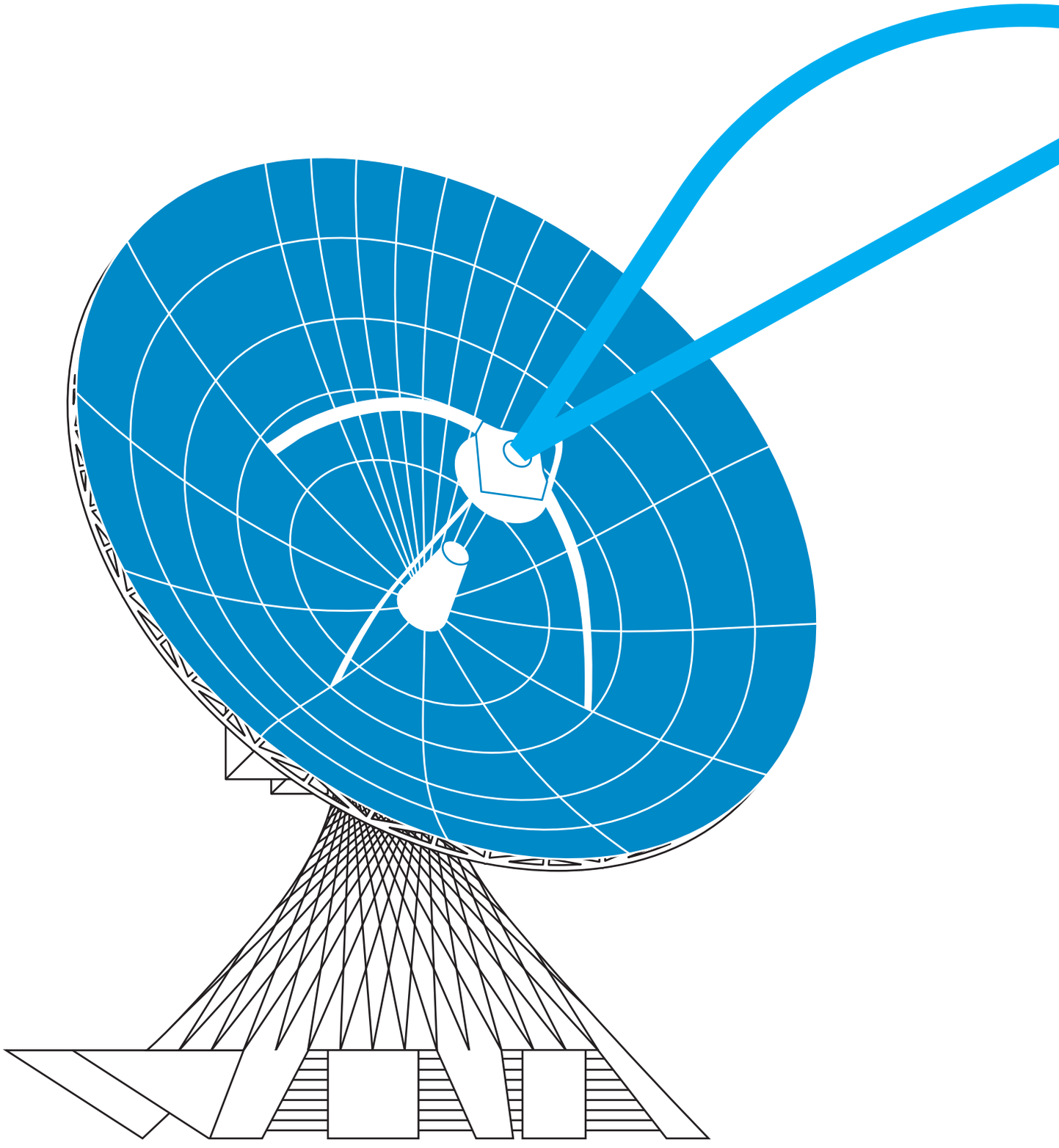
The plethora of inappropriate devices illustrates how often designers ignore disabled users

"Most rehabilitation involves one-to-one supervised physiotherapy. Patients get attention, compassion and bespoke exercises, which makes this the gold standard treatment," says Bentley. "But NHS resources are limited. Millions of patients need physiotherapy, and we know that the more someone exercises, the better the outcomes are, so there has to be another solution."

It has to be the way forward, adds Faisal. "What we've seen in many areas of assistive technology is a lot of engineers making things to show other engineers how smart they are. If you really want to design things that work for people, you need to take very different approaches." ◆

Right: Ramona Williams and her smart baby buggy prototype. Features include: handlebars fitted with 'trembling' pads that give feedback on surrounding hazards and obstacles to the user; rechargeable power pack and control unit mounted under the buggy; and LiDAR unit and four ultrasonic sensors that detect obstacles and hazards in front of and around the side of the buggy.


YOU SHALL NOT PASS!
G30



HOW QUANTUM ENTANGLED THE WORLD

THE QUANTUM WORLD HAS ARRIVED WITH AN INFINITESIMALLY TINY BANG – AND A HUGE IMPACT.

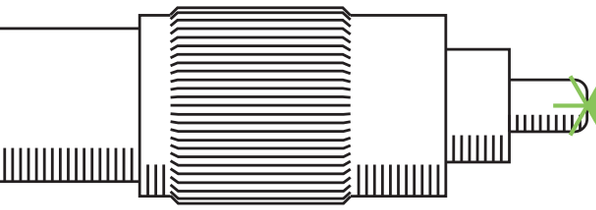
Words: **Philip Ball** / Illustration: **Ian Dutnall**

Myths about quantum technology abound: it will revolutionise computing; it will enable communication faster than the speed of light; it will make the most powerful AI ever seen; or even, it is so complex it's beyond our understanding.

Thankfully we *can* understand it – without that knowledge we wouldn't have smartphones, lasers, GPS or MRI scanners – but as with everything within the quantum world, the unexpected is never far away. However, although the rules of quantum mechanics ultimately govern the behaviour of all matter and energy, it's often only in rather ▶

special and extreme laboratory environments – such as ultra-low temperatures – that its true potential is revealed.

Quantum technologies are now one of the most rapidly growing areas of applied physics, producing high-precision means of measurement and sensing, tamper-proof data encryption, superfast computing and more. Quantum technologies, says Imperial Provost and optical physicist Professor Ian Walmsley (Physics 1980), are being used for sensing and metrology, information technology, telecommunications and the computational simulation of complex physical systems. "The promise of this area is the ability to do tasks that you couldn't do in any other way," he says.



If you send information using quantum rules, that inform

being detectable. That's a massive opportunity if you hav

It was way back in the early 1900s that Albert Einstein kicked off the field of quantum physics, by developing a 'quantum' description of light. He suggested that light – thought previously to be a wave – can behave as a stream of discrete energy packets or 'quanta', called photons. This discreteness of states – they can be this or that, but nothing in between – is one of the hallmarks of objects governed by quantum mechanics.

QUANTUM SUPERPOSITIONS

Information can be encoded into such states just as it can be represented by the discrete binary digits 1 and 0 in conventional computers. But what makes quantum objects different is that they can be placed in so-called superpositions of such states, so that a measurement of the state can elicit either a 1 or a 0, or can see wavelike interference between them. And these quantum states can be 'entangled' (meaning that they are interdependent), creating new possibilities for manipulating data.

Quantum superpositions and entanglement are central to quantum information

technologies such as quantum computers. "The race is on internationally to make a quantum computer," says Walmsley, "and the UK is in a good position thanks to its strong history in this field." Already, prototype devices have been made by giant companies such as IBM and Google, but these are not yet commercially available.

In principle, it should be possible to make an all-optical quantum computer, but Walmsley thinks that a more near-term use of light could be to 'wire together' small units that contain quantum bits (qubits) made from other components.

"Say you have some small system of a few qubits," he says. "In order to scale that up, you have to connect those nodes together, and for many architectures an obvious way to do that is with light." This is the approach being taken in the Hub for Networked Quantum Information Technologies, centred at Oxford University and directed by Walmsley, which aims to build the core systems of a quantum computer.

ation can't be intercepted without the tampering

e sensitive information that you want to transfer

And some countries are already exploiting the potential of optical devices such as lasers, to encode photons and manipulate information according to quantum rules. The result is quantum-enabled, long-distance telecommunications optical networks: a quantum internet. Optical signals are already used to send information over long distances down fibre-optic networks. But if this is done using quantum rules, it is possible to encrypt information in a way that can't be intercepted and read without that tampering being detectable: the encryption is secure.

"That's a massive opportunity if you've got very sensitive information that you want to transfer," says Walmsley, who has made pioneering contributions to quantum information using light, including the first experiments – based on individual photons and photonic integrated circuits – on an algorithm that can deliver a quantum advantage with a relatively small number of resources.

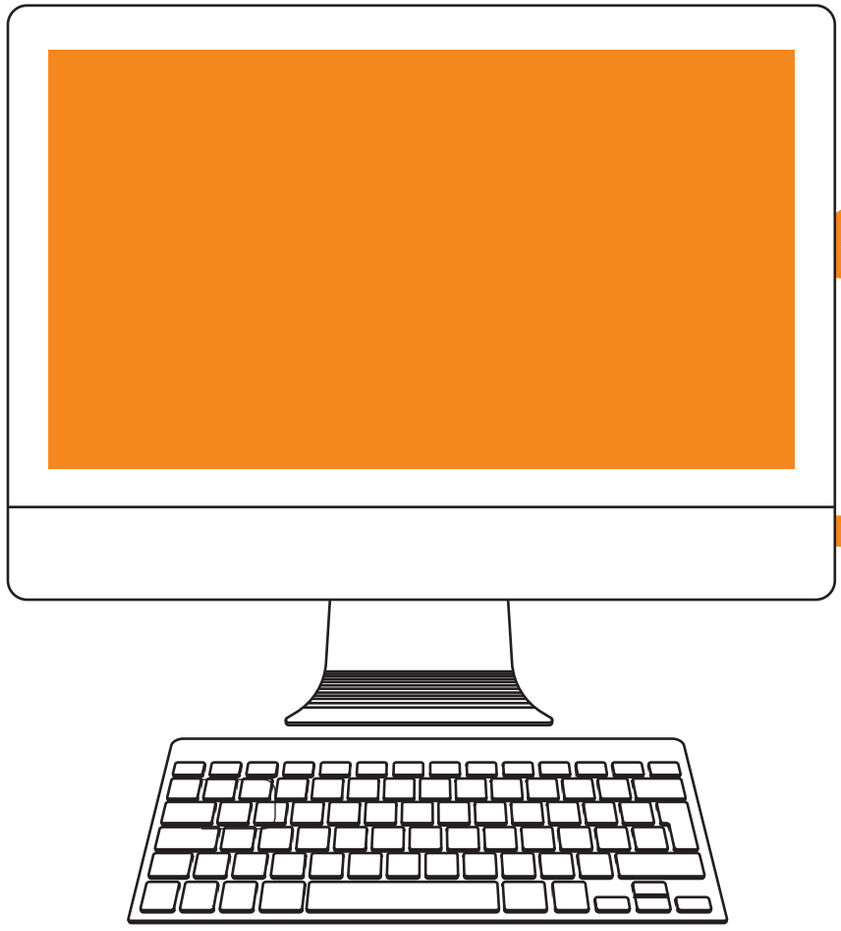
China has a link between Beijing and Shanghai, and has also demonstrated the use of satellites to send quantum-encrypted data across continents. Walmsley says that the UK is also getting close to having a terrestrial network with this capability. "In the next five years, we'll see real quantum communications systems starting to be deployed," he says.

It's no simple matter to make those interconnections, though: they require a good theoretical description of what happens at the interfaces. This is among the problems that Imperial physicist Professor Myungshik Kim is exploring. He is also attacking one of the biggest challenges for quantum computing: developing new algorithms that can solve useful problems.

WALK IN THE LIGHT

One such class of algorithms makes use of a so-called quantum random walk for carrying out database searches. Conventional search engines like Google use 'classical' random walks, where the search just wanders at random (but very quickly) from one item to the next. But quantum random walks could search much faster, says Kim, because they can exploit interference between different paths to extend the range of the search. "In a given time, a quantum walker can go to much wider places with equal probability."

Kim is exploring ways to carry out quantum random walks using light. Light signals travelling down a bundle of adjacent fibres can jump between them, which sets up what is effectively a quantum random walk. This system would then act as a kind of analog computer: the output could encode the answer to a search problem encoded in ▶



Quantum random walks could s

CONVERTING SCIENCE INTO TECHNOLOGY

The importance of quantum technology is reflected in the establishment, five years ago, of a high-profile UK initiative called the National Quantum Technology Programme (NQTP), which brings together academia, industry and government.

The scheme began in earnest in 2013 when the government pledged £270m of funding; contributions from other sources have now swelled this to £400m at the end of the first five-year phase.

Sir Peter Knight, Emeritus Professor of Physics at Imperial, was one of the prime movers of the project. Its purpose, he says, "was to build on the excellent science base in the UK and to convert it into technologies" – to which end the NQTP has established four research hubs at universities throughout the country.

The NQTP is developing a broad spectrum of quantum technologies, says Knight. For example, it uses quantum physics to make high-precision clocks that can be housed directly on silicon-chip circuits.

And the rules of quantum mechanics permit new ways of encoding, storing, transmitting and manipulating data for information and communication technologies – most notably, quantum computers, which can potentially do some calculations much faster than even the best of today's 'classical' computers. It might have a big impact on fields as diverse as healthcare, oil exploration, artificial intelligence and financial markets.

The second five-year phase of the project is about to start from autumn of this year, with a similar level of funding as before: around £100m per annum. It will include a new hub, the National Centre for Quantum Computing, at an institution yet to be disclosed. "Imperial was at the forefront of creating this field," says Knight, and he anticipates its close involvement as the field unfolds further.

search much faster because they can exploit interference between different paths

the inputs. Random walks can also be used to simulate complex phenomena such as financial markets, says Kim – and quantum versions could supply faster answers.

REAL-WORLD QUANTUM

Quantum information theorist Dr Mario Berta is developing some of the theory needed to bridge the gap between 'ideal' schemes for quantum communications and the practical realities of real devices, principally through the potential of quantum cryptography. "Our community recently started taking the experimental limitations into account and studying what is possible under these constraints. This is crucial to make quantum technologies a practical reality."

The advantage of quantum cryptography is that it allows the completion of various cryptographic tasks that are presumed to be impossible using only classical communication. For example, he has studied how much information a transmission channel can actually carry if, like all real-world devices, it experiences some random noise in the signal. He has also worked on the theory of a 'quantum-enhanced' radar, in which the signal radar beam would be entangled with a reference beam to increase its sensitivity. Even if the entanglement is totally destroyed by a noisy environment, says Berta, "there is still a quantum advantage, which makes the method more robust to practical environments than some other quantum technologies".

Quantum superpositions and entangled states are generally rather fragile, being easily disturbed or destroyed when they 'feel' and interact with their environment. That's a nuisance for quantum information technologies – but it can be turned to an advantage in sensing technologies, where detecting and measuring the environment is the whole point.

Superposition, for example, relies on the fact that quantum objects have a wave-like character, and can therefore interfere with one another, in a way that is highly sensitive to the environment. Ed Hinds, Director of Imperial's Centre for Cold Matter, and his team have developed a quantum accelerometer that works by measuring interference like this in a cloud of ultra-cold atoms of rubidium cooled to just a few thousandths of a degree above absolute zero. At those low temperatures, explains research associate Joseph Cotter, the atoms reveal their quantum-mechanical wave-like nature. The researchers use pulses of light to split and then recombine the clouds, whereupon the phase of the waves may be sensitive to the local acceleration of the device and interference can result.

Accelerometers are crucial for navigation systems such as GPS. The advantage of the quantum device over conventional accelerometers, says Cotter, is that "atoms are all identical and don't change over time" – so there's far less 'drift' in the output of the device, which would demand periodic recalibration with some external reference signal, for example from GPS. As a result, the quantum accelerometer is self-contained. The prototype isn't yet small enough to be incorporated into hand-held devices, but the team is looking into commercialisation. Cotter says that quantum sensors like this might also be used for fundamental physics; for example, to detect gravitational waves or search for the elusive stuff called dark energy.

So, while quantum physics has a reputation for being elusive, its continuing emergence could transform our lives in ways that we might not see, but will definitely feel. ◆

Pavan Inguva, photographed by Josh Moody:
I typically use a Canon 700D with an 18-135mm IS STM lens. I also have a 70-200 F4L and 10-18mm f5.6. I use a Canon 1N with a 50mm f1.8 lens for film shots.

Aidan Cunnington, photographed by Kaiqian Lu:
The camera I shoot most of my stuff on at the moment is the Kyocera T with Kodak Portra 400 film. My dream camera is the Contax T3.

SOCIETY

Strike a pose

Lights, camera, action! The Photographic Society put themselves in the picture.

Words: **Sarah Woodward**

Photosoc President Pavan Inguva says the best images sometimes come from the unexpected. "I was taking pictures in Iceland of a rugged landscape against a beautiful sky, when suddenly a child ran into shot just as I clicked. It's still one of my favourite photos."

Now in his final year of a Chemical Engineering degree, Inguva got into photography at school, because he wanted to find a way to capture the wonder of the Milky Way. "I knew I could do better, so I made a beeline for the Photographic Society at the Freshers' Fair, with the aim of improving my technical skills." In fact, Inguva got more than he bargained for: not only did his technical skills improve, but he acquired a whole new set of possibilities. "The dark room here means I can afford to shoot film – new territory for me. I recently did some portrait shots on slide using medium format and was stunned at how beautiful they were." Darkroom membership costs just £10 a year, including chemicals and paper, though Inguva concedes that "although we can develop colour, we're still struggling to work out how to print it".

Kaiqian Lu, photographed by Aidan Cunnington:
I shoot both digital and film, but use film more often. The digital one is a Leica X2, with 24mm 2.8 fixed lens. The film one is a SLR Canon 300v, with 50mm 1.8.

Josh Moody, photographed by Pavan Inguva:
I like to shoot using a Canon 500D with a sigma 18-200mm most of the time, but enjoy using a 100mm prime and Mavic Air (for aerial photos) as well.

That is a challenge for dark room manager Aidan Cunnington to solve. Cunnington, a third-year mechanical engineer, started taking pictures as a child when his mother bought him a disposable camera, and he has happy memories of family snaps. But while his mother is now wedded to digital, Aidan relishes "the sheer delight of shooting film. I am fully transitioned – on my last holiday I took three cameras, two film and one digital, but after a week I stopped using the digital one."

That is a decision made easier by the fact that Photosoc runs an equipment rental service, with three full-frame cameras and a range of lenses available, so members thinking of experimenting with film can try before they buy. "A lot of people come here not owning a camera and, to be fair, a phone can now do 90 per cent of the job of a good digital camera," says Inguva. "Plus, the techniques needed, and those we teach, are pretty much the same."

Members have the opportunity to try out their equipment and new skills on the regular photo walks. "One highlight is the early-morning Richmond Park walk we do at start of term to welcome new members – though some alumni come along as well," says Inguva. "I also really enjoyed a trip to Brighton in my second year, when we had a great time eating fish and chips on the pier as well as taking pictures. We had such fun, we are going back this term."

The trips are subsidised but another popular event for the 200-odd members is more local. The social last year was what Inguva describes as "a rave in the dark room". "It wasn't exactly a rave," says Cunnington, "but there were about 25 of us – and the dark room only fits five or six." There is also a sound system, as members enjoy listening to music as they are learning to develop film.

Music aside, Cunnington is determined to persuade others to invest in mastering film, though he has yet to convince his supervisor. His last presentation featured a grainy picture shot on film. "My supervisor wondered why I was spending time using a filter trying to get an arty effect. He couldn't believe it when I told him it wasn't from using a filter but shot on film!" ◆

TEST YOUR BRAIN POWER

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

1: HARD

My doctor prescribed some red tablets to be taken: one each day from 1 January this year. They come in packets of 10. Later, my doctor decided that I should also take some green tablets, one each day from 1 February. These come in packs of seven. I am very conscientious about taking my tablets and I was wondering what would be the first date (if any) when I would be opening new packets of red and green tablets on the same day.
Dr Lynda White, Principal Teaching Fellow in Experimental Design, Department of Mathematics

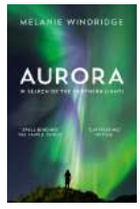
2: VERY HARD

Can you find a nine-digit number using each of the digits 1, 2, 3, 4, 5, 6, 7, 8 and 9 exactly once each, with the following property: the first two digits (reading from the left) form a number divisible by two, the first three digits form a number divisible by three, the first four digits form a number divisible by four etc up to the nine-digit number that is divisible by nine?
Dr Lynda White, Department of Mathematics

3: FIENDISH

I always had difficulty remembering my PIN number until I noticed the following. My house number has three digits and is different if I write it backwards. If I take the difference between my house number and its reverse I get another three-digit number. If I add this new number to what I get if I reverse it, I get my (four digit) PIN number. It's secret because no-one knows where I live. So what is my PIN number?
Professor Jonathan Mestel, Professor of Applied Mathematics

HOW TO ENTER: Senders of the first 10 correct solutions for two or more of the puzzles will receive a copy of *Aurora: In Search of the Northern Lights* by alumna Dr Melanie Windridge, featured on page 45. Winners' names will be printed in *Imperial* 47 in November 2019, and solutions published online at www.imperial.ac.uk/be-inspired/magazine. To enter, please email **imperialmagazine@imperial.ac.uk.**



FOR ISSUE 45 SOLUTIONS, visit www.imperial.puzzles.co.uk
ISSUE 45 WINNERS: Congratulations to the first ten respondents who contacted us with two or more correct solutions from the previous issue:

Osemwaro Pedro *(MEng Computing 2006, PhD 2010),* ***Jonathan Wells*** *(Biological Sciences 2007, MSc Management 2008),* ***Xin Yi Leong*** *(Mathematics 2012),* ***Jeremy L A Kong*** *(MEng Computing 2016),* ***Hannah K Collingwood*** *(MSc Physics 2015),* ***Lewis Wong*** *(MRes Surgery and Cancer 2015),* ***Galen J E Voysey*** *(Mathematics 2017),* ***Steve Gutteridge*** *(Physics 1988),* ***John T Hilbourne*** *(Mathematics 1983), and* ***Robert Maciejczek*** *(Physics 1991).*

ILLUSTRATIONS: MIKE LEMANSKI

ALUMNI

A class apart? It's time to reconnect

IMPERIAL'S ALUMNI RELATIONS TEAM CAN HELP YOU ORGANISE YOUR OWN CLASS REUNION

Photography: **Nato Welton**

Ever wondered what the people from your course or year are up to now? Each year, many Imperial graduates get back in touch with the College's Alumni Relations team to help them organise reunions. Could yours be next?

"As it was 50 years since our arrival as undergraduates in the Department of Physics, we wanted to do something special," says Charles Skinner (Physics 1971, PhD 1974). "So I contacted the College about running some sort of event. They were great. They put me in touch with quite a few of the people on our course, and we all got together for a night hosted by the Department of Physics. We had a few drinks in the Student Union Bar and, because it was outside of term, we were even able to stay the night in halls.

"It might not have been quite as raucous as it was 50 years ago, but it was just fantastic to catch up, reminisce and swap stories about what we've been up to since."

The class of '71 physicists also wrote and exchanged autobiographies of themselves, something which another reunion organiser, Barry Lanz, recommends. "We had a small get-together of the Mining class of 1958 at last year's Alumni Weekend," says Lanz. "As well a social dinner and lunch with academics from the Faculty of Engineering, we also produced a small booklet with details of what each of us have been up to in the 60 years since graduating. It was fascinating."

According to Alex Gibbs, Alumni Events Officer, the Alumni Relations team are on hand to help you arrange a reunion, from offering advice, helping with invitations or arranging tours . "Over the past few years, we've had the pleasure of working with alumni from 1958 all the way up to a group who graduated in 2014 – from every faculty and medical school, and across our campuses. However big or small, we're here to help."

> *If you would like help setting up a reunion, contact the alumni team at alumni@imperial.ac.uk.*

A chance to remember: Imperial's Alumni Relations Office can help with all aspects of organising a reunion – from advice and invites to handling responses and arranging visits – to help you reconnect and rekindle your memories of life at Imperial.

A time to explore

You might not be able to teach a spirit of adventure, but you can nurture and encourage it. Three Imperial graduates tell us how they have taken on the world (and beyond).

Interviews: **Sarah Woodward**

DR GEORGE MCGAVIN
(PhD Entomology 1978), entomologist

Q. Where does your love of insects come from?
As a child, I believed that we would one day name all the species on Earth, but by the time I was a PhD student there was a dawning realisation that we would never succeed. We may have named and described about 1.5 million species, but it is believed that there are between eight and 10 million out there still undescribed, mainly insects. If we carry on as we are, we are likely to lose over half the species on Earth without ever knowing they were there.

Q. How did Imperial fuel your passion?
I arrived at the Natural History Museum and Imperial for my PhD already knowing that, for me, insects would always be the main event. As a student, my world was concentrated on the plant bug family *Miridae* and my travelling was limited to around the UK to local collecting areas. But I was surrounded by eminent entomologists and spent a lot of time in the bar talking of following in their footsteps, although I was actually 29 and had gone on to Oxford before I set foot in my first rainforest.

Q. Did the rainforest live up to expectations?
Even now, it takes me an hour to cover 100 yards in the rainforest – there's just so much to see! After three years surrounded by the vast and sometimes overwhelming collection at the National History Museum, I was ready to go out and look for species to add to their list. I was setting out to explore the world of insects – and I still find it just as interesting whether it is on my back doorstep or in some remote part of the world. Which is not to say I don't still get the 'wow' factor when I am in the Amazonian jungles or the east African savannah, but I get my most incredible thrills from observing insects in the wild, wherever they are.

> *Dr McGavin is an award-winning author and academic and a regular on television, including as co-presenter of the BBC series Expedition, and has had several insect species named in his honour.*

DR MELANIE WINDRIDGE (PhD Physics 2009), fusion physicist

Q. How did you discover your wanderlust?
I learned to climb as a student at Imperial. I had always been a keen skier and hiker, and about halfway through my PhD I joined the Outdoors Club, to learn the basics on the climbing wall. I went on a sport climbing jaunt in Spain and a winter climbing expedition to Scotland, but there was so much snow we ended up skiing. Otherwise, I was very much wrapped up in my fusion physics and I was always motivated by the bigger picture of a new, clean-energy source.

Q. How did you combine travel and study?
My supervisor constantly reminded me that I was studying plasma physics, not just fusion – and plasma is tremendously abundant, making up 99.9 per cent of the universe. The most beautiful plasma in the world is the aurora, so when I finished my PhD I thought I really ought to get out there and see the incredible phenomenon of the Northern Lights. I set out to do it in the style of the old polar explorers, skiing across the Arctic wastes in a truly wilderness environment. I soon found that when it is a choice between stepping out of your tent to see the aurora or staying inside, safe from cold and polar bears, survival comes first.

Q. What is your biggest motivation?
No-one sets out to be an explorer. For me, it is the desire to find out more, and all of us have that hidden somewhere in us. Science is my exploration and I always say you don't have to leave the lab to explore. Of course, I am very glad that my own scientific search has taken me to the wilds of the Arctic and to the top of Everest. But it is about people as much as place, and I am as inspired by the people I've met along the way – who share my curiosity and offer me new perspectives – as I am by the incredible scenery and beauty.

> *Dr Windridge summitted Everest in 2018 and is the author of* Aurora: In Search of the Northern Lights, *chronicling her pursuit of the Northern Lights across the northern hemisphere. To win a copy of the book, turn to page 42 for the Imperial puzzle challenge.*

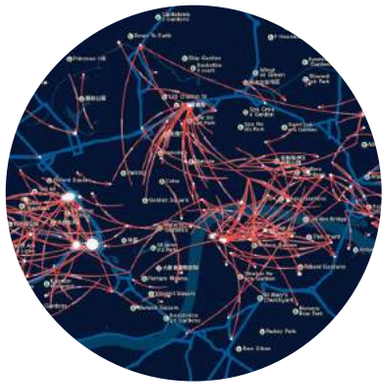
DR ANDREAS MOGENSEN (MEng Aeronautics 1999), astronaut

Q. Has it always been about space?
Like many small children, I was fascinated by science and dreamed of being an astronaut. As an aeronautical engineering student at Imperial, aiming to get a job working with satellite and space technology, I joined four other Imperial students on a canoe expedition through the Amazon in Venezuela, testing the use of the internet for scientific research in remote locations. Later, I joined the Exploration Society, climbed Mounts Kilimanjaro and Kenya, and went white-water kayaking in Peru.

Q. Becoming an astronaut is straightforward, right?
When I finished my degree, jobs in aeronautical engineering were hard to come by. I had been introduced to Schlumberger at the job fair and ended up working for a couple of years on off-shore oil rigs in the Republics of Congo and Angola. I still burned to be an astronaut, but if I hadn't had that experience, I probably wouldn't have made it through the selection process. Oil rigs and space stations have similarities – you are isolated, working non-stop in close proximity to your colleagues. But, of course, you don't have the thrill of working in space.

Q. What's it like in space?
Arriving at the International Space Station is simply indescribable and the peace that comes with weightlessness unforgettable. The exploration of space follows in the tradition of the great explorers of the 15th and 16th centuries who set out to discover the New World. Exploration is about science, but it is so much more than that. Astronauts are asking questions that have as much relevance to philosophy and religion as science: we want to know what is over the other side of the mountain, the sea or, in our case, in outer space – and could mankind live there in the future?

> *Dr Mogensen became the first Danish citizen in space in September 2015 on the 10-day 'iriss' mission to the International Space Station.*



DATASET – DR KE HAN, SENIOR LECTURER AT IMPERIAL CENTRE FOR TRANSPORT STUDIES

The map with the potential to transform the transport system

Words: **Peter Taylor Whiffen**

Context:

Since their launch nearly ten years ago, 'Boris Bikes' – bicycles available as part of London's cycle hire scheme – have made 70 million journeys and undoubtedly helped many users to be fitter and healthier. But who actually uses them, where do they go – and why? Understanding this, says associate professor Dr Ke Han, is the key to building a truly joined-up transport system for the city.

Background:

"Initially, some critics felt the bikes would mainly be used by tourists or for non-commuting purposes," says Han, Senior Lecturer at the Centre for Transport Studies. "But they are very popular with London-based commuters, particularly to get to and from public transport hubs such as tube stations. Mining deep into the data tells us many things about where people live, how they get to work and where congestion hotspots are. That might help to plan transport infrastructure such as road usage or placement of bus stops. In a wider context, it also reveals different behaviours dependent on different social economic status."

Methodology:

Han and his team analysed existing data from London Data Store and, using a 'time series clustering' technique [left], produced a series of maps and graphs to pinpoint where Santander Cycles (the bike-sharing scheme's official title) are picked up and dropped off, the spatial and temporal patterns of their usage, the duration of the journeys, and daily and hourly peaks and troughs.

Findings:

"We found the highest concentration around particular stations – for example, King's Cross and Waterloo," says Han. "This suggests they are used for last-mile commuting." The shapes of the hourly pick-up and return curves of the stations are indicative of the surrounding land use, such as residential areas, transport hubs or business districts. "We also defined particular 'communities' of London and found that the vast majority of bikes are picked up and returned in that same community. In other significant usage areas such as Hyde Park, even though the bikes are again picked up and returned a short distance from each other, the hire pattern is more even through the day and the journeys are longer, suggesting these are leisure users."

Outcomes:

Han's work has valuable insights for the cycle scheme itself, but the patterns he reveals could also influence London's transport policy. "As well as enabling the scheme to distribute bikes more efficiently," he says, "we can delve deeper and ask, for example, why people are choosing to cycle rather than walk in certain areas, or if this movement of people can be managed with financial incentives, to encourage them to cycle to a certain tube stop rather than the congested one, or even to entice them into areas where commercial operators want them – such as Oxford Street. The bikes should not operate in isolation but in an integrated, properly joined-up policy with buses, tubes and road systems. This data offers so much potential to explore the movement of people around the capital, and to plan infrastructure accordingly. Next steps include exploring similar types of mobility data, such as the stationless, floating bike sharing scheme (Mobike) that has been in operation in London and Beijing, to gain deeper insights into urban mobility patterns and inform policymaking." ◆

DISRUPTOR / PROFESSOR FRANKLIN ALLEN, PROFESSOR OF FINANCE AND ECONOMICS AND DIRECTOR OF THE BREVAN HOWARD CENTRE

"In China, the link between stock market and economy is broken. Why?"

The Chinese economy is a powerhouse. It has led the field for economic growth among major economies for the past 35 years. Its GDP has gone up nine-fold, outpacing both Taiwan and South Korea. And it has become the world's largest market in terms of purchasing power parity.

Yet despite this, between 2000 to 2014, China has been home to one of the worst-performing stock markets in the world. An investor who took the plunge in the early 1990s would have ended up with almost nothing to show for it by 2014. Stashing the money in a deposit account would have been a better bet – and this is peculiar, because in most countries, stock markets are a leading economic indicator. If people think the economy's going to do well, they buy stocks and those stocks then go up.

But in China that link is broken. The stock market, established in 1990, offers no indicator of where the economy is going. We wanted to understand why that is, and what the policy implications might be.

To start off, we compared the Chinese stock market with those in other countries – both emerging economies such as India and Brazil and developed economies like the US and European nations. One thing we discovered is that if you look at Chinese firms that are listed outside mainland China, they do much better than those on the domestic markets. This seems to hold true for those listed in Hong Kong, New York, London, Singapore and elsewhere. What's more, we found that unlisted firms also do better than counterparts on the Chinese stock market firms, even when you compare ones of similar size, with similar characteristics and in the same industry.

We have documented two big problems. The first is with the firms chosen for listing. In China, getting listed is a political process and companies have to have the right connections. That means that the listed companies are not representative of the Chinese economy as a whole. Also, to fulfil the criteria, you have to make profits for at least three years. Many high-profile companies, such as internet giants Alibaba, Baidu and Tencent, are yet to make profits, although they're growing extremely fast. Consequently, these companies are listed outside mainland China.

The other major problem is with corporate governance. Listed companies in China invest enormous amounts, compared with similar firms in other countries, but they don't produce much in the way of cashflow or profits from it. We found that was primarily because they use resources inefficiently. There is also a lot of evidence of tunnelling, where unlisted parent groups get their subsidiaries listed on the stock exchange and then do transactions with them at artificial prices to extract money.

So, what can be done? Our main policy implication is that the China Securities Regulatory Commission (CSRC) should substantially lower the financial hurdles for stock-market launches and encourage more privately owned firms – especially those from growth industries – to enter the market. This would improve the quality of the mix of listed firms. Our results also suggest that the CSRC should be more proactive about de-listing poorly performing firms, and ensure the listing process shifts from one based on political considerations to market-based concerns.

Finally, continuing efforts are needed to improve corporate governance. These reforms would enhance the efficiency of the domestic stock market, helping it to play an enhanced role in allocating resources.

The Chinese government is already taking steps to tackle these issues, but we would argue that this process needs to be speeded up. Thanks to the one-child policy, China has an ageing population. There is still a strong culture of children supporting their parents, but it is essential that people can save for their old age. Having a stock market that creates wealth for shareholders is an important part of achieving that – potentially averting a demographic time bomb in the world's most populous nation. ◆

> We have documented two big problems: the firms chosen for listing and corporate governance. Reforms are needed to spur further growth

> ***Professor Franklin Allen*** *is the author of various studies of the Chinese economy, includng the co-authored An Overview of China's Financial System and A Review of China's Institutions.*

INTERVIEW: WILLIAM HAM BEVAN

MY IMPERIAL

I'll see you on court

Aishwarya Chidambaram (BSc Mathematics, Optimisation and Statistics) and her love for the Millennium Arena.

Interview: **Diane Shipley**
Photography: **Hannah Maule-ffinch**

My Thursday practice nights at the Millennium Arena in Battersea Park are the highlight of my week. It may be dark, cold and wet in the winter, but there's a special feeling when you play under floodlights, a different sound and feel. And the games are so fast-paced you don't have the chance to think about anything other than the ball and your team-mates, so it's also a great escape.

We have games on Mondays, but because it's hard to get the same courts in London each week, our home grounds vary considerably, so the arena is our netball home. We're the largest all-female club at Imperial, and it's great to have a group of people who are all equally passionate about the sport.

Having said that, the social aspect is really important too – you always need other women to turn to and we're a minority at Imperial. I've met such a great bunch of people since joining netball, and I was thrilled to be given the 'most valuable player' award last year.

I've had plenty of ups and downs on court already. Our striped faces for the Varsity game stands out but, although it sounds odd, my proudest moment came when we were pretty well beaten at a game in Potters Bar. We were two players short, but those of us there really rallied together and I think we all raised our game massively. That strength in adversity is the sort of thing netball teaches you.

All in all, we have about 70 members across three competitive teams that take part in both the London Universities Sport Leagues (LUSL) and the British Universities and Colleges Sport, as well as two social teams that just do LUSL. I'm captain of one of those: we're still competitive and train hard, but we have matches once a week rather than twice, so it's slightly more relaxed.

The atmosphere is always sociable. As captain, I try to arrange a team dinner about once every three weeks when all the different years come together – but it's always a special thrill when we start throwing the balls about at the arena, particularly at the end of the second term when we actually get to train in the light! ◆

There's a special feeling when you play under lights, a different sound and feel

WHAT'S ON AT IMPERIAL

May - November 2019

You are invited to connect with world-leading researchers, inspiring students and the College's leaders at events throughout the year, in London and around the world.

29/MAY

The Bioengineering Lecture 2019

Distinguished physicist Professor Albert van den Berg presents the 2019 Department of Bioengineering annual lecture.

South Kensington Campus

30/MAY

Peter Lindsay Lecture 2019

Professor Christopher Bishop, Microsoft Technical Fellow and Director of the Microsoft Research Lab in Cambridge, discusses 'The AI Revolution: Hype vs Reality'.

South Kensington Campus

05/JUNE

Athena Lecture 2019

Science is an inherently collaborative activity, though it is infused with competition. Where does the balance lie between the two? And what kind of leadership will the 21st century require? Dr Margaret Heffernan, author and CEO, presents the annual Athena lecture.

South Kensington Campus

13/JUNE

IMSE Annual Lecture 2019

Tony Wood, Senior Vice President, Medicinal Science and Technology at GlaxoSmithKline, will give the first annual lecture from the Institute of Molecular Science and Engineering.

South Kensington Campus

19/JUNE

Imperial Inaugural: Tina van de Flierdt

Professor of Isotope Geochemistry Tina van de Flierdt presents her ongoing research in the Department of Earth Science and Engineering.

South Kensington Campus

THE GREAT 2019 EXHIBITION ROAD FESTIVAL

28-30/JUNE

The Great Exhibition Road Festival and Alumni Weekend

Imperial's Festival and Alumni Weekend will join up with all the other institutions in South Kensington to form one giant fusion of the arts, science, learning and curiosity.

South Kensington Campus and Exhibition Road

29 JUNE/03 JULY

Dyson School of Design Engineering Summer Show

Discover creations from the Dyson School of Design Engineering as they exhibit the work of their students in the annual summer show.

South Kensington Campus

02/OCT

Imperial Inaugural: Jason Hallett

Jason Hallett, Professor of Sustainable Chemical Technology, discusses his research in the Department of Chemical Engineering, which includes waste recycling and the manufacture of vaccinations.

South Kensington Campus

09/OCT

Imperial Inaugural: Gareth Tudor-Williams

Professor Gareth Tudor-Williams takes us through his research in the field of paediatric infectious diseases.

South Kensington Campus

06/NOV

Imperial Inaugural: Johannes Nicaise

Johannes Nicaise, Imperial's new Professor of Pure Mathematics, will talk about his research within the field of algebraic and non-archimedean geometry.

South Kensington Campus

20/NOV

Imperial Inaugural: Alessandra Russo

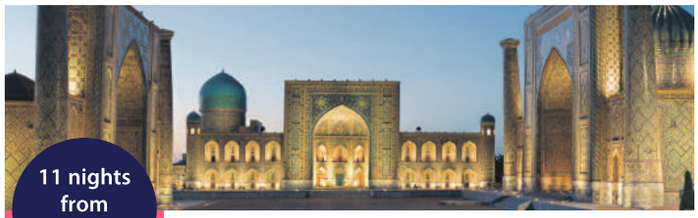
Professor Alessandra Russo will discuss the application of logic-based learning within the fields of machine learning and Artificial Intelligence.

South Kensington Campus

Visit www.imperial.ac.uk/whats-on to view a full listing of public events and www.imperial.ac.uk/alumni/events to find out about Imperial alumni events around the world.

SMALL GROUP TOURS

JULES VERNE
INSPIRING TOURS WORLDWIDE



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- No Single Supplement (limited dates/availability)

SOLO GROUP DEPARTURES *(5 Jul & 1 Nov '19, 10 Jul & 30 Oct '20)*

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INDIA'S GOLDEN TRIANGLE

- Staying in Delhi, Jaipur and Agra, visiting the Taj Mahal, iconic forts, majestic palaces and abandoned cities
- Special Events – Special Meals
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2 UNESCO WORLD HERITAGE SITES

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ABTA No.V1661

Prices are correct at the time of going to press. If our specially negotiated airfares are unavailable at the time of booking, a supplement may apply.