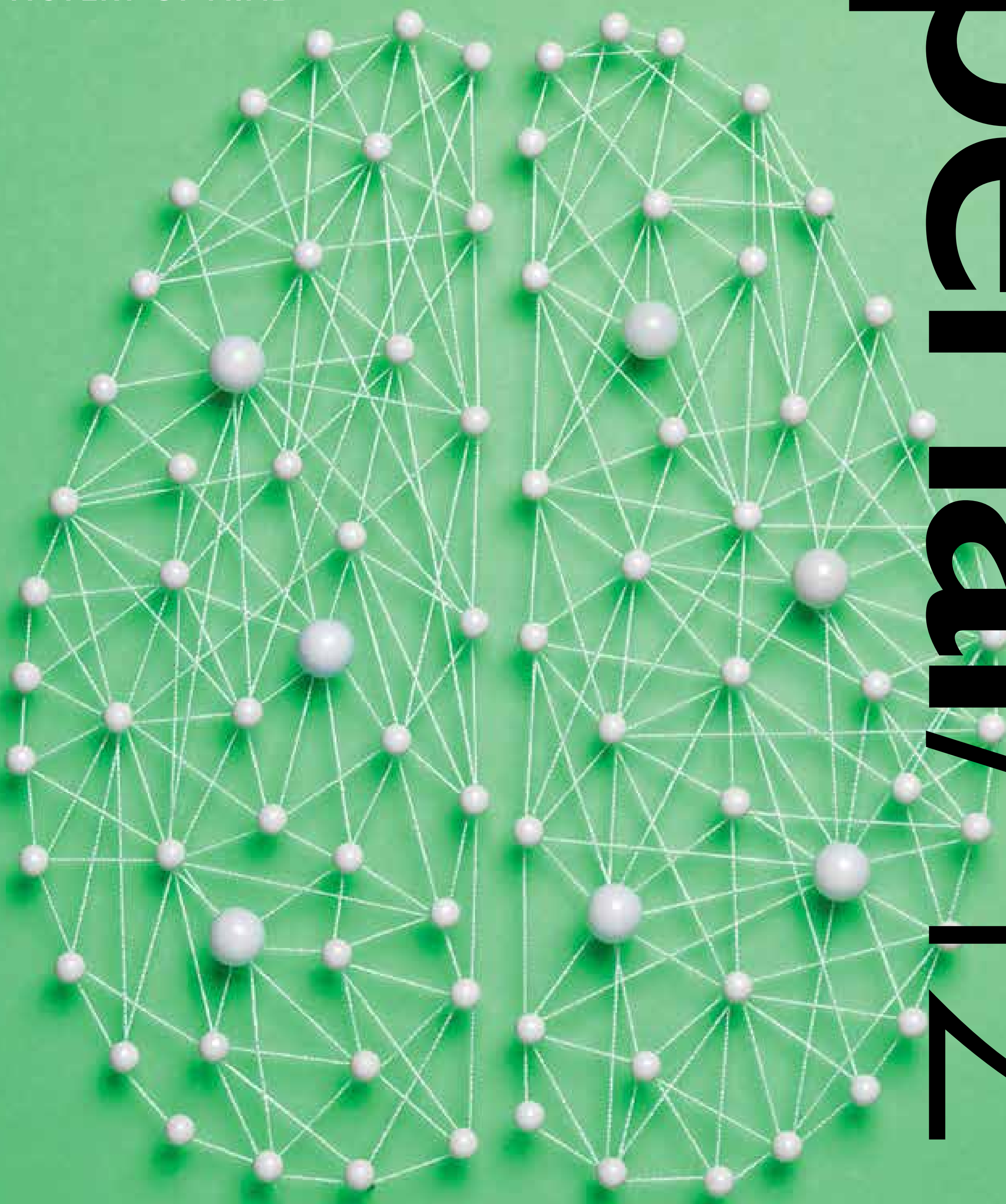
Imperial/42

THE MAGAZINE FOR THE IMPERIAL COMMUNITY

SPRING 2017

YOU ARE YOUR BRAIN

BUT THE BRAIN REMAINS ONE OF SCIENCE'S FINAL FRONTIERS. WE EXPLORE THE MYSTERY OF MIND



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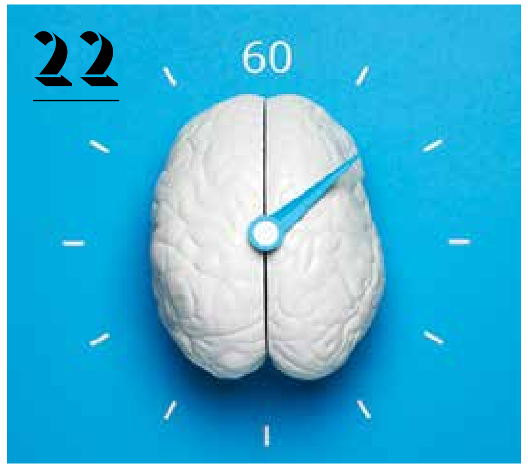

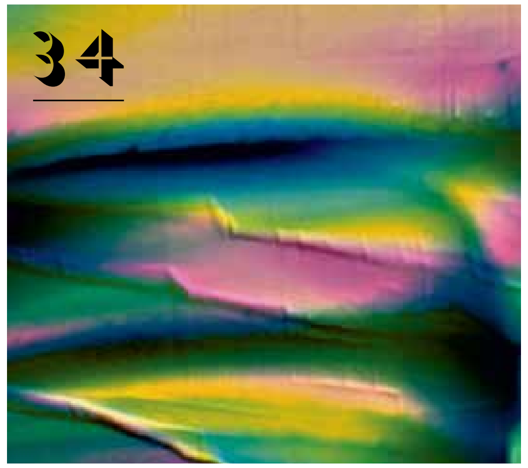

Imperial/42

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Imperial is published by YBM Ltd on behalf of Imperial College London Communications & Public Affairs
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YBM

DIGEST

COMPUTING

IdeasLab at Davos

The College's Vice-Provost (Research), Professor Nick Jennings, warned an audience of industry leaders at Davos that seeing machines as slaves will limit their potential.

Speaking as part of the IdeasLab presentations at the 2017 World Economic Forum, Professor Jennings highlighted the potential of high-performance computing to improve human decision-making in a data-driven world. "Humans alone cannot hope to process the vast volumes of data our modern world creates," he explained. "If we are to make informed decisions, we need assistance from Artificial Intelligence systems. Humans should no longer simply be the 'masters' and technology the 'slave'. Machines and people have complementary expertise that can be harnessed to tackle complex problems. But for this to happen, machines need to be able to cooperate with humans."

The Forum also heard addresses from President Alice Gast and colleagues from the Department of Computing and School of Public Health, discussing how advances in artificial intelligence, simulation and analysis techniques are transforming the way we make decisions and solve problems.

To read the President's blog for the World Economic Forum on immigration and innovation, visit www.imperial.ac.uk/president/writing-and-speeches

> **"If we are to make informed decisions, we need assistance from Artificial Intelligence systems. Humans should no longer simply be the 'masters' and technology the 'slave'"**

ILLUSTRATIONS: THIS PAGE: TOMMY PARKER. OPPOSITE PAGE: GIACOMO BAGNARA

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LETTERS

IMPROBABLE PROBABILITY

In 2006-07, during my MBA studies in Boston, I was in a grocery store when I noticed someone who looked like one of my lecturers from the first year of my Maths degree at Imperial. I approached him and asked whether he was Dr Crowdy, who led mathematical methods in 2001. His response was positive, and I discovered he was a visiting professor at MIT.

At the time, I was surprised at the coincidence. Professor Hand's article shed some light on this, explaining why such seemingly improbable events do occur.
Christian Schmidt (Mathematics 2004)

My parents own a holiday cottage on the Isle of Wight. During my time at Imperial, my father and I were outside the cottage when a man came up to us and addressed my father by name. They had met each other 25 years ago whilst sailing in the Hebrides, when they had anchored next to each other one evening and shared a drink. It turned out he had just bought the house two doors down.

The coincidence was compounded when we discovered not only that his godson was studying at Imperial, but that he was a member of the four I was rowing with at Henley, and one of my best friends.
Angus Rivers (Medicine 2004)

MRI-PET SCANNER

Thanks for your fascinating insight into Imperial's new MRI-PET scanner (*Imperial 41*). I would add, however, that I believe there to be seven, rather than five, such scanners in the UK, and that the value of this scanner lies in its ability to take simultaneous PET and MR images.
Dr Charalampos Tsoumpas (DIC Clinical Medicine 2007)

CHEMISTRY MEMORIES

I and another Imperial alumnus, Professor Hannah Gay (Chemistry 1961, PhD 1964), have recently published a book, *The Chemistry Department at Imperial College London: A History, 1845-2000*. The history of Chemistry at Imperial spans three centuries. The College was the cradle of the British chemical industry, where William Perkin, one of its first students, discovered the dye, mauveine, and many other world-leading chemists and industrialists started. We have tried to provide a comprehensive picture of the department, using archival sources, oral and written testimony, and published and unpublished material.
Professor Bill Griffith, Emeritus Professor of Chemistry at Imperial (Chemistry 1957, PhD 1960)

IMPERIAL COMMUNITY

Having been a past and current student at Imperial, I can attest to the fact that it is an extremely open, diverse and welcoming community (as President Alice Gast recently wrote in the *Times of India*). I am grateful and fortunate to have got great support and encouragement throughout my time here. That said, the UK visa system is an absolute mess and needs serious revisiting. I have first-hand experience of the difficulty faced by non-EU nationals whilst looking for work placements, internships or full-time positions. This is something for UK universities to get together and petition the government about.
Parth Shah (Chemical Engineering 2015), via LinkedIn

AERONAUTICS THROUGH THE YEARS

Eddie Bittel, David Carrington and Paul Melling (Aeronautics 1969) revisited their old lecture theatre recently. David comments: "The most memorable thing about second year was the end of year aerodynamics exam. It was a horror story! I scanned the first question and decided I couldn't do it. I turned the page and couldn't do question two either. By the time I'd got to question five or six, panic had well and truly set in. I even checked the front of the paper to make sure we'd been given the correct exam!

"Eventually I recognised half a question and with some considerable struggle, I managed the other half as well. I never finished the exam but, as all three of us passed to final year, we had obviously done sufficiently well."
David Carrington (Aeronautics 1969), via Facebook.

MORE FROM THE MAILBAG

We were thrilled to receive a full mailbag this issue. Many of you were pleased by the magazine's new look. John Swallow was happy to see "greater depth of focus on subject matter", adding that, "The latest copy is on my son's bed with two of the articles flagged for him to read". Peter Riding (Physics 1964) agreed, emailing to say that he thought the "content was excellent, the design superb. Roll on Issue 42!" However, Roy Gardiner (DIC Physics 1968) felt that the new look lacked the "more modern, funky layout of its predecessors" – we hope that this issue answers some of these criticisms. Your feedback is invaluable and will continue to inform the style and content of the magazine.

Chemists among you may be interested to hear of a new history of the Department, published this year (see Professor Griffith's letter, left). To win one of five copies of Professors Griffith and Gay's book, share your memories with us by writing to imperialmagazine@imperial.ac.uk. Alternatively, Imperial alumni and friends are able to purchase a copy of the book at a 25 per cent discount by visiting: bit.ly/wspc-cdic with the code wscdic25.

Finally, in Issue 41 we published a letter from Professor Donald Perkins FRS (Physics 1945, PhD 1948) on his memories of Imperial in wartime. Professor Perkins' daughter, and his contemporary at Imperial, Jack Pearson (Chemistry 1944), wrote to point out our error in referring to Professor 'David' Perkins. We apologise to Professor Perkins and his family for this mistake.

As you may know, the UK privacy laws for charities and universities are changing. Please be on the lookout for notifications from us on this matter so that we may continue to be in touch.

Are you getting the alumni newsletter, 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. Email alumni@imperial.ac.uk or use the form enclosed with this magazine to update your information.

FROM THE PRESIDENT

Passion and patience

Why an Imperial education is valued by students, past and present, throughout life and around the world.

It is always inspiring to read through the pages of *Imperial* magazine and see such talented academics pushing the boundaries of discovery and to read about our brilliant students and amazing alumni from around the world, living around the world, and making the world a better place. We currently have eight alumni in the *Forbes 30 under 30 Europe* list, along with David Goodall, the world's oldest active scientist, who celebrated his 103rd birthday in April. These are only a few of the many wonderful stories from alumni who relished their time at Imperial and have achieved so much since graduation.

I focused my 2017 Address on 'patience' and how important it is to have patience in order to see the full benefits from research discoveries, the value of an Imperial education and the fruits of translation of research, partnerships and philanthropy. One thing I emphasised is that we are passionate about teaching students. Education is at the heart of Imperial and we have generations of stellar alumni who make us proud of what we do. When I talk to our alumni all over the world I am impressed by the way our extremely rigorous education inspired them to learn, to think, to dig deeply into themselves to master the concepts. This hallmark of an Imperial education has shaped them as people.

While alumni educated at Imperial all have much in common, we know that the world is changing rapidly and our students are changing too. This means that we need to be open to new ideas about the way we teach. But we must do so in a way that does not harm what we are really good at. We must be patient.

We have created a new Excellence Fund for Learning and Teaching Innovation to serve as a catalyst for innovation in our teaching. Our first cohort of successful proposals includes innovative learning initiatives such as Professor Roger Kneebone's simulated surgery workshops, whose highly realistic surgical anatomies and professional actors aid learning, and a project bringing together data on learning from maths, chemistry and the Imperial College Business School. We know that these projects will help us deliver our world-class educational experience.

I also noted in my speech how advanced education arose out of both secular and religious organisations to produce learned members of society and an educated workforce. Discussion about the value of a university degree is important, and yet I believe we have lost touch with these founding principles.

Too often today, value is reduced to a measure of salary, job placement or a student opinion survey. Our system of higher education brings much more to our society than we commonly realise. It is hard to imagine where the world would be without the millions of university graduates contributing to it.

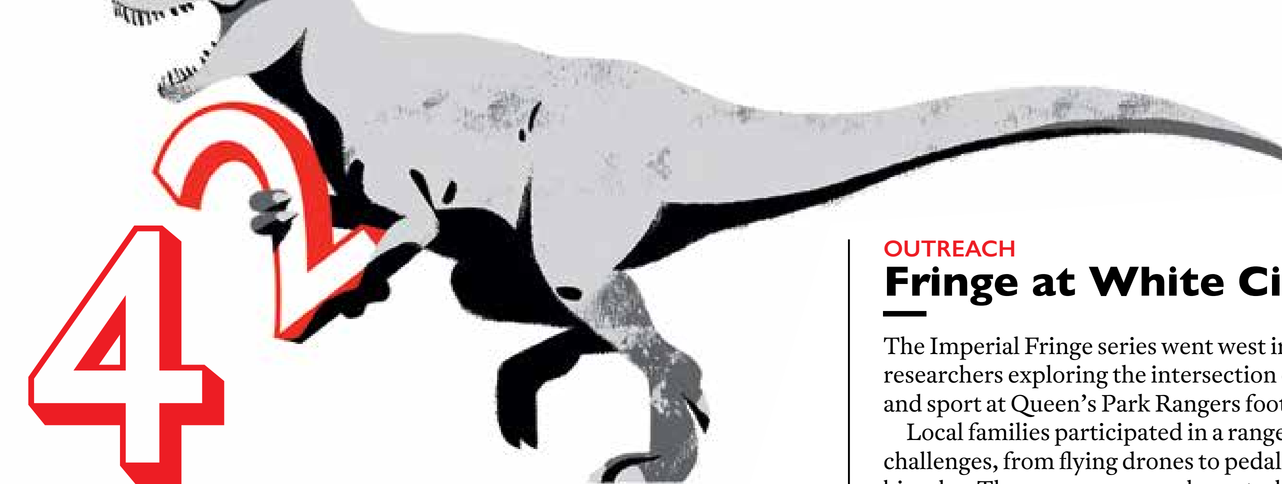
How can we measure the value of an educated citizenry? How can we appreciate the lives well-lived and the communities that thrive thanks to experiences gained in the formative years in university? We see some of these values displayed in the pages that follow. Wonderful people doing great things all over the world.

It is also worth noting the great value in our international mixture of staff, students and alumni. Many have travelled, and lived, around the world; most have worked with, and sometimes shared their lives with, people from different countries. This international mix and experience contributes to creativity and productivity and is an important part of an Imperial education. This is evident from the stories of our distinguished alumni, our winning teams of student entrepreneurs, and the research our diverse academics are pursuing in collaboration with people from around the world. You see this in Sarah Malik and Henrique Araujo's work at the forefront of particle physics in collaboration with the Large Hadron Collider project in CERN, along with scientists from 60 other countries.

> **We have generations of stellar alumni who make us proud of what we do**

This is all the more reason to cherish our international students, our colleagues, our collaborations, our visitors and our travels. As leaders embark on negotiating Britain's exit from the EU, we need to know that Imperial's colleagues who are EU citizens will be able to remain in Britain. While some may say this is a negotiating point with Europe, I strongly believe our leaders should take a proactive and unilateral position, and tell Europeans who live here today that they can stay. On our part, we will continue to do our very best to let European colleagues know just how much we want them here.

PHOTOGRAPHY: IMPERIAL COLLEGE LONDON/THOMAS ANGUS



According to *The Hitchhiker's Guide to the Galaxy*, 42 is the answer. But what is the question? We investigate the questions scientists are asking to solve global challenges, including the death of dinosaurs.

We are fairly sure that we know how the dinosaurs were wiped out. Sixty-six million years ago a ten-mile-wide asteroid smashed into the earth. The dinosaurs were destroyed, along with 75 per cent of all plant and animal species on earth. Described as "the event that changed the course of evolution", the world of science continues to be absorbed by the details. But for Joanna Morgan, Professor of Geophysics in the Department of Earth Science and Engineering, the question she wants to answer is: exactly what effect did this large impact have on the future of the planet?

Professor Morgan's work is focused on the Chicxulub crater, buried underneath the Yucatán Peninsula in Mexico and widely accepted as the place the asteroid crashed into the earth, triggering the Cretaceous-Paleogene extinction. The crater is more than 110 miles in diameter, making it the third of the largest confirmed impact structures on Earth.

"What we were expecting prior to drilling the crater – which we started last March as part of the International Ocean Discovery Program – was for the area to be a ground zero. If anywhere on earth would be sterile just after the impact, it would surely be here. But what we actually found was similar fossils as elsewhere, showing us that, even with potentially toxic, hydrothermal venting, life returned to the ocean above the crater immediately after the impact."

Another unexpected finding from the drilling, she adds, is that there is life today in the crater several hundred metres below the surface, suggesting that the crater has been colonised since the impact. "We've extracted DNA, which has been cultured, and the indicators are that all three domains of life – bacteria, ucerota and arcaea – are present in the crater. We have started the sequencing now to find out exactly what type of life that is."

As a geophysicist (the others on the international team include geochemists, paleomagnetisists, geologists and microbiologists), Morgan explains that the Imperial group is currently working on one specific aspect relating to the crater. "We are simulating the formation of the crater to try and work out what direction and angle the earth was hit – and what we can see is that the crater is asymmetric, which suggests the angle may have been oblique. And we're also trying to unravel how differences in the rocks at the impact site affected that crater asymmetry.

"Discovering more about this incredible event should help us understand other craters and their effects on life. In early earth, for example, there were many more large impacts – and there have also been such impacts in Mars, where researchers are also looking for life."

ILLUSTRATIONS: TOMMY PARKER. PHOTOGRAPHY: JODY KINGZETT

OUTREACH

Fringe at White City

The Imperial Fringe series went west in March, with researchers exploring the intersection of science, technology and sport at Queen's Park Rangers football club.

Local families participated in a range of sporty science challenges, from flying drones to pedalling on water-purifying bicycles. They even even saw how students in the Department of Bioengineering hope to drive Team GB's Paralympic athletes on to future gold medals with bespoke products, such as a custom-made bicycle for cyclist Jon-Allan Butterworth and specially adapted stirrups for swimmer Andrew Mullen.

Finally, the Community Engagement Team provided a taster of the activities that will shortly be available to families in The Invention Rooms, an innovative new community workshop, which will open later this year.

BUZZWORD

OVERHEARD ON CAMPUS

Kisspeptin *n: The hormone that Imperial researchers believe enhances activity in brain regions associated with sexual arousal and romantic love.*

AquaMAV *n: A prototype robot developed by the Aerial Robotics Lab that takes inspiration from gannet dives and flying fish launches to monitor changes in large bodies of water.*

Ecolibrium *n: A framework for engineering co-cultures – the growth of different types of cells together. Created by students from the Departments of Life Sciences and Bioengineering, Ecolibrium won the International Genetically Engineered Machine (iGEM) competition in 2016.*

ILLUSTRATION: JOEL KIMMEL

IMPERATIVE

From SW7 – to the world

Bruno Cotta (Electrical & Electronic Engineering 1992, MBA 2002) is founding Director of Imperial's Enterprise Lab.

Innovations that come out of universities such as Imperial affect us all. And by all, I'm not just talking about the campus, or even the country. I'm talking in global terms.

Take the case of two Imperial alumni – now California based – who recently raised $14m to develop sailing drones that capture ocean data. So if you needed to pick up data about habitats or oil spills, they've produced something very special to do this. And while students like this go on to attract significant investment, in other cases, a large company spots their extreme talent. Magic Pony is a great example – an artificial intelligence startup from two of our graduates that Twitter acquired for around $150m.

These, and others like them, such as the electronics specialists FlickTek (featured in the last issue), are the product of a growing focus on design, technology and innovation. The Enterprise Lab has huge reach because it's a place where our students and alumni – as well as the wider world of employers and decision makers – can mix in supporting innovation within and outside the university, not just in terms of entrepreneurship but enterprise more generally.

> **"We have a chance to really help our next generation of innovators make an impact"**

It's why Imperial is an essential destination for any serious tech discussions and visits. After Fiona Murray, MIT's Professor of Entrepreneurship, visited us recently, she went on to the Prime Minister's office to continue a discussion with government on the value of enterprise education and improving the skills and competencies of not just graduates, but others in the economy. After all, there's a growing recognition that skills over and above technical skills – things like being able to negotiate, build a team, manage scarce resources and being resilient to deal with failure – are hugely valued by employers and essential to create growth.

Located in the heart of the university, our Lab takes up 250 square metres in what used to be a basement of the College library. The £1.7m refurb means we now have five key areas – a reception for hosting visitors; a studio with a hang-out area where students engage informally with each other and us; a work-out area where they get more serious with business planning; a dedicated office for up to nine staff; and a small, but state-of-the-art boardroom to engage aspiring entrepreneurs and corporate executives alike. We've also incorporated a reconfigurable 'green room', where students and others can prepare to present in the main studio, or practise in front of a simulated audience.

The Lab is open to students from all disciplines at Imperial, and alumni are seen as equally important stakeholders. We know alumni are really keen to be involved, so we are working with them locally and globally to help guide and mentor our students and act as role models. What we do here is very much a cyclical process, so when students graduate, we aim to keep on supporting their success. The Lab also targets many nuanced areas, such as the particular challenges that women can face when it comes to pursuing their entrepreneurial ambitions, and how international students can bring their ideas to fruition whether here in the UK or in their home countries.

Imperial is already well known for its impact on society through its world-leading science. But in today's world, where career aspirations are constantly changing, we have a chance to really help our next generation of innovators make an impact through enterprise too.

» To find out more about the Enterprise Lab, including opportunities for alumni to get involved and use the facilities, visit www.imperial.ac.uk/enterprise/enterprise-lab/

RESEARCH

$35million

Value of funding extension from the Bill & Melinda Gates Foundation for Target Malaria, a research consortium involving Imperial and universities in the United States, Europe and Africa to explore the genes in malaria-transmitting mosquitos.

ALUMNI

Flex your network

Looking for local connections or a killer piece of business advice? Wherever you are in the world, don't miss the opportunity to join the College's leadership, academics and alumni at our special events.

This year, President Alice Gast has shared insights into Imperial research and developments at events in Australia, the United States, Germany, France, India and the UK. Elsewhere, alumni met Faculty of Medicine academics at healthcare workshops in Japan, participated in a roundtable discussion on innovation in Cyprus, and met Heads of Departments from the Faculty of Engineering in the US. Meeting Professor Simone Buitendijk, Vice-Provost (Education), in Boston was, for Harmail Basi (Aeronautical Engineering 1981), "a perfect evening to reflect and meet some outstanding students".

In the UK, alumni attended a networking event for finance professionals and enjoyed exclusive tours of the Queen's Tower and the Science Museum. At a Presidential reception in Birmingham, Mohammed Kamran (PhD Clinical Medicine Research 2000), said: "The networking was great from a social and business perspective. I had great conversations with fellow alumni, and I'm looking forward to the next Imperial alumni event."

If you'd like to find out more about alumni groups and events, and to hear about news and developments near you, please visit www.imperial.ac.uk/alumni

SUSTAINABILITY

FIXING THE WORLD'S FOOD SUPPLY

With more than half of the world's crop production currently produced by smallholder farms, a new project aims to create a better financial environment for farmers and draw them into sustainable global food supply chains.

The WINnERS project, which is led by Imperial academics and being rolled out initially across Tanzania, is based around an insurance infrastructure that protects the most vulnerable members of the supply chain against crop loss caused by weather hazards and climate change. It will, for the first time, provide farmers with risk management solutions that will then allow financial services firms to provide investment capital for smallholder farm operations.

The scheme is expected to contribute two per cent to Tanzanian GDP annually, saving the average supply chain – from smallholder farmers to end buyers, such as supermarkets – billions of dollars per year.

Dr Enrico Biffis, Associate Professor of Actuarial Finance, Imperial College Business School, said: "The WINnERS project demonstrates that properly designed risk solutions can provide a powerful mechanism to incentivise smallholder farmers to adopt more resilient production technologies. These in turn reduce insurance costs and attract cheaper investment capital. Big data allows us to upscale insurance at an unprecedented level, and has the potential to generate a systemic shift in food systems."

The project is led by academics from the Centre for Environmental Policy and Imperial College Business School, and supported by the World Food Programme's Patient Procurement Platform.

ILLUSTRATION: TOMMY PARKER

PEOPLE

In brief

Professor Michele Dougherty (featured in *Imperial 41*) has been awarded the Royal Astronomical Society Gold Medal – its top honour – for her work in space physics missions.

Dr Andrea Alenda Gonzalez has pioneered a new Science Toy award to inspire the next generation of scientists and engineers, as part of a gender-neutral STEM toy initiative.

Professor Dario Farina is leading research into controlling prosthetic limbs through motor neuron signals, opening up the possibility of more intuitive and useful robot prosthetics.

Professor David Goodall (Botany 1935, PhD Biology 1939), the world's oldest working scientist, was celebrated by fellow Imperial alumni in Perth, Australia, in January 2017.

No fewer than eight Imperial innovators have been named in this year's *Forbes 30 Under 30 Europe* list, spanning healthcare, finance, technology and social entrepreneurship.

GIVING

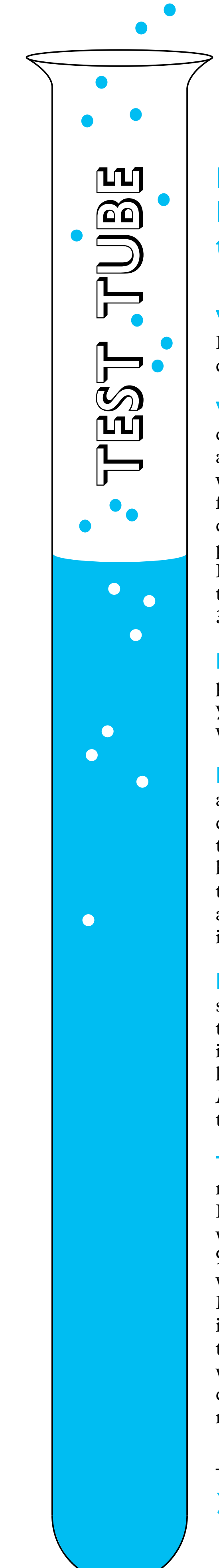
GIFTS PUT IMPERIAL AHEAD

Two recent gifts are helping to keep Imperial at the forefront of pioneering work.

The Schistosomiasis Control Initiative (SCI) aims to treat up to 27 million people with schistosomiasis and intestinal worms across East, West and Central Africa, and has benefited from a $13.5m donation from Good Ventures, a philanthropic foundation whose mission is to 'help humanity thrive'. For more on the initiative, which will help improve the health of some of the world's poorest populations, *see page 41*.

And another Imperial initiative is bringing together the College's world-leading researchers, engineers, scientists and clinicians under one roof. The Michael Uren Biomedical Engineering Research Hub will support work on life-changing research into new and affordable medical technology.

Sir Michael Uren OBE and trustees of his foundation, who are behind a £40m gift, recently attended the construction launch of the Hub, due for completion in 2019.



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

WHO Malav Sanghavi (MSc DIC Innovation Design Engineering 2016). Innovation Design Engineering is a course offered jointly by Imperial and the Royal College of Art.

WHAT LifeCradle makes low-cost baby incubators from cardboard. Our aim is to provide the basic functionality for a child's survival in the critical first days of its life, including warmth, humidity, monitoring of vital signs and phototherapy for babies born with jaundice. After this time, the bottom part can be given to parents to use as a rudimentary cot. It has the potential to save millions of lives, especially in countries like India, which has the highest number of babies dying within the first 24 hours of their birth in the world – at more than 300,000 a year.

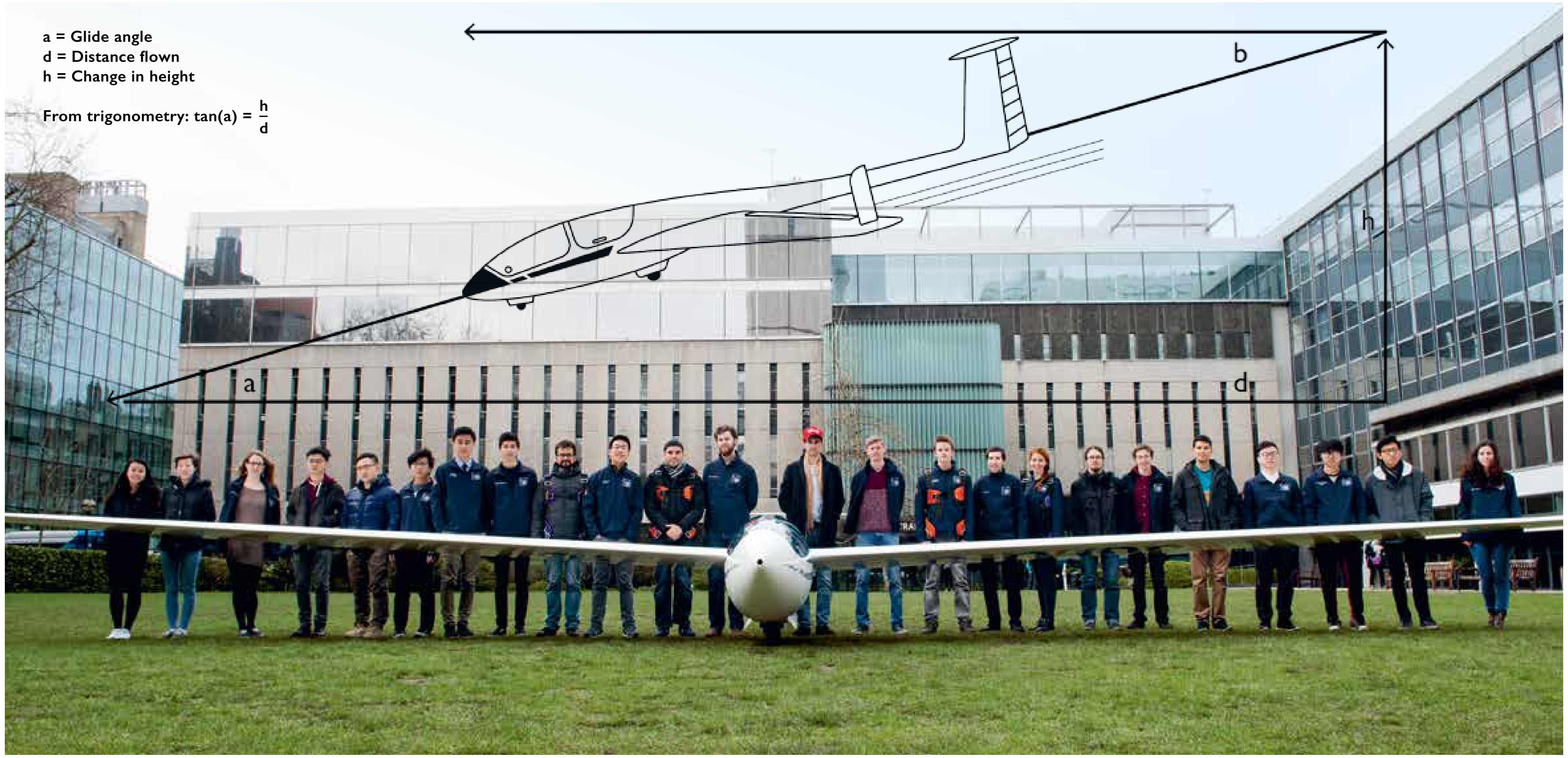
HOW The incubator is currently in the product development phase, with pilot testing due to be completed by the end of this year in several Indian states, where we've been collaborating with different organisations, including the United Nations.

INSPIRATION My cousin's daughter was kept alive in an incubator when she was born in India. After research, I discovered that three million children die within one week of their birth every year and that 99 per cent of newborn deaths happen in middle and low income countries. My inclination towards designing in the field of healthcare now had a focus and led me – with the help of experts – to develop LifeCradle, inspired by Finnish baby boxes and neonatal care in the UK.

MOTIVATION I've always been attracted to the field of social entrepreneurship and I believe that if I can bring change to the life of just one individual with the cardboard incubator, it's worth it. The recognition for our efforts to save lives also keeps me going. Recently, I got into the *Forbes 30 Under 30 Europe* list and our solution was named as one of the best at the Vatican Youth Symposium late last year.

THE FUTURE By 2025, my goal is to have substantially reduced the local infant mortality rate in India, Africa and Latin Amerca. Because LifeCradle is a social enterprise, we anticipate the price of each incubator being around 90 per cent cheaper than existing ones – and we are working with organisations including UNICEF, WHO and the Bill & Melinda Gates Foundation to help set up low-cost neonatal intensive care units in places where they are not available at the moment. Eventually, we want to widen our aims to work with women from day one of pregnancy to ensure there is less chance of death – to include things like raising awareness of reducing risk and giving out healthy diet plans.

Malav Sanghavi is the founder of LifeCradle, the low cost cardboard baby incubator for developing and under-developed countries, and founder and director of Creto Ltd, developing programmable smart sockets for amputees.



SOCIETY

With the greatest of ease

Peace and quiet at 4,000 feet. The Gliding Club have a unique way to escape from it all.

Words: **Sarah Woodward**
Photograph: **Hannah Maule-ffinch**
Diagram: **Ian Dutnall**

If gliding looks the epitome of peacefulness from the air, the reality is somewhat more hairy, admits Gliding Club secretary Amy Whistlecroft. "I couldn't help screaming the first time I went up," she says – a fact helpfully recorded in the log book by her instructor. "So now everyone knows about it. I just didn't realise how steep or how fast the launch would be. With a winch launch, you go from 0 to 60 mph in a few seconds. And from the canopy it looks like you are going straight up into the air."

Amy had always wanted to learn to fly and joined the club in her second year. It's the UK's oldest university gliding club, founded in 1930 in rather ignominious circumstances when the club's first glider – hand-built by Imperial students – blew over and was destroyed. They quickly decided to buy one instead, and today the club has three modern gliders of its own.

Club captain, Thomas Pleece, had already tried motor-gliding as a member of the Air Cadets at school before he signed up for the gliding club in his first term as a student of aeronautical engineering. His engineering skills came in useful recently when he punctured a tail wheel on landing. "We didn't have any tools with us to change the wheel so we got some knives and forks from the canteen and used those instead."

Whistlecroft, a third year biologist, has just got a Saturday job as Aircraft Workshop Assistant at Lasham Airfield in Hampshire, where the club does most of its flying. "I love tinkering with the planes but I became secretary for the social side of the club. We have 118 members, including eight alumni, and I organise who goes up each weekend, so I get to know everyone. It can be quite dangerous on the ground. But I've gone up to 4,500 feet and I just love it. It's so quiet." Unless, of course, you scream.

By purchasing lifetime membership of Imperial College Union, alumni are free to join clubs and societies. For more, visit www.imperial.ac.uk/alumni/benefits

SECRET SAUCE

Hildur Einarsdóttir

(MSc Biomedical/Medical Engineering 2006)

Össur's Director of Global Product Management, Prosthetics, Hildur Einarsdóttir, says her 'secret sauce' is the amputees who test their products.

Össur is the world's second largest designer and manufacturer of prosthetic limbs. But much more than simply providing them, we work with the people who wear them, and that's what makes this job what it is. We might put a prosthetic foot on the table and we will all look at it from a different angle. But only the amputee will truly understand what it is like to walk on that foot. They are the essential ingredient.

Amputees are an essential part of everything we do, not only as a natural part of our own mix within the company, but also as the users of our products. Recently we have been developing waterproof prosthetics, especially important here in Iceland, where the windy conditions also mean we need heavier products. We have a global community of thousands of amputees who feed their individual experiences into our product development. If our products do not meet the needs of those who use them, then we have failed completely.

We also have what we call a gait track here at head office with all sorts of different terrains. One of my most fun days is when we get the children in. The kids don't care how much a product costs or how we feel about it – they just want to test whether it will break. The children push us to our limits on design and development. When we get a product that really meets their needs, it is so rewarding.

I trained as an electrical engineer and did an MSc in biomedical engineering at Imperial, but I always knew I wanted to connect with healthcare. Now I love that I get to use my education at work. I am an engineer inside but I enjoy the human touch. For an engineer, working in prosthetics is the perfect task. We already have the gold standard – the human leg. So we know what we are aiming for in our products. And the amputees can tell us whether we have the mix of ingredients right.

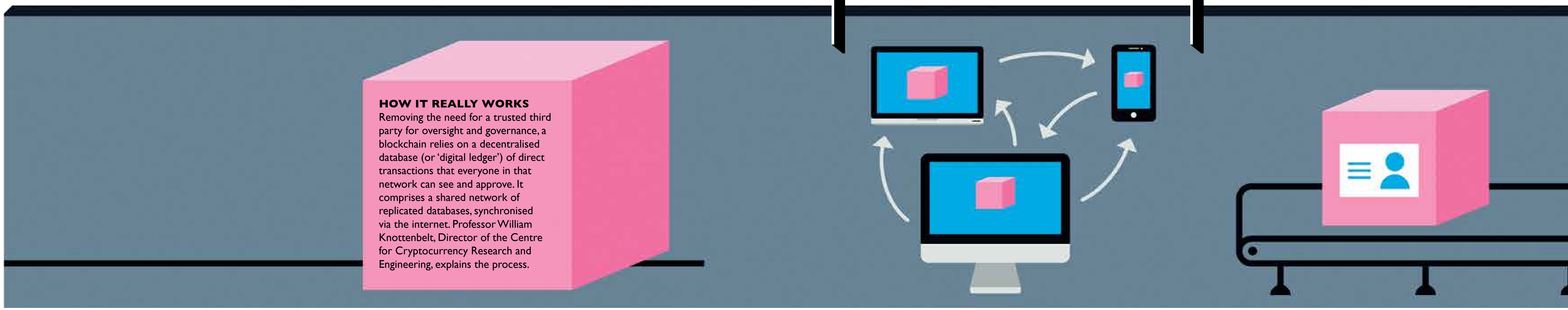
ILLUSTRATION: TOMMY PARKER

To watch a video of Hildur at work in Iceland, visit www.imperial.ac.uk/be-inspired/magazine.

BLOCKCHAIN

1. THE DEAL
A deal is agreed between two users and its details are entered on a ledger using a simplified interface. Transactions can involve cryptocurrency (such as Bitcoin for example) but also contracts, records or other agreements involving two or more parties.

2. THE DETAILS
Details of the transaction are captured in a 'block' of data, typically containing information about the sender, the receiver, a date/time stamp and details of the asset type and quantity. Each block has a unique identifying number and 'hash', a reference to the previous block in the chain.



HOW IT REALLY WORKS
Removing the need for a trusted third party for oversight and governance, a blockchain relies on a decentralised database (or 'digital ledger') of direct transactions that everyone in that network can see and approve. It comprises a shared network of replicated databases, synchronised via the internet. Professor William Knottenbelt, Director of the Centre for Cryptocurrency Research and Engineering, explains the process.

THINK BLOCKCHAIN IS SOMETHING TO DO WITH CRYPTOCURRENCIES AND NOTHING TO DO WITH YOU? THINK AGAIN.

Words: **Jessica Twentyman**
Illustration: **Stephen Cheetham**

It's an act of reinvention that would impress even the most avid social climber. Blockchain is kicking off the traces of its somewhat shady past and now, in 2017, the former *enfant terrible* of finance is wearing the mantle of respectability.

Today, giants including Microsoft, IBM, HP and Intel are all backing the technology. And big banks are in thrall to the promise of what it could do for them, with Credit Suisse, J.P. Morgan, Royal Bank of Scotland, UBS and BNP Paribas, among others, all signed up to a consortium that aims to explore the technology's potential for banking, led by start-up company R3.

Which is all a far cry from blockchain's beginnings as the underpinning mechanism for cryptocurrency bitcoin. Launched in 2008, this alternative currency was an anti-establishment, post-financial crisis initiative that aimed to play the global banking system at its own game.

Efforts to uncover the real identity of its creator, Satoshi Nakamoto (assumed to be a pseudonym), have come to nought. What is clearer, however, is that bitcoin has been used by a rogues' gallery of money launderers, Ponzi-scheme fraudsters and illegal drug-dealing sites on the 'dark web', albeit alongside more legitimate customers. But as Professor Andrei Kirilenko puts it: "The interesting part of bitcoin isn't bitcoin. Not any more. It's the blockchain technology that underpins it."

Kirilenko, the Director of the Centre for Global Finance and Technology at Imperial College Business School, points to blockchain's superiority at enabling individuals to engage in transactions without relying on traditional gatekeepers such as governments, exchanges or financial institutions. The fact that the technology provides a way to create tamper-proof ledgers of transactions could, he says, ultimately transform the way that many organisations – such as banks, law firms and public-sector agencies – keep records, because blockchain provides a robust and more cost-effective alternative to traditional clearing and settlement mechanisms.

It's the distributed nature of blockchain, however, that has got so many people excited. When a blockchain transaction takes place, it is processed and authenticated across a potentially vast network of separate computers, without the use of a central server. In this way, the distributed ledger of transactions continually grows and is shared in real time with users, but once it is added, a transaction record is permanent and cannot be changed – it's 'immutable' in blockchain-speak – because altering it would require access to millions of separate computers.

"In other words, no one person or group holds the entire ledger of transactions, nor can they falsify a transaction, because every member of the network helps to validate and run the database," explains Kirilenko. "It's a complete, immutable and, at the same time, freely observable record of transactions that protects the identity of participants while preventing them from cheating each other or the system."

This brings us to the tricky issue of scalability: a blockchain requires an amount of computer space commensurate with its length (that is, the number of blocks it contains). In a public blockchain, where thousands of 'nodes' (the computers owned by participants) store copies of blockchain content, some believe this could ultimately limit the volume of transactions the network is able to handle, although this is largely unproven at this early stage in the technology's development. In a private blockchain, which is open to only a handful of pre-approved participants (the model most often explored by banks for interbank trading, for example), participants could reasonably be required to dedicate greater quantities of processing and storage resource to the network, thus boosting scalability.

Beyond financial services

All this makes this distributed ledger technology suitable in all manner of applications, explains Dr Catherine Mulligan, research fellow and co-director at the Imperial College Centre for Cryptocurrency Research and Engineering (IC3RE).

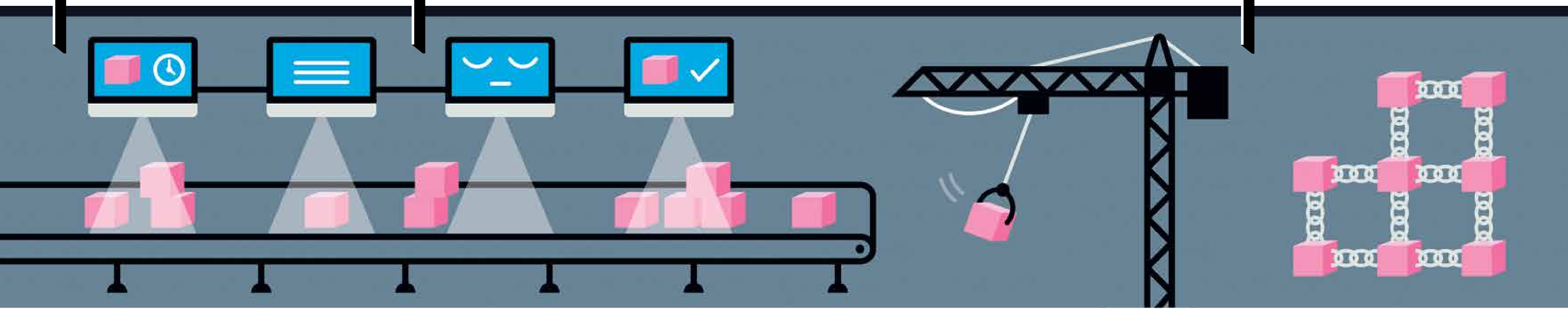
While much mainstream attention is focused on how financial services companies will use blockchain, she says, the technology's ability to deliver complete transparency and auditability could have a big impact elsewhere. She's lead investigator on CREDIT (Cryptocurrency Effects in Digital Transformations), a project at IC3RE funded by the Engineering and Physical Sciences Research Council, which aims to investigate and understand the potential of blockchain to create decentralised records of transactions in sectors such as energy, insurance and healthcare. And last year she contributed to a report for the UK government, exploring how it might revolutionise both public and private sector services.

"The reason that blockchain is so fascinating to me is that I see it as the world's first digital economy, allowing the exchange of value between individuals in ways that could help us combat some huge global challenges," she says.

3. THE APPROVAL
At frequent intervals, a cryptographically protected group of proposed transactions is shared peer-to-peer across the network of participants. In order to be added to the blockchain, each block must contain the answer to a mathematical problem created using the cryptographic hash data.

4. THE VALIDATION
Participating computers in the network are incentivised to automatically check the blocks, to confirm that they follow the rules. Once satisfied, they validate them and apply the included transactions to their own ledgers.

5. THE CHAIN
The validated transaction is added to the continually updated chain in a linear, chronological order and is considered 'complete', with every participant in the network having the ability to prove who owns what.



Take, for example, the traceability of food in global supply chains – an issue that was highlighted by the 2013 horsemeat scandal, casting a worrying light on the dubious provenance of frozen beefburgers and ready meals. It's hard to build a clear picture of events in supply chains that span many stages of production and geographical incidents, so supermarkets and shoppers have no reliable way of knowing that the lasagne they're buying, for example, contains the ingredients listed on the label. Here, Mulligan believes that blockchain could help. If every producer and manufacturer involved in the creation of a foodstuff used blockchain to register the transfer of goods it would clearly identify each party in the supply chain and provide further information on the date, location, quality and processing of ingredients.

According to Professor William Knottenbelt, Director of the Centre for Cryptocurrency Research and Engineering, The Gemological Institute of America (GIA) hack in 2015 represents a perfect of example of how a blockchain – with its key characteristic of immutability – could work much better for some applications than a standard database. The GIA revealed that a database used to store grading reports into the cut, clarity, colour and carat of specific precious gemstones had been accessed and changed without authorisation by former employees of its database support contractor. The GIA was subsequently forced to invalidate 1,042 of these reports.

"Normal databases don't come with mechanisms to ensure the integrity of records," says Knottenbelt. "If you've got permission to access the database, you can modify the records it contains. In a blockchain environment, it would be impossible to change those records and edit the characteristics of a diamond without others knowing about it."

Disruption ahead

From an economic perspective, however, Kirilenko predicts enormous disruption ahead. "While there's certainly plenty of activity and experimentation going on, there are very few people looking into how blockchain will change the fundamentals that financial economists really care about: where do buyers and sellers come from, how do prices form, and how do traders handle different types of risk in a transaction?" he says.

In other words, the world needs to better understand the wider implications for market participants of what Kirilenko calls the "incredible technology" that underpins blockchain – the maths, the computer science, the cryptography. Regulators must walk a fine line between taking action that runs the risk of stifling innovation on the one hand and allowing it to subvert established trust mechanisms in an entirely uncontrolled way on the other.

But as he scans the 2017 horizon for new blockchain milestones, Kirilenko says he'll be looking for the first limited regulatory approval of a blockchain-based service as the starting pistol for a much wider lift-off for the technology and the emergence of many new business models.

In any case, blockchain isn't all about big business, says Jeremy Pitt, Professor of Intelligent and Self-Organising Systems and deputy head of the Intelligent Systems and Networks Group in the Department of Electrical and Electronic Engineering. He espouses a rather more radical vision, one in which "blockchain provides a way for communities of people to self-govern and to share assets, regardless of their wealth".

This thinking, he explains, draws on the theories of Nobel Prize-winning political scientist and economist Elinor Ostrom, whose primary focus was the role of group choice and consensus in the use of shared goods and services – for example, the community management of common pasture in Africa and of community irrigation systems in Andalucia, Bali, California and Nepal.

As a technology, Pitt believes, blockchain (or more generally, distributed consensus technologies) could provide a verifiable way to keep track of the conventional agreements and rules that allow such communities to organise themselves and their assets. "Although the idea of a tradeable, traceable digital token was originally intended to represent a unit of an electronic currency, the token could represent an asset of any kind, for instance a vote, a share, an identity, a social contract – or indeed anything to which you want to ascribe a value," he argues.

By implementing a blockchain to record contracts and conflicts, and then layering it with a software layer that supports active participation of all the stakeholders, Pitt says that such systems could be used to spur collective action, public decision-making and the 'fair' sharing of common resources. He asserts that this is one way to sustain local economies and communities that enable a disparate and heterogenous group of individuals to satisfy a congruent set of shared values.

But Knottenbelt is quick to point out the need for a multi-disciplinary approach. "A major point of concern is that with blockchain, you've got software developers performing economic experiments, governed by purely technological considerations rather than with reference to panels of economic experts. I'm not convinced they have thought through the consequences of these experiments at all. Yes, you can use blockchain to tackle money supply issues, but that can have serious knock-on effects. This is why, at IC3RE, we're pursuing a multi-disciplinary approach, bringing together people from different fields and disciplines to have a look at these kinds of applications and how they might be used in constructive ways, taking into account the context, challenges and consequences of different consequences."

That the technology is here to stay is becoming less of a point of discussion, as the trusted advisers of some of the world's highest-profile private and public sector organisations continue to jump on the bandwagon. In January 2017, 'big four' consultancy and accountancy firm Deloitte announced it was launching a blockchain lab in Dublin's Silicon Docks district; respected academic institutions have their finest minds trained on the technology; and some supporters claim that blockchain expertise could be the key to London continuing to lead the world in fintech innovation in a post-Brexit era.

The trust mechanisms that blockchain might support, then, are wide-ranging, largely untested – and have the potential for huge socio-economic and socio-political disruption. Which, in a way, was what bitcoin's inventors intended.

HYDE \ PARK / STUDENT \ RELAY / RACE \

It's the biggest student race of its kind, but not for the faint-hearted.

Words: **William Ham Bevan**
Photography: **Chris Lee**

One or two barely-dressed members of the Flintsones. A court jester. A handful of superheroes. And a deluge of panting, baton-wielding athletes. Hyde Park on the first Saturday in February can be an alarming place.

It's all part of the Hyde Park Relays, an annual fixture since 1949 and the UK's biggest student race of its kind. Primarily a team competition, with runners following a 5km course through the Royal Park, it is organised entirely by the Imperial College Cross Country and Athletics Club (ICXC&A).

Will Jones, club president, Physics student and a former race organiser, says: "We normally have 600 or 700 runners from Imperial and universities across the UK. Then we get alumni and international entrants, with two or three regular teams from places such as the Netherlands and Poland."

Among the founders of the Hyde Park Relays is Tony Watts (City and Guilds 1947, PhD Mechanical Engineering 1953), now approaching the age of 90. Unusual in that he was both a sprinter and a long-distance runner,

Hyde Park Relay Co-Organiser
Fergus Johnson (Mathematics 2nd Year)

"After many fairly stressful months of planning (alongside co-organiser Lewis Jackson), it's just a massive relief to see everyone going in the right direction and a good crowd cheering them on."

Team: **Marathoil**
Current students (l-r) Jordan Sawadogo (MSc Petroleum Engineering) and Fatin Fariha (MSc Petroleum Geoscience)

Fatin: "I'm from Malaysia so I wanted to run in a cold country. It actually snowed this morning and I'm the only person who was pleased! It's certainly harder to breathe when it's this cold."

Team: **I've run out of Mini Cheddars**
From left to right: Stephen Laws; Paul Batthyany; Henry de Winton (all Mechanical Engineering 3rd Year)

"This is our third year running so doing the relay has become a tradition. We must be real gluttons for punishment! These are the boiler suits we wear in the workshop when we're doing mechanical engineering, so we thought they were appropriate. Stephen's even has aluminium oxide shavings on it to give it some proper authenticity."

he spent his first years at Imperial on the track, representing the University of London in the 440 yards. It was only in 1949 that he joined the Cross Country Club (then a separate society) and helped to instigate the race.

He says: "We began talking about road relays and I was full of enthusiasm, because they were between two and three miles – part way between my cross-country and track running. So we started the men's Hyde Park Relay, with the first race in March. The women's event came later."

Under the captaincy of Bob Gigg, his team won that first race against eight other teams, and he realised it could become a yearly fixture. He says: "Every team was invited back the next year. I took over organisation of the race for 1950 and 1951, building up the numbers to 24 teams, and it went on growing from there."

It did not take long for the race to become established as a highlight of the university running calendar, with teams from across Britain competing for the Sir Roderic Hill Trophy.

It's a measure of its success in attracting serious competitors that Imperial had to wait until 1962 for another win – and even then, it had no chance to rest on its laurels. The mid-Sixties saw the race dominated by Edinburgh University, and a cheeky act of appropriation.

Watts says: "They won the cup three times consecutively and kept it, although it was meant to be a perpetual trophy. Years later, when a College contemporary of mine became Rector, I asked him to make enquiries with his opposite number at Edinburgh and ask 'where the hell is our cup?'."

Word of the Hyde Park Relays spread beyond the English Channel, and teams from overseas universities soon came knocking. Erwin van Harten competed as a member of Erasmus University, Rotterdam, and like hundreds of other international entrants, was granted free accommodation in the Southside or Union Gym.

He says: "It was like a magical area. There was no security – the door was always open. There would be around 200 people in sleeping bags on that wooden floor. There would be parties in the basement bar, and we'd make a lot of contacts with international teams who came every year."

A further innovation was the appearance of alumni. Ian Isherwood (Chemistry 1974) says: "They began to allow old boys' teams in the late Seventies, initially as a favour to those who had helped organise it while at College. Then other universities heard about this and asked if they could run."

He now runs every year as part of the Imperial College Ancients, along with van Harten (a certain number of non-Imperial 'ringers' being accepted). Isherwood says: "I go back to renew friendships, and then there's the sense of unfulfilled ambition at College, as I never got into the team when I was there!"

Another of the Ancients is Stuart Littlewood. He ran for Imperial back in the Seventies when he was studying at the Royal College of Music, a place too small to raise its own team. He remembers: "Everybody who was anybody ran it, and there were some high-profile competitors. I remember Hugh Jones, who went on to win the London Marathon. Dave Clarke was national cross-country champion several times and he ran in Hyde Park at least once."

This has been another signature of the Hyde Park Relays: talent drawn not just from university athletics but from top-level international competition. As early as 1954, a race preview in *Felix* noted that runners would include an Australian champion and Olympic 1,500m finalist, an Olympic steeplechase medallist and two members of world-record relay teams.

Other notables have included the world 5,000m record-holder David Moorcroft, and most famous of all, Sebastian Coe. He first ran in 1978, setting a record for the fastest leg and helping Loughborough University to their team victory. Coe ran again in 1979, then returned in 1981 after a year's break to win 1,500m gold and 800m silver at the Moscow Olympics.

It was at this time that a formal women's race began to take place. Although mixed teams were against the rules governing UK university athletics, European entries had for some time been including women on the understanding that the organisers would turn a blind eye.

By 1980, the practice had been normalised, with a *Felix* race report noting that "a novelty of this year's relay was the number of ladies running... 26 took part and it is hoped that next year a ladies' event will be introduced". Just two years later, 40 women's teams appeared at the starting line.

Alex Mundell, a Medicine student and the current women's captain, ran for the third time in 2017. She says: "The atmosphere is incredible. Everyone comes out to support you, and there's so much noise when you come in for those changeovers. And you have all these famous sights: you pass Buckingham Palace, and you can see the London Eye."

Signposting, marshalling and timing the race is also the club's responsibility. Today, each runner's time is recorded on a chip inside the baton itself, hiding the complexity of the operation. Club member Roland Teare (Medicine 2005) says: "Back then, there'd be a small army of timekeepers. For every lap, a cyclist would ride back from the bandstand to the Union Bar where the results were compiled."

Then there's the hospitality to organise, with a meal in the Senior Common Room and an infamous after-party at Metric nightclub. The on-site College caterers now provide baked potatoes for everyone. "When I was involved, we'd just go to the cash and carry to buy a huge amount of Nutella and jam," says Teare. "Then, on race day, someone would go to Sainsbury's on Cromwell Road to buy about 125 baguettes. I roped my parents into that job for a couple of years."

The raucous after-party is the one time of year when the race's emblem makes its appearance. Donated by a grateful Dutch team in the Eighties, the Hyde Park Relays horn is passed around for finishers to blow a celebratory fanfare – or at the least, a raspberry. For race organisers, a different use is sometimes found. "The year I first ran it, they made me drink a lot of alcohol from the horn," says Chris Bannon (Medicine 2011). "You could still get a note out of it afterwards, just about." Bannon first won the fastest individual leg in 2013, repeating his feat the following year.

So what is it that makes it so special? As one of the two committee members charged with making the 2017 race a success, Fergus Johnson is perhaps best placed to answer. He says: "I became a member of the Cross-Country Club in my first year. Throughout the year, when I was doing races, I kept hearing the Hyde Park Relays mentioned without knowing what they were.

"It was only when the day came that I realised how big an event it was – and that it's an occasion when everyone in the club works together to make the best race experience we can."

Team: **Falmouth and Keogh**
From left to right: Paul Vidal (Computer Science and Mathematics 3rd Year); Saturnin Pugnet (MSc Computing 2nd Year); Madison Borghini (Mathematics 2nd Year); Enzo Bermond (Mechanical Engineering 3rd Year); Cesar Maklary (Aeronautical Engineering 3rd Year); Sacha Salphati (Biochemistry 1st Year)

"How did we all meet? It's obvious! We are all French, of course. The French connection, you see, the French culture. It was a good race, if cold. We'll be doing it again."

Team: **Keith's Caravan**
From left to right:
Amy Barker (Biology 2016); Caoimhe Canavan (Biology 4th Year); Catherine Spurin (Geophysics 4th Year); Bunny Upton (Biology 2016)

"We're mostly very cold. No, really, we love the cold. The team name is all about being a first year and procrastinating, really. Caoimhe sounds a bit like Keith. Her second name is Canavan. You see? Keith's Caravan. It's obvious, really..."

YOU ARE YOUR BRAIN

WHICH IS WHY IMPERIAL'S BRAIN SCIENTISTS WANT TO UNDERSTAND HOW IT WORKS

Words: **Lucy Jolin** Illustration: **Kyle Bean**

What makes you who you really are? Forget family history or deep self-analysis. You are your brain. Which is why, when Professor Steve Gentleman, Professor of Neuropathology at Imperial, carefully and with precision, slices into a brain, he does so with great respect.

"It is as individual as we are," he says. "The size, the shape and the folding pattern are as unique as your fingerprint. One of the first things I point out to my students is that you treat the brain with the exact same respect as you would treat the patient while they are still alive."

It has long been understood that the brain is the storehouse of personhood – of emotion, thought, memory – of all the things that make us the individuals we are. But how does this fleshy, vulnerable looking organ actually do it? Dr Dan Goodman, lecturer in the Intelligent Systems and Networks group in the Department of Electrical and Electronic Engineering, is using cutting-edge technology to investigate.

Dr Goodman's work focuses on the nuts and bolts of how our brains work (as opposed to studying pathologies). Right now, he is studying 'spikes' – tiny bursts of electrical activity that occur when a neuron talks to another neuron – and how networks of neurons work together using spikes to process information in the brain more rapidly and efficiently. This matters because, as Dr Goodman explains, being able to process information in multiple ways could be a significant advantage.

"This way of processing information may well enable us to understand the connections between things that don't seem obviously connected – for example, when you're in a lecture and you notice a light moving around the ceiling. Eventually, you realise that it's the reflection of the sun on your watch, but that's actually quite a hard thing to realise. You've got to connect up the motion of your wrist as it moves around with a spot of light on the wall. Your brain has done this quite amazing thing: it's realised that they are connected, even though there is no reason to expect there to be a relationship."

Not satisfied with simply leading the research, Dr Goodman has developed a free open source simulator for spiking neural networks (nicknamed – what else? – Brian. After all, it's written in programming language Python). The programme makes it easier for researchers to connect different neurons to inputs from different systems – such as auditory or visual – and see what happens. "It helps us create simulations of the brain," says Dr Goodman. "Imagine that I want to connect specific neurons or connect one to a particular muscle and then get input from a particular system – then see what happens. Brian allows me to do that – it saves a lot of time."

Over at the Hammersmith Campus, Dr Robin Carhart-Harris is taking a different approach to unlocking the secrets of the brain. Head of Psychedelic Research at the Centre for Neuropsychopharmacology, he is the first UK scientist for 40 years to gain permission to use psychedelics including LSD and psilocybin (the substance which makes magic mushrooms 'magic') in his research.

"We can use the state that these drugs induce to gain insight into some fundamentals about how the brain works, and address some very profound questions," he says. "Consciousness: what is it? What

The brain is as individual as we are. The size, the shape and the folding pattern are as unique as your fingerprint

Professor Steve Gentleman, Department of Medicine facets of it do we take for granted? For example, during normal waking consciousness, most of us have a certain assuredness about who we are, which we feel is fixed, absolute and perennial. It's difficult to imagine the world without this sense of self seemingly at the centre of things. But under psychedelics, people report experiencing a curious dissolving away of this inner subjectivity."

Indeed, under the influence of psychedelics, Carhart-Harris says, the brain becomes less specialised. The different compartments start to break down and begin to communicate more. The whole brain is more interconnected. This can be frightening – it is associated with psychosis – but it can also be transformative and occur in states of naturally occurring spiritual experience, such as with focused prayer or meditation. Carhart-Harris' most recent trial involved studying the effects of psilocybin in people with treatment-resistant depression.

"The connectedness we see in peoples' brains while they are on psychedelics correlates with their descriptions of a profound sense of oneness," he says. "In depression, patients refer to feeling disconnected from themselves and from others but, post-treatment, they describe feeling a remarkable reconnection, so that they can live their lives normally again, being back in the moment but also with a new understanding of their suffering. There are huge potential applications in medicine, from depression to alcohol dependence to obsessive compulsive disorder and even cluster headaches."

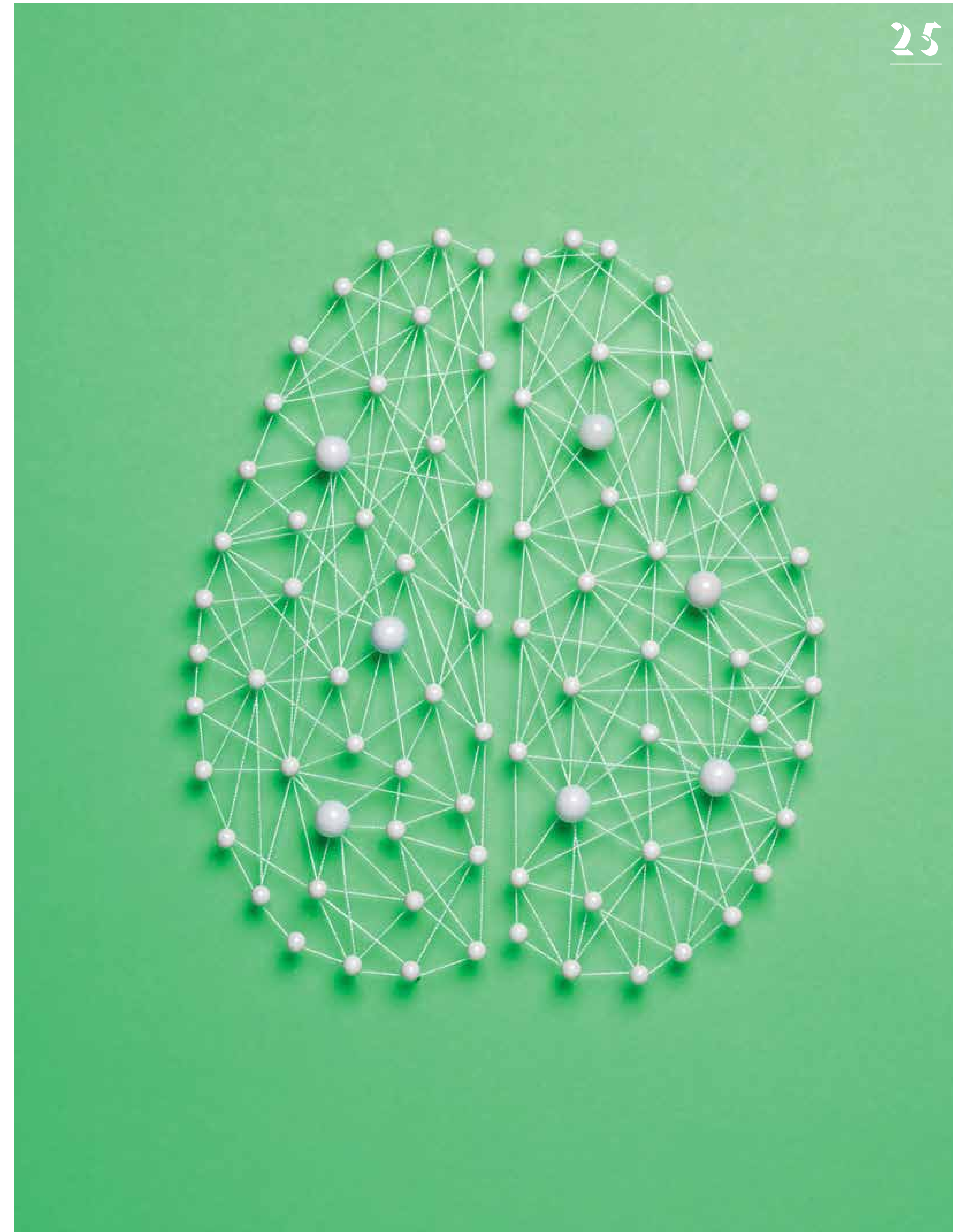
In Carhart-Harris' view, psychedelics are incredibly powerful and underutilised research tools. In the same way a damaged brain can tell us what is important in a normal brain, so can a brain under the influence of a psychedelic. Altered states of consciousness can be induced using various different methods: sleep is one, anaesthesia is another. But in both of these, the patient isn't able to say what is happening to them – whereas psychedelics profoundly alter consciousness while the patient is still wide awake.

'Spikes' – tiny bursts of electrical activity that occur when a neuron talks to another neuron – matter in terms of how they might work together to process information in the brain more efficiently

Dr Dan Goodman, Department of Electrical and Electronic Engineering

Despite – or perhaps because – of its complexity, the brain sometimes goes wrong. And when it goes wrong, the impact can be simultaneously devastating and not immediately obvious. Professor Mark Wilson, puts it like this: "If you lose an arm, you are still the same person afterwards. If you suffer a brain trauma injury, it affects who you are." The cost to society is huge – recent research from the Centre for Mental Health, the UK's leading authority in mental health research, estimates £15bn per year in the UK alone – and the personal cost, to individuals and their families, incalculable.

As a consultant neurosurgeon working at St Mary's Major Trauma Centre and on the Air Ambulance, Professor Wilson is working at the cutting-edge of both brain research and medical practice. "After cardiac arrest your chances of survival fall by ten per cent for every minute you don't have CPR or defibrillation," he explains. "Neurons die in four minutes without oxygen. You need someone there within one or two minutes to have a good chance of survival."



Rapid on-scene diagnosis is also key. At the moment, brain injuries on scene are classed as brain injuries, with no differentiation. "Get hit by a bus and no one can say with any confidence what type of brain injury, if any, is going on inside your skull. If we can improve diagnosis we can target treatments and improve outcome. This could be anything from giving you an appropriate drug to doing a surgical intervention such as a borehole to relieve an expanding blood clot," says Wilson.

In his role at Pre-Hospital Care, he's driving a programme aimed at trialling and developing medical devices that will make it easier to diagnose brain injuries pre-hospital. The team are currently trialling the Infrascanner, a hand-held device that uses infrared scanning technology to check for blood clots and is thought to have a 90 per cent accuracy rate in a hospital setting. "Developing those tools is where we will make a difference," he says.

Your chances of survival fall by ten per cent for every minute you don't have CPR or defibrillation. Neurons die in four minutes without oxygen. You need someone there within one or two minutes to have a good chance of survival
Professor Mark Wilson, Department of Surgery and Cancer

The brain doesn't give up its secrets easily, even in death, but sometimes the cells can speak across the years. That's why Professor Gentleman dissects brains every Monday morning, in front of a select audience of medical students, healthcare professionals, and representatives from charities such as the Multiple Sclerosis Society and the Parkinson's Society.

His work as a neuropathologist focuses on trying to match up those patterns of pathology that emerge under the microscope with what was happening to patients when they were alive. In some conditions, such as Alzheimer's and Parkinson's, the brain can begin to change up to 15 years before the patient even starts to show any symptoms. Control brains from people with no symptoms can also show changes. "In this population, there's almost an expectation of changing behaviour – you're just getting old, aren't you? But actually it's more than that. And you can't always work out those changes while the patient is still alive."

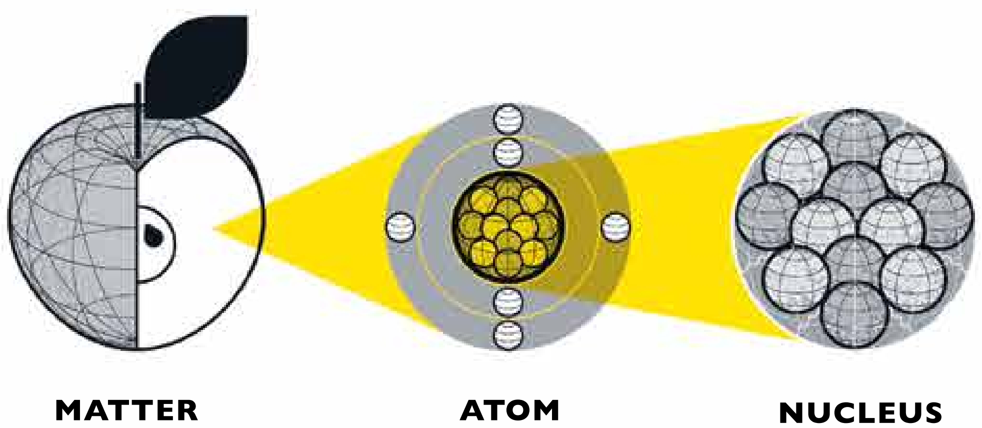
In the future, the detective work involved in early diagnosis of brain disorders might not even involve looking at a patient's behaviour or brain scans at all. "Our big aim now in terms of brain diseases is to identify those people who are brewing the disease, so to speak," says Gentleman. That might involve testing for biomarkers that might be triggered by changes in brain chemistry: changes in blood, sputum or even the air we exhale, as cancer researchers are currently investigating.

Whether it's searching for clues by the roadside, in a person's behaviour, down the microscope or in data, understanding the brain is an investigation that's never likely to be concluded. But by analysing the insights new technology and techniques offer, and by understanding more about how the brain works, we understand more about what makes us, us.

Standard Model, 3.0

The Large Hadron Collider at CERN has found the one thing no one could have predicted: nothing new. *Imperial* reports on what this means for CERN insiders – and for the future of big physics.

Words: **Peter Taylor-Whiffen** Illustration: **Ian Dutnall**



Twelve fundamental particles. Four fundamental forces. The Standard Model does a pretty good job of describing the universe – if it weren't quite so frustratingly incomplete. And then there are the questions that the Standard Model can't help with, such as: 'what is dark matter?' and 'what happened to the antimatter after the big bang?'

Which is where CERN comes in. We think. Because as physicists explore the properties of nature at higher energy levels than ever before they have discovered perhaps the one thing no one predicted 30 years ago when the project was conceived: nothing new.

That's not to say the Large Hadron Collider (LHC) has not been successful. This extraordinary project, involving 10,000 scientists from 60 countries, recreates the instant directly after the Big Bang. It fires protons at 670 million mph in the European Centre for Nuclear Research's 17-mile tunnel underneath the Swiss-Franco border and records the resulting 600 million collisions a second on the most powerful supercomputer in history. Its discovery of the Higgs boson in 2012 – the particle that gives all others their mass – spectacularly confirmed the broad accuracy of the Standard Model.

But what happens now? With so much of the universe still unexplained, where does this leave the Standard Model? And where does particle physics go from here? Have we actually learned anything at all?

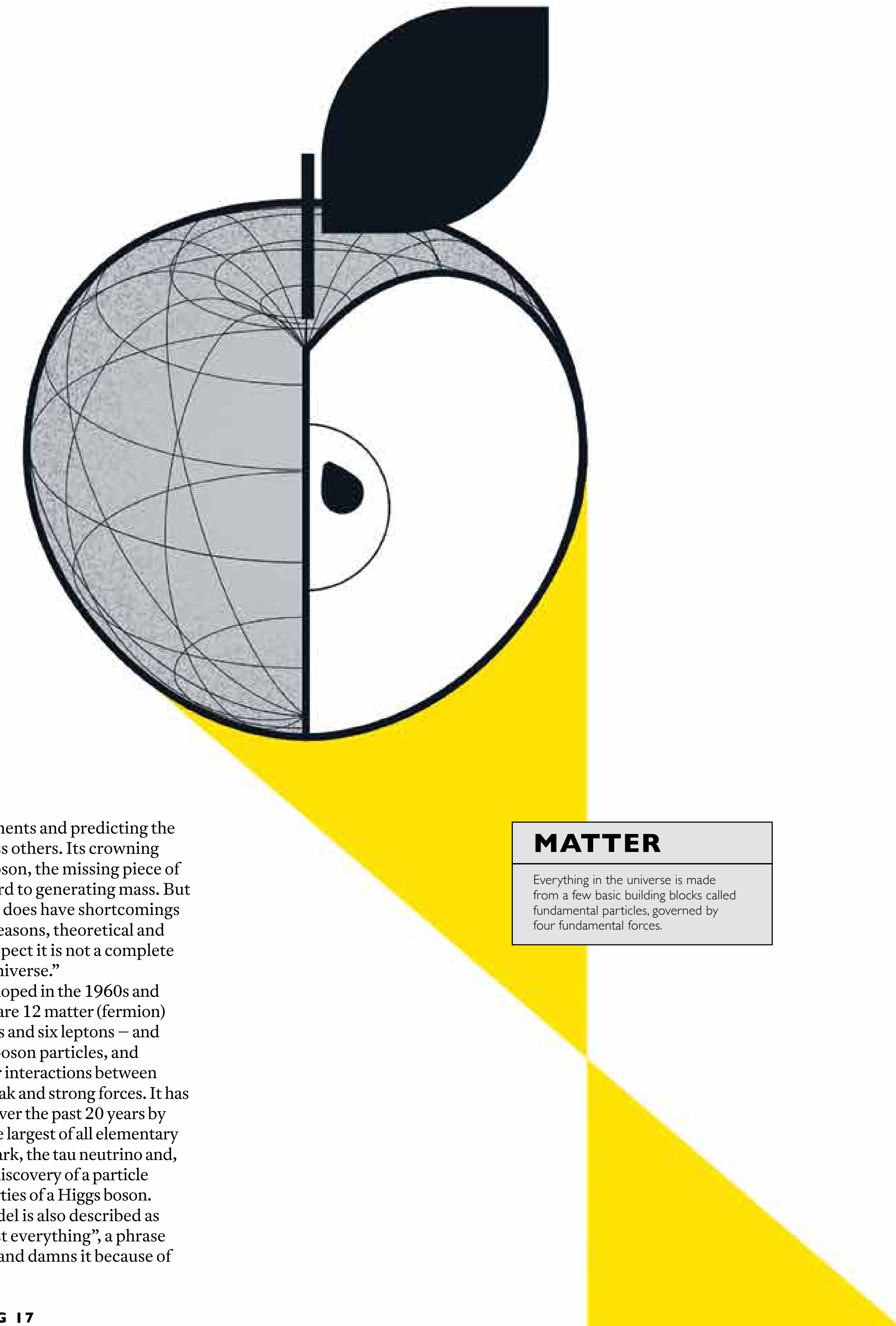
"Absolutely," says Professor Jordan Nash, head of the Department of Physics. "No new particles is an extremely significant finding. Every result teaches you something, even if it wasn't the one you were necessarily hoping for. We may have to look at the data we have in different ways, or possibly build higher energy or higher intensity accelerators to see evidence of new particles."

Nash also spent time as a CERN senior staff scientist helping develop and prepare upgrades for the CMS (compact muon solenoid) experiment, a 'general purpose' detector on the Collider. "We need a future version of the detector to give us the capability of analysing much higher intensity examination," he adds. "The LHC is a fantastic machine and the best tool we've currently got to search for new physics. We need to replace certain detectors in order to enable us to work with more particles in the accelerator. These need to be capable of withstanding up to a factor of 10 times more intensity. Precise measurements of so many collisions may allow us to spot small deviations from the predictions of the Standard Model."

Nash's CMS colleague Dr Sarah Malik agrees. "The Standard Model is our current best theory of fundamental particles and the interactions between them," she says. "It is the current state of the art theory and it has worked extremely well, offering explanations to countless experiments and predicting the outcome of countless others. Its crowning glory is the Higgs boson, the missing piece of the jigsaw with regard to generating mass. But the Standard Model does have shortcomings and we have many reasons, theoretical and experimental, to suspect it is not a complete description of the universe."

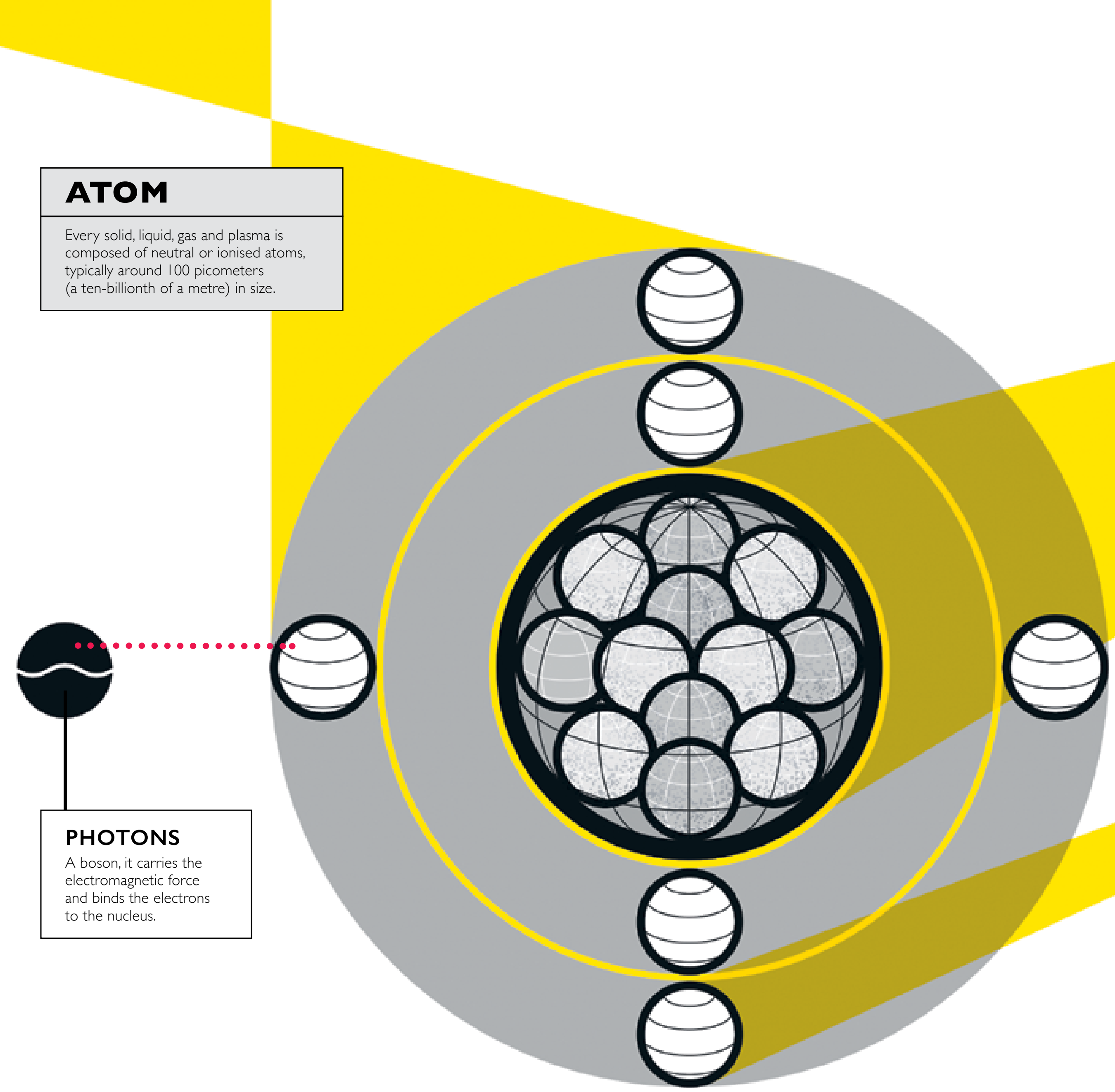
That Model, developed in the 1960s and 1970s, deems there are 12 matter (fermion) particles – six quarks and six leptons – and five force-carrying boson particles, and theorises the nuclear interactions between electromagnetic, weak and strong forces. It has been corroborated over the past 20 years by the discoveries of the largest of all elementary particles, the top quark, the tau neutrino and, most famously, the discovery of a particle matching the properties of a Higgs boson.

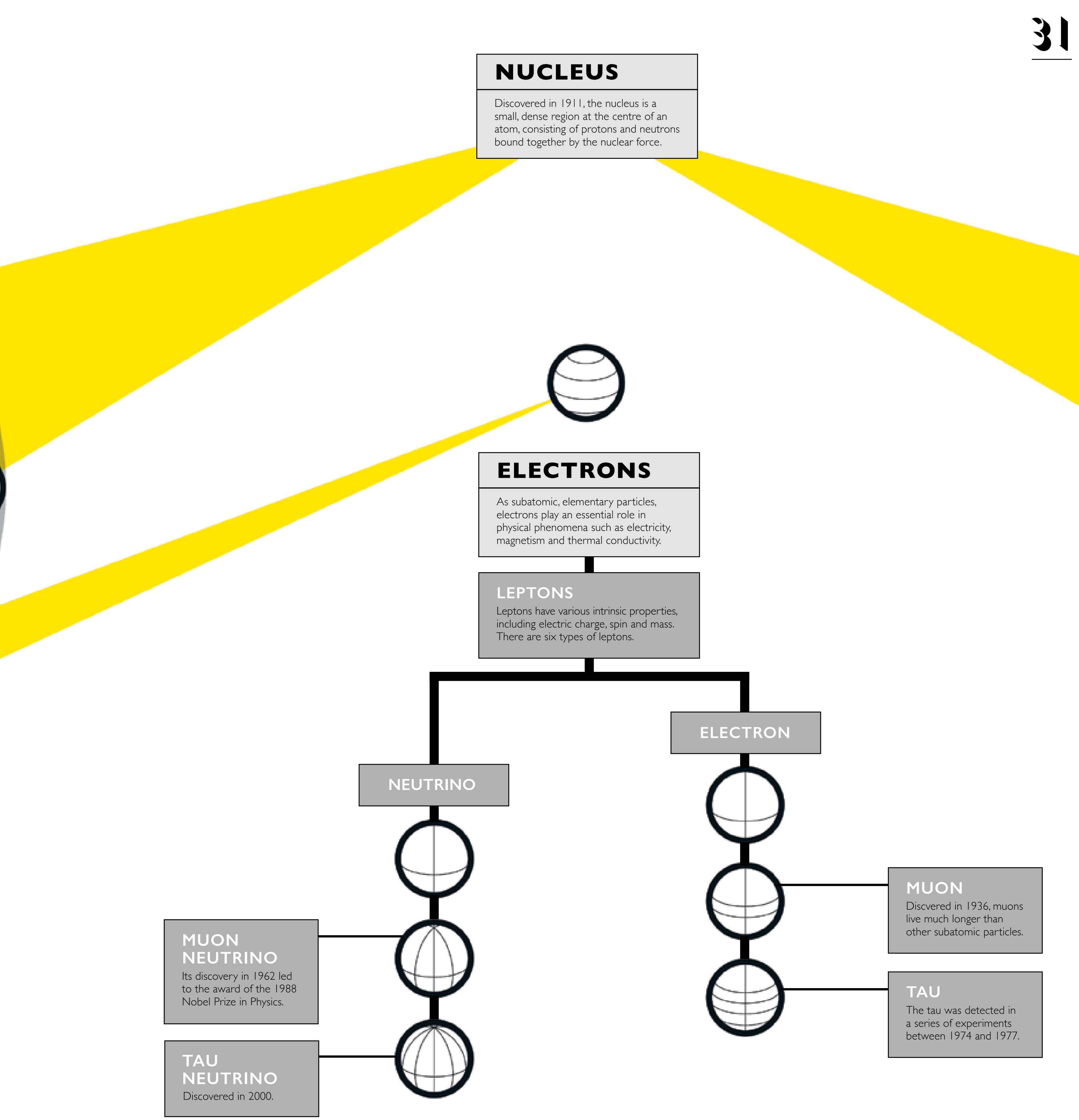
However, the model is also described as "the theory of almost everything", a phrase that equally praises and damns it because of



MATTER

Everything in the universe is made from a few basic building blocks called fundamental particles, governed by four fundamental forces.





both its wide reach and its failure to explain such fundamental phenomena as gravitation, the accelerating expansion of the universe and dark matter. Which means that, while the Model theory turns out largely to be true, it leaves us literally in the dark.

"We know a lot about five per cent of our universe, and almost nothing about the other 95 per cent," says Professor Henrique Araujo of the Department of Physics. "In particular we don't know for sure the energy scale of the new physics – it could be just above the current level probed at the LHC, or we could be a million miles off and barking up the wrong tree completely."

Which brings us to LUX-Zeplin (LZ), a separate detector in the US attempting to find dark matter. Araujo led an Imperial team on the LUX (Large Underground Xenon) experiment, which was sited at the Sanford Underground Research Facility under the Black Hills of South Dakota, and used a third-of-a-tonne of cooled liquid xenon surrounded by sensors designed to detect the weak light pulses if a WIMP (weakly interactive massive particle) collides with a xenon atom.

"We know dark matter exists – this is proved by its gravitational effects," he says. "And we know it makes up around 27 per cent of the energy content of the universe. However, beyond that, it remains unidentified because of its failure to emit or absorb any electromagnetic radiation – such as light. But hopefully the particles will still interact through the very tenuous weak nuclear force."

While the nature of dark matter particles is unfathomable (their elusive nature prompted author Bill Bryson, in his book *A Short History of Nearly Everything*, to gently parody physicists' liking for acronyms by describing them as "Dark Unknown Nonreflective Nondetectable Objects Somewhere – DUNNOS"), Araujo is hopeful we are on the verge of a breakthrough.

"The LZ detector is 30 times larger than LUX, and is vastly more sensitive than anything previously built," he says. "I'm very hopeful we will find WIMPs, which will bring us conclusive results about the nature of dark matter – and within the next 10 years. If this doesn't happen, I think it will not be because we don't have the right equipment, it will be because this particular type of particle is not there. But we believe they are, so I'm very hopeful we'll get some answers."

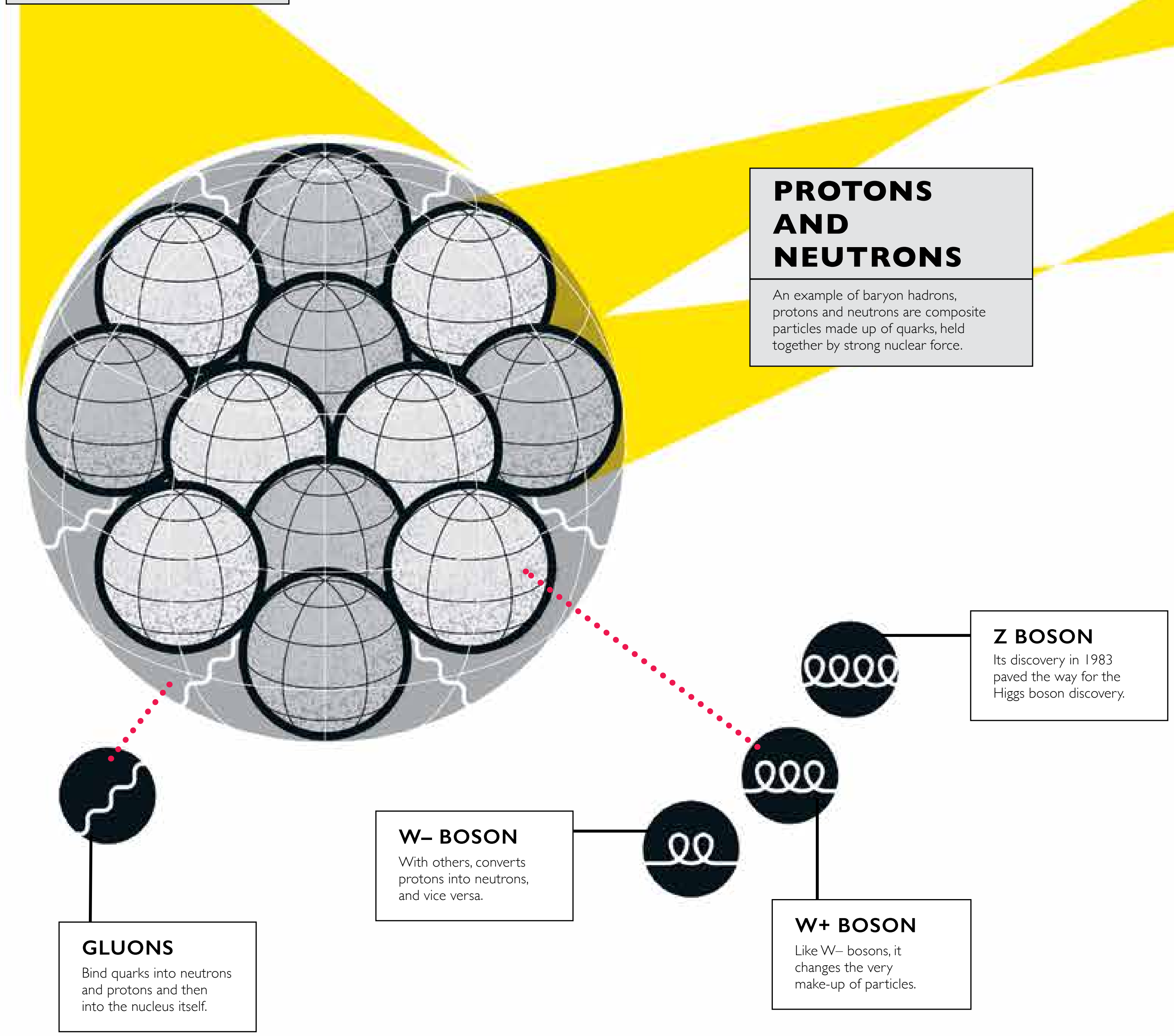
Those answers, from the LHC or the LZ, may, says Malik, further our understanding of, say, the role of supersymmetry – the theory that every fermion in the Standard Model has a boson superpartner, and vice versa – as well as what happened to the anti-matter after the Big Bang, and whether the Higgs boson is even what we believe it to be.

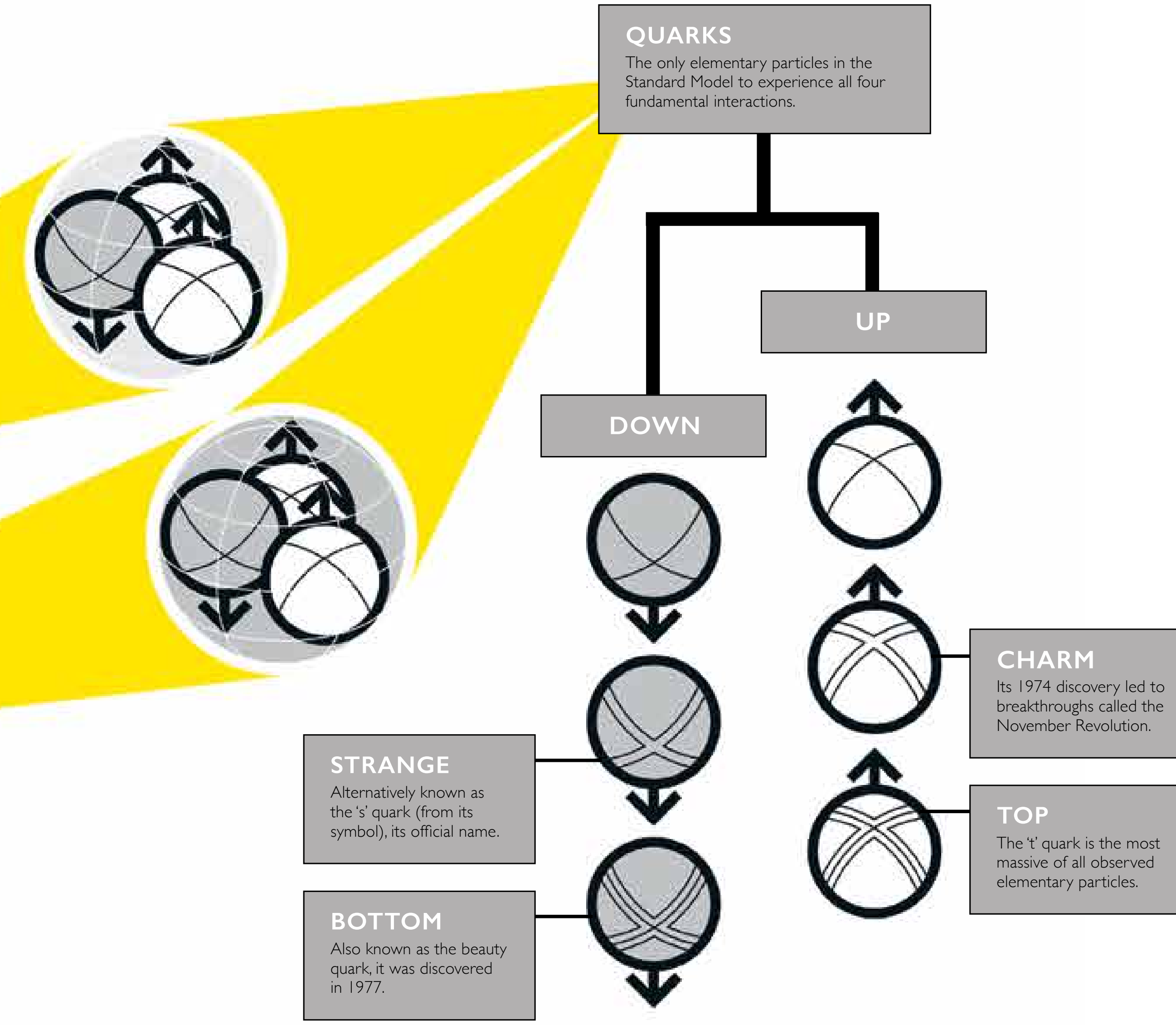
"The theory is that the Higgs particle generates mass. But its own mass is unstable and has divergent contributions, which brings us to theories like supersymmetry, which not only solve this issue but also postulate a particle that could be the perfect candidate for dark matter. A more powerful accelerator means we can probe heavier particles," says Malik. "Since dark matter carries no electric charge and interacts very weakly, these particles would leave no trace in our detectors and their presence must be inferred by applying momentum conservation and attributing to them any imbalance in transverse momentum.

"The new data will also allow us to make precise measurements of how strongly the Higgs couples to other Standard Model particles and hence ascertain whether the Higgs boson fits what we expect from the Standard Model or if it's the product of some other theory. We have many well motivated reasons to expect new phenomena beyond the Standard Model."

The LHC has upped its game significantly since its launch, and will continue to do so. Its first research run in 2010 was at an energy level of 3.5 teraelectronvolts (TeV) per beam – it now runs at 13 TeV and CERN is planning over the next five years to raise this to 14 and increase its luminosity.

"It will bring us a huge amount of new information," says Dr Alex Tapper, who leads the Imperial group involved in developing new electronics boards to cope with the increased data from the enhanced LHC.





"Normal PCs simply aren't fast enough so we developed a custom processor and a system of optical fibres that can carry huge amounts of data very quickly.

"I'm hopeful we will find an anomaly that does help us identify and define dark matter. The Standard Model has guided experiments but we know there's something way beyond that, as yet undiscovered. People like answers that fit the theories, and these are valuable, but I'm an experimentalist – I'll be overjoyed if we find something that is so unexpected it takes us in a completely different direction."

It's ironic, then, and arguably neatly supersymmetrical, that the one thing likely to shine the greatest light on the origin, development and workings of the universe is the as yet impenetrable dark matter.

"You could put it like that," says Nash. "But that mystery and uncertainty does make it interesting. The Standard Model is the best, most accurate description of the universe we have, but with an enhanced accelerator we could see a breakthrough in the next two, five, 10 years and it could change our thinking completely. There are as many radical theories out there as there are radical scientists and new data could turn up something utterly surprising. That's really exciting."

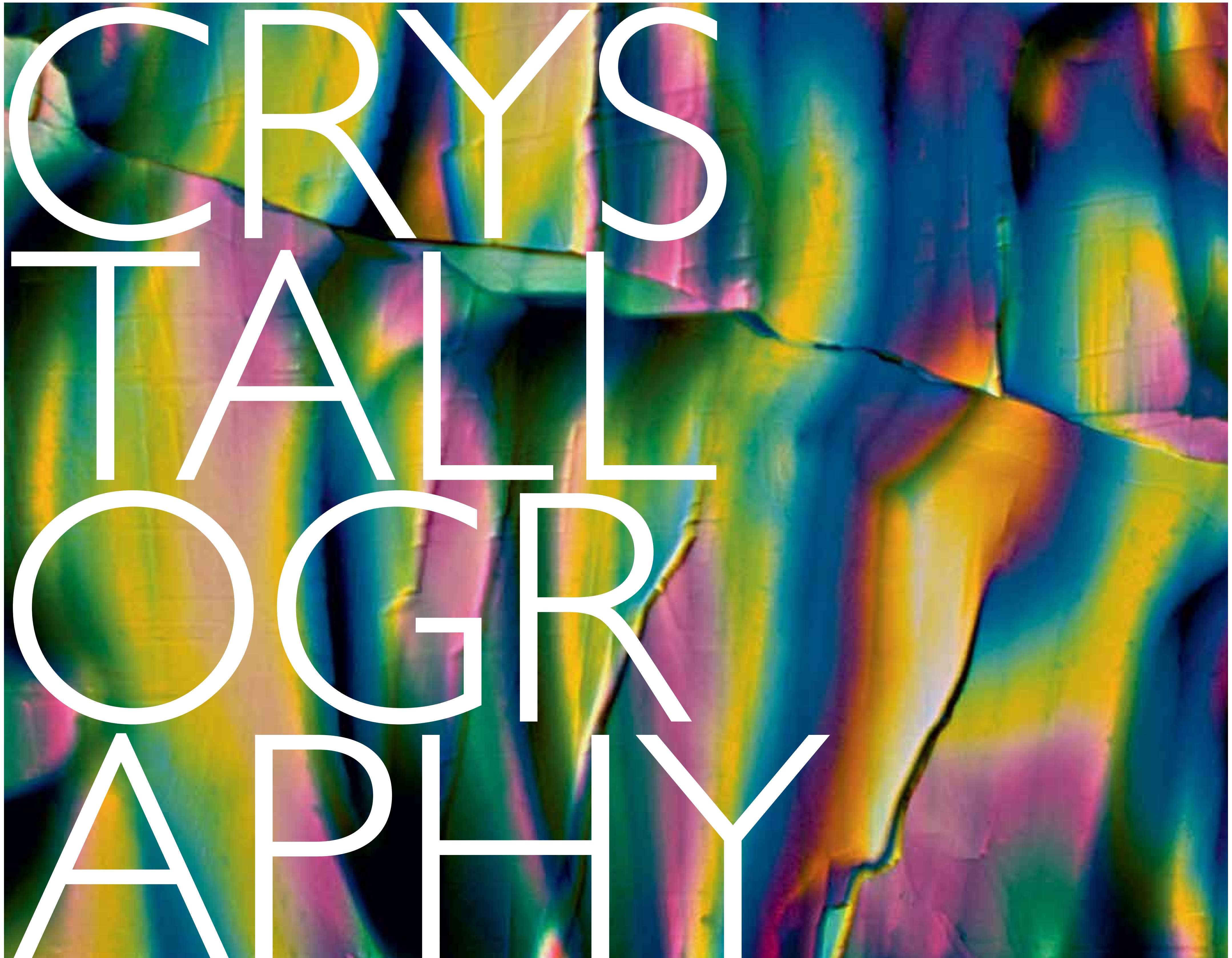
Tapper agrees: "No, we haven't found anything new. Yet. But the possibilities to do so over the next few years are huge – and anything we do find will give us greater understanding of the universe than ever before. It doesn't get more exciting than that. It's clear that particle physics is still the biggest game in town."

In 2015, Professor Henrique Araujo and Dr Sarah Malik presented their work at a Blackett Colloquium. To see the video, visit youtube.com/imperialcollegevideo and search for 'Dark matter'.

Higgs boson

In 1964, six physicists, including Peter Higgs, theorised about the existence of an energy field that is thought to exist everywhere in the universe and which is accompanied by a fundamental particle which the field uses to continuously interact with other particles – to give them mass. Its existence was the last unverified part of the Standard Model, and the hunt to verify it led to the construction of the Large Hadron Collider. On 14 March 2013, scientists at CERN tentatively confirmed they had found the elusive particle, and later that year Higgs and François Englert were awarded the Nobel Prize in Physics for "the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles".

CRYSTALLOGRAPHY



Above: Light micrograph (LM) of Insulin crystals. Insulin is a polypeptide hormone that regulates carbohydrate metabolism. It also takes part in the metabolism of fat (triglycerides) and proteins. Insulin, one of the smallest proteins known, is produced as a prohormone molecule - proinsulin - that is later transformed by proteolytic action into the active hormone. Magnification: x30 when shortest axis printed at 25w.

Professor Naomi Chayen explains why, when it comes to medicine, crystals may indeed have magical properties.

To grow a crystal used to be considered a kind of magic. Perhaps that's because crystals are so beautiful: it is easy to understand why so many people are fascinated by them and believe that they bring good fortune, or have healing powers. And yes, they do have powers. Crystallise a substance – a protein, for example – and you can understand its structure. We prize diamonds for their beauty: I prize protein crystals for their potential power to unlock new treatments, in everything from cancer to diabetes. They are my diamonds.

My own involvement with crystallography was a happy accident. I was encouraged into the field by one of its great pioneers, Professor David Blow. At that time, growing a crystal was regarded as more of an art than a science. There was a sense that one had to have 'green fingers', like a gardener: knowing the basic components of success but also using some kind of indefinable sixth sense.

I became fascinated with them. I wanted to bring scientific fundamentals to the process and create crystallisation methods that would work all over the world, from Kathmandu to Tokyo. Of course, crystallisation is not new. In 1914, Max von Laue won a Nobel Prize for his discovery that X-rays could be diffracted by crystals, making it possible to work out their structure. In those early days, there was a great rush to crystallise as many things as possible. Any substances that were simple to crystallise, were crystallised.

All prescription drugs on the market today, accounting for billions of pounds in sales, directly or indirectly target proteins. Proteins are responsible for many of the body's functions such as oxygen transport, food digestion, muscle movements and many more tasks. And disease often occurs due to the malfunction of proteins.

Once the human genome was sequenced, the need to crystallise became more urgent than ever, as for the first time there was an exponentially increasing number of proteins that could be identified as potential drug targets. But there was a bottleneck. The crystals that they needed could not be produced at the required quality.

Each protein has a different role. Its three-dimensional shape, or structure, determines this role. In order for a medicine to be effective, it needs to know what this role is, as it needs to target the specific protein that is involved in the disease that is being tackled and influence its activity, by either blocking or enhancing it. To achieve this, we first need to know exactly what the protein looks like – in other words to determine its structure. It's a bit like looking round a room in order to give the right task to the right person: there's no point asking the shortest person in the office to reach down a book from the highest shelf.

The most powerful method for determining the structure of proteins is X-ray crystallography. In their natural state, proteins – in the blood, for example – are liquid. Unlike solids, which have a definite shape and size due to orderly arrangement of their molecules, liquid proteins are hard to visualise. Hence, in order to enable us to visualise their shapes clearly, we need to change the proteins' liquid state to semi-solid. In other words, into a crystal which can then be X-rayed. But there's a problem: this method is totally reliant on the availability of high-quality crystals – and they are very hard to produce.

Crystals of proteins and other biological molecules are particularly difficult to obtain. This is because they are very large molecules consisting of millions of atoms, and the crystallisation process depends on many different factors. Most proteins of interest are limited in supply (less than 1mg). Most importantly, proteins are biological materials, sensitive to external conditions. They cannot be made to form crystals by the harsh means that are applied to producing crystals of diamonds and gems, such as high pressures or high temperatures.

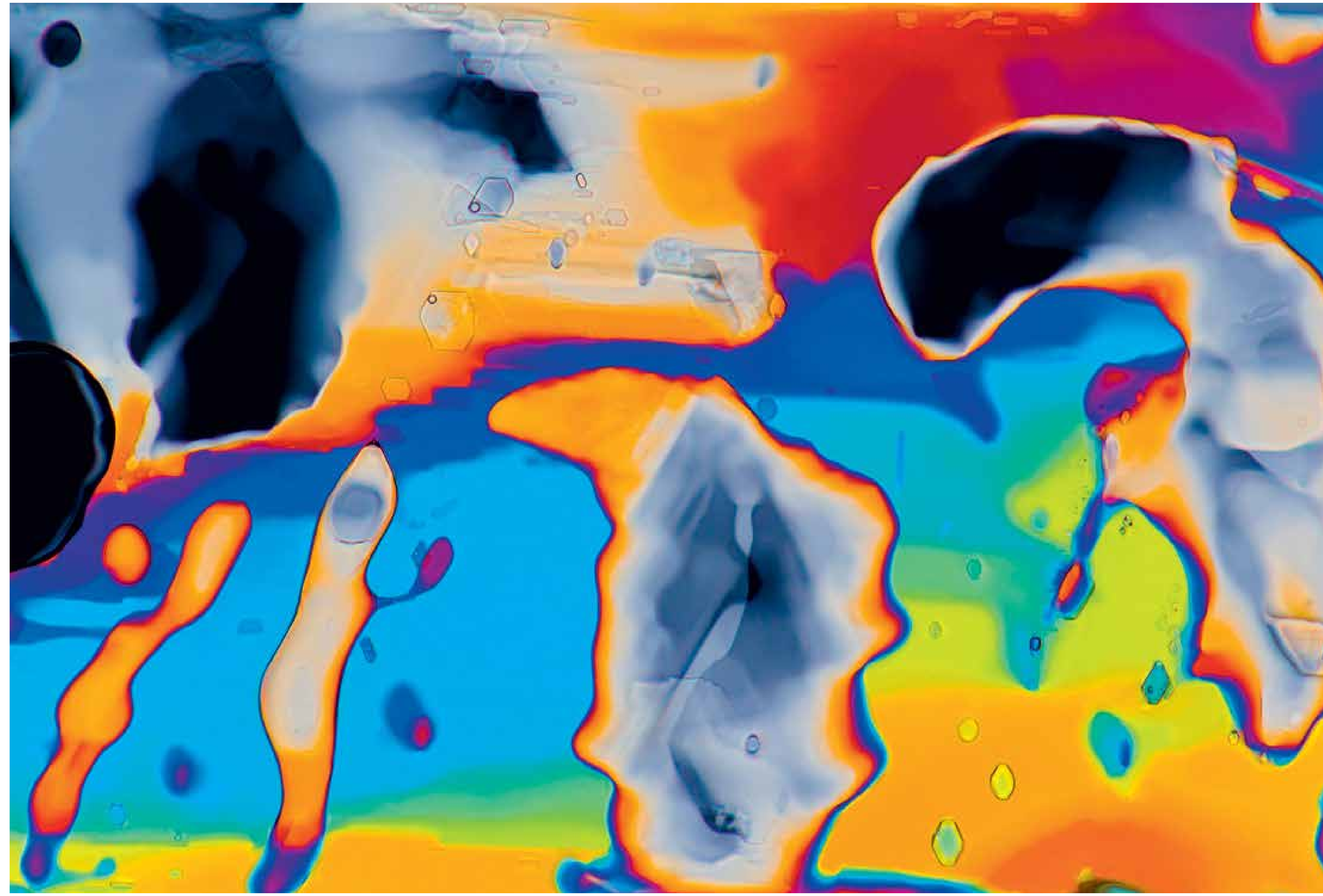
INDUCING NUCLEATION

Meeting this challenge is where my lab comes in. Our first strand of work is to develop a fundamental understanding of the crystallisation process and exploit this to design practical methodology for producing high quality crystals of medical and industrial interest. The second is crystallising target proteins to determine their structure and enable rational drug design. At the moment we are working on the crystallisation of proteins related to cancer, HIV, diabetes and heart disease.

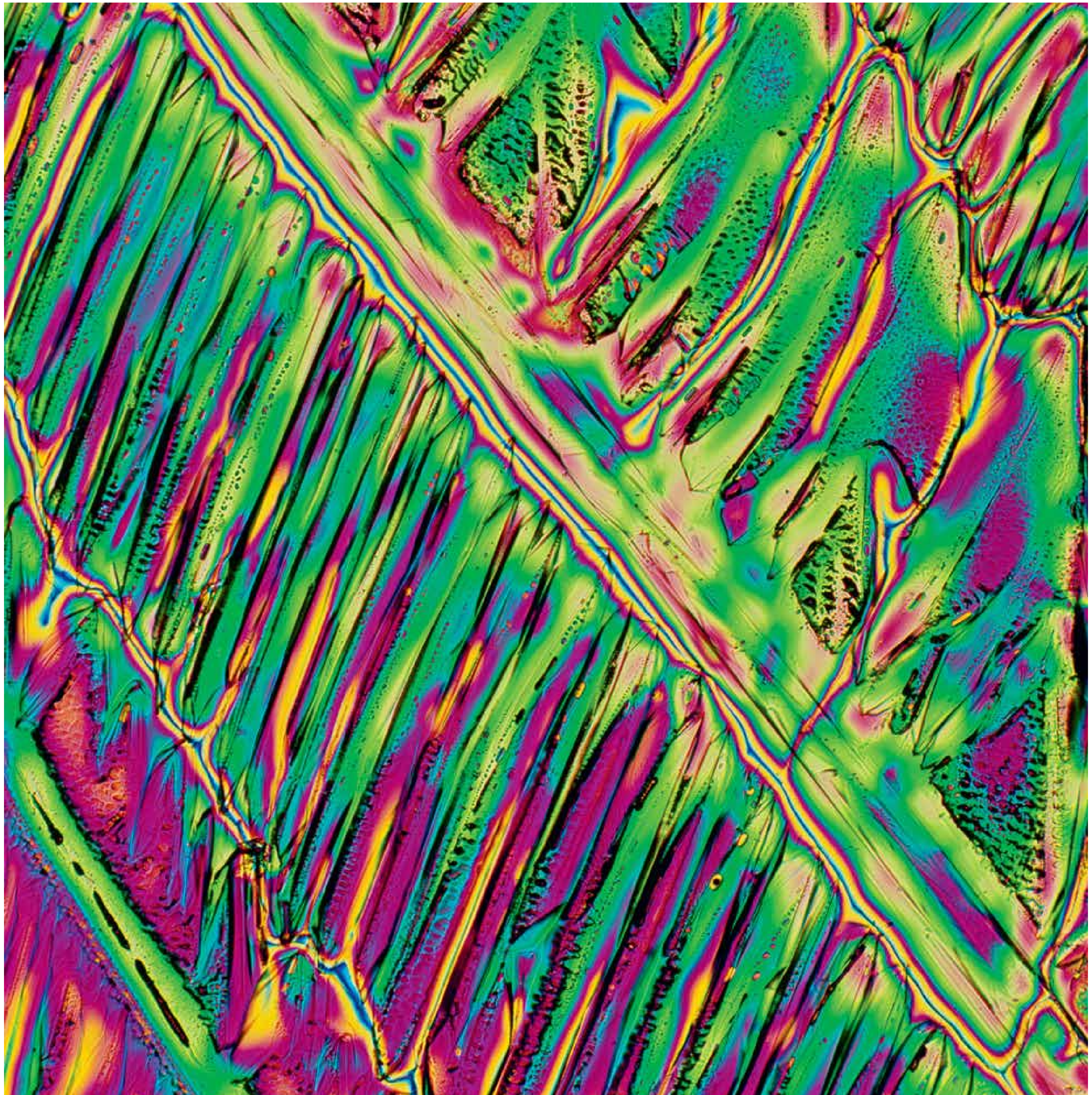
Our latest breakthrough was around nucleants. Growing a crystal requires tender conditions, similar to the formation of a baby. In the first stages of growing new life, two molecules are brought together and, if they connect well, you get a healthy embryo which then turns into a healthy baby. But if too many molecules come together – which can happen during in-vitro fertilisation (IVF), for example – they may compete with each other and lead to difficulties.

So when it comes to crystallising proteins, success lies in being able to control the 'conception' stage of the process, applying materials that induce nucleation and formation of crystals. These nucleants can help the crystallisation process by serving as an anchor or template for the protein molecules to stick to and gather around. Early nucleation-inducing materials were based on a process called epitaxy – electrostatic attraction of the protein molecules by oppositely charged surfaces – or attempts to increase the contact area between the crystallisation solution and the surface. These approaches had limited success.

In setting out to find a nucleating agent that would work via a completely different mechanism, I introduced the idea of designing



Above: Polarised light micrograph of crystals of serine, one of the 20 amino acids used to form proteins. This is the naturally-occurring L-stereoisomer known as L-serine. It is critical for the synthesis of the body's proteins and enzymes, and necessary for specific functions in the central nervous system, as well as the proper metabolism of fats, fatty acids, cell membranes and muscle growth. Field of view size: 0.740 x 1.110 millimetres.



Right: Polarised light micrograph of pepsin crystals. Pepsin is an enzyme secreted in the stomach of vertebrates, along with hydrochloric acid. In acid solution pepsin splits proteins into peptones (large protein fragments), thereby contributing to the digestive process. The stomach lining itself is protected from the action of the acid and the enzyme by its coating of mucus. About 30 grammes of pure crystalline pepsin would be capable of digesting nearly two metric tonnes of egg white in a few hours. Magnification: x100 at 6x7cm size.

PHOTOGRAPHY: SCIENCE PHOTO LIBRARY

nucleation-inducing agents that contain pores of similar sizes to those of protein molecules. The pores entrap protein molecules and encourage them to coalesce in crystalline order. Porous materials have worked well and have set a trend in the field.

Building on the success of such porous materials, in particular a specifically designed bioglass (patented and commercialised under the name of 'Naomi's Nucleant'), we sought to design nucleants with improved specificity for protein molecules while maintaining the idea of harnessing pores. We discovered the existence of polymers imprinted with proteins (MIPs), also referred to as 'smart materials'.

Molecular imprinting creates polymers formed in the presence of a molecule that is extracted afterwards – leaving behind cavities imprinted with that molecule. The cavities in the gel retain a memory of the molecule after it is removed and exhibit highly selective rebinding of the given molecule. In collaboration with the University of Surrey, we had MIPs imprinted with a variety of proteins, and experimentally found, as we had hypothesised, that the cavities acted as templates for crystal nucleation and facilitated crystal growth. This has led to a second patented product, commercialised by Imperial Innovations, by the name of 'Chayen Reddy MIP'.

CRYSTAL CLEAR

In the past 15 years, there has been momentous progress in the miniaturisation, automation and analysis of crystallisation experiments. X-ray beams have been developed, for example, that can X-ray tiny crystals, and I have been involved in several pioneering aspects of protein crystallisation, such as the development of nano-scale crystallisation procedures, robotics and the design of screening and optimisation techniques.

The research has established new concepts in the field and unique ways of producing crystals, making experiments more efficient as well as saving time and materials. The new methods have resulted in successful crystallisation, leading to the structure determination of numerous proteins, including membrane proteins and large macromolecular complexes that had previously failed to crystallise using conventional techniques.

I have also sent experiments into space with NASA, the European and Russian Space Agencies and on the International Space Station. With no distractions – such as gravity, which pulls them down, and convection, which makes them mix – crystals can grow more effectively.

Yet producing useful crystals still remains a major barrier to progress, but we're continuing to develop rational approaches to find new ways of overcoming this problem. Nowadays labs conduct crystallisation trials mainly using robotics, so any methods that we design need to be adapted to automation and high throughput mode. For me, the really big question of finding that magic bullet has yet to be solved.

I know that we will continue to be inspired by the structures that we prize so highly: after all, the expressions 'crystal clear' and 'to crystallise thoughts' stem from our science. Just like the crystals that provide atomic structures, our initial thoughts are jumbled. Yet as they gradually come together in an ordered way, we then begin to see the whole picture and understand what is going on.

ILLUSTRATION: JOEL KIMMEL

DISRUPTOR

Their lives in our hands

Professor Alan Fenwick says the treatment of 140 million children in 15 years is medicine on a grand scale.

> **"Our work is supporting the treatment of 30 million children a year in 18 countries across Africa"**

Trying to combat one of the world's deadliest diseases is hard enough. It's even more challenging when it's got a name that most people cannot spell, very few can pronounce and few have ever heard of – even in the countries where it's most prevalent.

But I'm a glass half-full sort of person, so I'm proud and excited by the amount of progress we've made in the treatment of schistosomiasis. It's easier to call it 'snail fever', but whatever you call it, its consequences in Africa are horrific.

Schistosomiasis (bilharzia) is the second most important parasitic disease in Africa (beaten only by malaria); it infects 258 million people in 78 countries, 90 per cent of them in Africa. The parasite itself lives and multiplies in freshwater snails and is so powerful that it can infect people who swim, bathe, fish and even wash in the fresh water lakes, dams and rivers it inhabits. Depending on the strain, it can attack the liver, kidneys and bladder, causing 200,000 deaths a year – all of which are entirely preventable.

That's the bad news. The good news is our work at St Mary's Hospital is supporting the treatment of 30 million children a year in 18 countries across Africa – and has resulted in the treatment of a total of 140 million in the 15 years since we started. That's disruption on a grand scale.

You might think our work would be focused on finding a vaccine, but even though one doesn't exist, vaccination is not our priority. Schistosomiasis can be effectively 'cured' by pills that kill the parasite and, as our drugs are donated, this approach is much cheaper than an inoculation programme.

I spent 17 years in the Sudan for the London School of Tropical Medicine and Hygiene and the Wellcome Trust, with grants from the US and UK governments to explore the prevalence and control of the illness. Subsequently I moved to Egypt with USAID and World Bank support, which resulted in cutting the rate of infection in the whole country from one in four people to just one in 50. In 2000, I took my results to Bill Gates, whose foundation gave me $34m over five years to do the same in sub-Saharan Africa. With this grant money, I established the Schistosomiasis Control Initiative (SCI) at Imperial and we have not looked back.

However, our biggest challenge has been, and still is, advocacy – approaching health ministries in countries to tell them they have a problem of which they weren't previously aware, and encouraging them to commit to doing something about it. The money, and the donated drugs, help our cause immensely, but it's that advocacy, getting governments on side, that is the real solution.

Our research today is not concerned with the disease itself – although there's always more to learn – but about the knowledge, attitude and practices in a particular area. But in the end, it is good governance that lets us in, giving us permissions to fund mapping exercises and test for prevalence.

It has been frustrating, because it is such a preventable illness. It's frustrating that there are hotspots where 80 per cent of the population will apparently always be infected because they have to use these bodies of water so much in their everyday lives. They can take a pill, and the parasite is gone, but they may pick up more worms again next time they're in contact with that water.

It's frustrating that these parasites can live up to 20 years, and it's frustrating that we can't get everywhere with our treatment. We can't treat children when they are taking exams because that becomes their priority, or when the schools are closed, in the rainy season because the roads are washed away, and the volatility of some governments in some states means we always having to have that initial advocacy conversation all over again.

But we are doing what we can, and we are achieving fantastic coverage with support from the UK Government Department for International Development (DFiD) and other donors – at very low cost. The SCI's work has been rated the most economic provider of this type of treatment: our donors – of money and of pills – enable us to treat each child for just 30p. The World Health Organisation set a target of eliminating transmission completely in many countries by 2020 and although this is an impossible target, I think we can go a long way towards doing that in several countries. It gives me a great sense of pride.

Alan Fenwick is Professor of Tropical Parasitology at the Faculty of Medicine, School of Public Health, and founder of the Schistosomiasis Control Initiative (SCI) in the Department of Infectious Disease Epidemiology.

THE INTERNATIONAL COMMUNITY

The making of me: alumni talk about their experiences of a diverse Imperial.

GUILLAUME PIARD
(MSci Physics 2003)

My family is French and I was born in the US and grew up in Chicago, Tokyo and Paris. The internationalism of Imperial was certainly a factor in my decision to go there, and London is by far the most international city I have lived in – Imperial particularly so. On campus it was such a cosmopolitan mix, and that was reflected in my friendship group. Given my background I have a natural tendency to be attracted to other cultures, and I believe everyone should live abroad for some part of their life. Imbedding in another culture makes you realise that people live differently but happily – there's not just one way of life. I think that Imperial students are naturally curious – that's what defines us.

When I graduated from Imperial I spent ten years in capital markets, working first for Lehman Brothers then for Nomura. After a while I started questioning my role in society. How was I helping things move forward? So I went and did an MBA and now I'm starting my own company.

Science in general is about searching for the truth, pushing the envelope of our knowledge, and seeing how we can influence the world. The product my company, Nalo (www.nalo.fr) is developing is an automated investment management service, within the bigger nebula of Fintech. It is an online platform that can bring financial advice to everyone, everywhere.

The way I've lived my life is thanks to my parents first and then to my studies. Studying in an international community gives you options. This is a gift that has been given to me. It's very humbling, and I'm trying to make the best of it, make my parents proud, and fulfil a social and moral contract.

POO SING WONG
(Medicine 1986)

It had always been a dream of mine to study at St Mary's, and I quickly immersed myself in medical school life. I studied hard, but also played hard, making many good friends. In my year, there were four students who had 'Wong' for a last name and two UK-based students with the last name 'Wright'. I hence became the butt of a year-long joke; apparently 'four wongs don't make two wrights!'

Having always been a sportsman at heart, I played in the hockey first team for St Mary's and even occasionally played for the rugby third team. Playing sports was a fantastic way to bond with the local students, not only while playing the game, but also during after-sports activities.

During my final year at medical school, I had a real passion for surgery. After graduating, I decided to pursue a career as a surgeon and trained in cardiothoracic surgery at the Royal Brompton Hospital and the London Chest Hospital. I put my heart and soul into my time there; the hours were long and hard and I sometimes had no life outside the hospital. Despite the hardships, I feel privileged to have been trained at these two prestigious institutions, having worked with the best surgeons who had great skills, were passionate teachers and had exemplary bedside manners.

After I was fully trained, I was given an opportunity in Malaysia in 1995 to set up cardiothoracic surgery centres in Penang and Johor Bahru. I then moved to the National University Hospital in Singapore where I was Associate Professor in Surgery. In 2006, I went into full-time private practice. Despite all the years that have gone by, I will never forget the fond memories I have of my time at St Mary's.

WORDS: ANASTACIA HANCOCK ILLUSTRATIONS: SAM KERR

MAX DUCKWORTH
(Physics 1992)

After three years studying physics at Imperial, I chose the US to do my PhD, but didn't feel intimidated about living across the pond as a 21 year old, partly because Imperial had provided me with such a multicultural experience. In addition, my mother is Italian and I was president of the Italian Society while at the College.

When the Superconducting Supercollider – and consequently my PhD project – was cancelled in 1994, I decided to pursue my growing interest in climate change and environmental issues by joining a small not-for-profit thinktank working on renewable energy and climate policies. A few years later, I started asking myself how the energy industry really worked, and joined Constellation Energy, which went on to become a leading global commodities firm. In 2012, I left and decided to try to address the lingering environmental and social issues we face by making direct investments in start-up companies.

The result was MaSa Partners – a for-profit company investing human and financial capital in people, technology, products and solutions across many sectors – including agriculture, energy, and healthcare. Our portfolio companies are mainly located in the US, but we have also invested in two UK-based companies. We tend to invest in early-stage companies that are global in outlook, offering world-changing products. Whether consciously or subconsciously, I do think globally because not only was I fortunate to grow up all over the world, but then was immersed in the wonderfully diverse, multicultural environment of Imperial.

AMY LE COZ
(MBA 2004)

I am American and had lived in Paris for ten years before joining Imperial. I have always felt most comfortable in mixed and cosmopolitan groups, so immediately was very at home here. I learned as much from the people in my cohort sharing their career experiences as I did from my professors.

My exposure to people from such a variety of backgrounds certainly contributed to giving me the courage to start my own business. When I was doing my Executive MBA, I was made redundant from the job that brought me to the UK. This was obviously a shock and at first quite devastating in particular because I was also recently widowed with two young children. However, I was specialising in entrepreneurship, and my experience of working in groups with people from international backgrounds made me realise how much more we could achieve with the diversity of input rather than with our own singular knowledge.

> **"Without a doubt, my experience at Imperial helped me understand the power of diversity"**

I definitely took this lesson with me in my own company, Digital Media Services, and positively sought to build a very international employee base. The company now has offices in London, Los Angeles and Sydney and employs more than 80 people who come from every continent except Antarctica. I know without a doubt that this diversity is the key to the company's success and my experience at Imperial helped me understand its power.

Imperial College London

WHAT'S ON AT IMPERIAL

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.

7 June
ATHENA LECTURE
Sinead Lynch, Chair of Shell UK, delivers the annual Athena Lecture.
South Kensington Campus, London

7 June
WELCOME TO WHITE CITY SUPPORTER AND ALUMNI RECEPTION
An event to thank donors to Imperial for their support and to welcome them to the College's White City Campus.
White City Campus, London

14 June
INAUGURAL LECTURE, PROFESSOR BEN SAUER
Measuring the shape of the electron: how round is the electron and why could this answer the mystery of antimatter?
Blackett Building, South Kensington Campus, London

21 June
FRIENDS OF IMPERIAL SUMMER PARTY
An annual summer celebration for members of the Friends of Imperial.
170 Queen's Gate, South Kensington Campus, London

22 June
DEPARTMENT OF BIOENGINEERING ANNUAL LECTURE
Professor Sangeeta Bhatia, cancer researcher and biotech entrepreneur, delivers the annual Department of Bioengineering lecture on the power of miniaturisation in medicine.
Sir Alexander Fleming Building, South Kensington Campus, London

27 June
INAUGURAL LECTURE, PROFESSOR WILLIAM KNOTTENBELT
Modelling the memoryless: explore the maths that underpins everything from digital money to tennis.
Huxley Building, South Kensington Campus, London

4–9 July
ROYAL SOCIETY SUMMER SCIENCE EXHIBITION
Join Imperial researchers presenting their work at this week-long celebrationof UK science.
Royal Society 6-9 Carlton House Terrace, St. James's Park, London

CAN'T MAKE IT TO CAMPUS?
Many events are now live-streamed or filmed so you can enjoy them.
www.youtube.com/imperialcollegevideo

www.imperial.ac.uk/whats-on

IMPERIAL FRINGE 2017/18
The Imperial Fringe series of public evenings celebrating the unexpected side of science will return in October 2017. *Visit www.imperial.ac.uk/festival/fringe*

IMPERIAL AROUND THE WORLD
Receptions for alumni and friends are held around the world. *Visit www.imperial.ac.uk/alumni/events for more information.*

DATASET

RISING DEMAND

Professor Geoffrey Maitland's work on carbon capture is crucial to meeting ambitious targets.

Words: **Lucy Jolin**

Professor Geoffrey Maitland is a realist. "If we are going to meet the rising energy demands of the developing world, we must accept the continued use of fossil fuels, in this century at least. The real question is, how can we do so without creating catastrophic climate change?"

This is a pressing question. Climate experts predict that the global demand for energy will double by 2050. Global emissions of carbon dioxide currently stand at a staggering 36 gigatons a year. Following the Paris climate conference of December 2015, ambitious targets have been set on a nation-by-nation level to reduce greenhouse gas emissions, with EU members, for example, agreeing jointly to aim at reducing emissions to 20 per cent below the 1990 level by 2020.

The ways this can be done include increased energy efficiency and greater use of renewable energy. But as Maitland, Professor of Energy Engineering and founder of the Qatar Carbonates and Carbon Storage Research Centre, points out, at least 20 per cent of the reduction in CO_2 emissions by 2050 demanded by the Paris agreement will need to come from climate mitigation technology for fossil fuels. This includes techniques such as carbon capture and storage (CCS), that can capture and store safely up to 90 per cent of the carbon dioxide CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere.

At present, there are 20 large-scale CCS projects in existence across the world, with another 15 in the pipeline. This is, quite simply, not enough, says Maitland. "Typically, each CCS plant will capture between two and three megatons of CO_2 per annum. Which means we would need something like 3,000 CCS projects to meet the 2050 targets of 10 gigatons of CO_2 stored per annum. But progress is very slow, largely because there are no strong commercial incentives, such as an effective carbon tax. We are currently relying mainly on altruism or on sites where injecting the CO_2 can enhance the production of more oil and gas to offset the CCS costs."

Some companies – and indeed nations – already recognise the need for a long-term change in attitudes and actions. The Qatar Carbonates and Carbon Storage Research Centre established in 2008 at Imperial is unusual: the $70m programme has a ten-year time horizon. This has allowed Maitland and his team to undertake their ground-breaking research, measuring the effectiveness of carbon capture and storage methods in depleted oil and gas reservoirs and the salt-water saturated layers of permeable rock found deep underwater that are known as saline aquifers.

4,000 million tonnes

– the amount of CO_2 that needs to be captured and stored per annum by 2040 under the IEA's 2°C scenario (2DS)

(it's currently at 70 million tonnes)

They are the first to apply to CCS the measuring methodology known as 'pendant drop' to accumulate data on how the captured gases behave under the kind of high temperatures (around 250°C) and pressures (more than one kilobar) found in locations suitable for carbon storage. As Maitland points out, developing a carbon storage facility in a saline aquifer is no easy exercise, as the aquifers are usually to be found between one and two kilometres below ground. The trick is to recreate these extreme conditions above ground.

The pendant drop methodology enables measurement of the interfacial tensions between the CO_2 and the fluids it encounters in the reservoir. It is all about contact angles that allow the team to characterise the 'wettability' of the rock to CO_2 – the aim is not to wet the rock. The results are crucial both for predicting the capacity of the storage facility and for ensuring that the injection of the noxious gases takes place at pressures which avoid fracturing the rock and that they remain permanently trapped.

Maitland works alongside Martin Trusler, Professor of Thermophysics, who designs the bespoke equipment needed to conduct the experiments under the very high pressures and temperatures required. The team's work supplies data to identify suitable reservoirs and to optimise the design for CCS facilities to ensure maximum efficiency and lowest risk, both commercial and environmental. "The benefit," says Maitland, "is that if you know in advance just how much CO_2 can be effectively captured and stored in differing locations, expensive, long-term commercial decisions are more likely be taken.

"We know how to capture and store CO_2, but inevitably it comes at a cost. At the moment, it is probably more expensive than using some renewable energies such as wind. But as we are going to continue to use fossil fuels, at least in the short-to-medium term, we have to do something – by industry and academia bringing costs down and governments introducing realistic carbon charges." The complex equations which lie behind his team's usage of the pendant drop methodology provide at least some of the answers.

ADVENTURES IN...

THE HUMBLE BEE

Dr Richard Gill is dedicated to saving one of nature's most important and hard-working creatures.

Words: **Lucy Jolin** / Photography: **Ben Mostyn**

In the apple and pear orchards of the Chinese province of Szechuan, a new job opportunity has opened up: human pollinator. With a dramatic decline in the population of insect pollinators over the past few decades, fruit trees now need to be pollinated by hand in order to produce high quality fruit. Human pollinators have replaced the worker bees that once efficiently carried out the job for free.

"It's not clear what the causes of the decline were," says Dr Richard Gill of the Department of Life Sciences. "But insect pollinators are incredibly important in terms of ecosystems processes, such as the pollination of wildflowers, and have an economic value of more than 150 billion euros every year by increasing agricultural yields. Bees are the biggest contributor to this service, and are also worth millions of pounds for the honey trade. They do a lot of work for us – and we may be repaying them by making their lives difficult."

Gill's work is focused on how bees interact with their environment and respond to rapid environmental change such as habitat loss, climate change, and the application of pesticides in the environment. The twentieth century saw some wild bee species become extinct altogether. It's been widely reported that pesticides are to blame, but Gill and his team believe it is more complicated and is likely to be an interaction of different factors.

Gill's past research used micro-tagging technology to reveal that bees exposed to a new type of pesticide – neonicotinoids – bring back less pollen and that colony growth was reduced. In a different type of study, where colonies were placed next to pesticide-treated fields, the number of new queen and new males was also found to be reduced.

However, both these studies had their limitations. Expose bees to pesticides in a lab and you're creating an artificial environment. Study them in the wild and you can't control what they're exposed to. So for his most recent study, Gill combined the two methods.

"We took the lab into the field. We put bee colonies outside at the Silwood campus, where we could be fairly sure that the only pesticide exposure they got was from us. We also put colonies out as a control where we didn't expose them to the pesticides. It's a combination of a realistic environment and controlled exposure."

While previous studies had found sub-lethal effects on foraging behaviour, they weren't replicated in this experiment. That could mean that there are more subtle effects, which are hard to detect. "But we did find the number of new queens and new males that were being produced by this colony was lower," says Gill. "There are limitations to the study, but we think it is evidence to suggest that neonicotinoids can have an effect on colony fitness. And that's very important in underpinning the population status of wild bees."

The next stage is to work out what's happening on a national scale. That means working out how to effectively monitor the bee population, and it involves thinking about all the factors that might be at play. The Gill team is now looking at how land use change over the whole of the UK might be driving changes and variation in different bee species.

"At the moment, we know that there are winners and losers," he says. "Some bee species are suffering – their ranges have contracted massively. Some seem to have done just fine. Why are some coping and some not? If we can figure this out, we can start to target conservation actions and mitigation strategies. David Attenborough put it very well: if all the mammals or the humans disappeared from the face of the earth, not much would change. But if all the insects disappeared, the world would be a very different place."

PIED PIPER

A breath of fresh air

FOR HENRY XU JIARUI, THE QUEEN'S LAWN AND TOWER ARE THE ESSENTIAL IMPERIAL EXPERIENCE

Words: **Lucy Jolin**
Photograph: **Hannah Maule-ffinch**

Footballs, frisbees and fresh air. You're pretty much guaranteed to find some combination of all of these on the Queen's Lawn, but for me it is so much more than just a great place to hang out. Rather, it's a meeting point for minds, a place where we can relax. And when Imperial students and academics relax together, great things happen.

It can feel daunting, spending all your time in the intensity of the lab. And being outside in the sunshine with the flowers and the trees helps me to relax and de-stress. But in the shadow of Queen's Tower, the Lawn facilitates the free exchange of ideas and thoughts. It's cool – unlike the library, which was nicknamed the Imperial Sauna before the new cooling system was installed this year. I used to go outside and take a short walk on the lawn just to cool myself down after a session studying.

On sunny days, it's buzzing with activity – you won't be able to find a seat in the café so the Lawn is full of students. I'll always remember picking up super-yummy food from the weekly farmers' market, sitting on one of the long benches, feeling the fresh air and sunshine on my face or just chatting with my friends. Something is always happening, from the farmers' market to students from ICU Rag bungee jumping near the Tower, or going on 'expeditions' up it.

And that's another reason that the Lawn feels like the heart of the university to me. They demolished the whole Institute in the 1960s, but they left the Tower, so now it's the oldest building at Imperial – it was built in 1887. You can see it across the whole of London, so it's a constant reminder of Imperial's presence. To sit on the Lawn and look at it gives me a real sense of history.

> **"When Imperial students and academics relax together, great things happen"**

Henry Xu Jiarui is a second year undergraduate, Biological Sciences.