Imperial/45

THE MAGAZINE FOR THE IMPERIAL COMMUNITY

WINTER 2018/19

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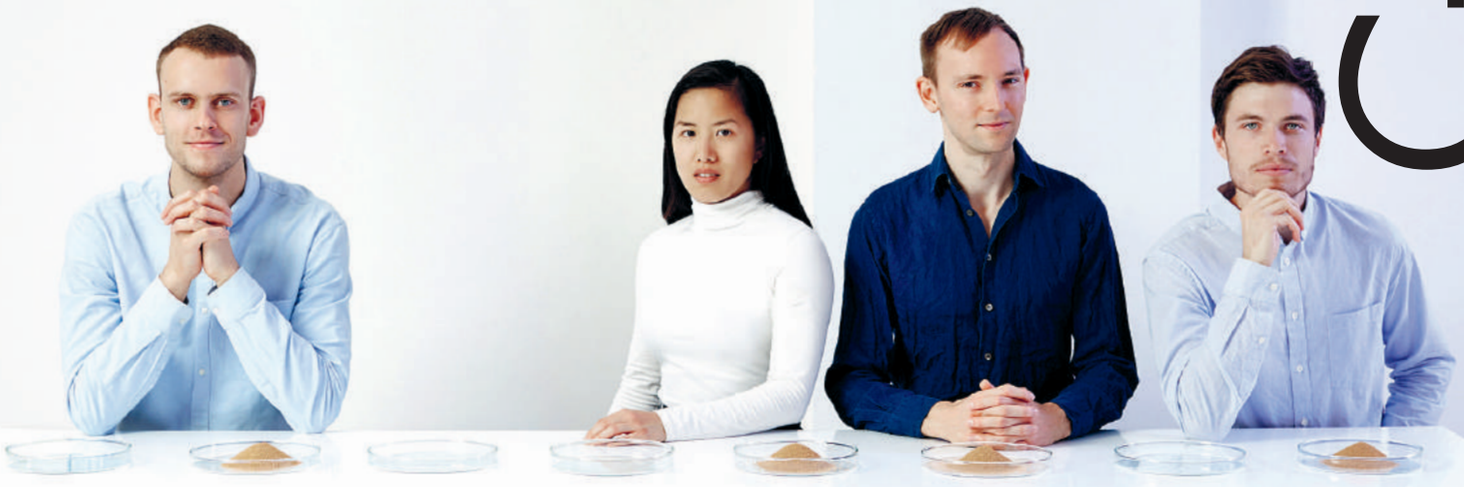

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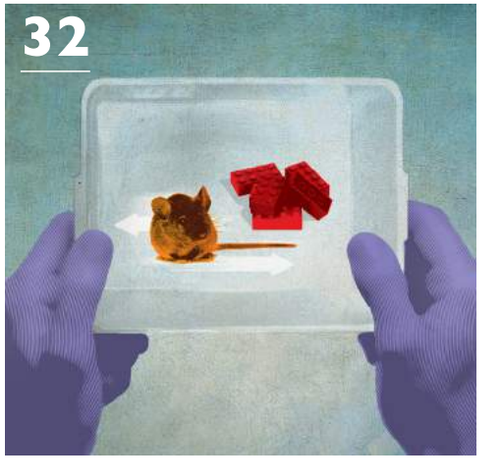

Regulars

Features

Imperial/45

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Letters

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Please mark your letter 'For publication'. Letters may be edited for length.

Stage fright

Thanks for the report on the performing brain (*Imperial 44*). I was surprised, however, to see no reference to the single greatest problem affecting musicians (and, I imagine, surgeons) who perform to an audience. Often misleadingly described as 'stage fright', it ruins careers – even of seasoned professional performers.

As the article suggests, some musicians seem to find performance enhances their ability. I have been playing folk music to audiences for 50 years and feel no anxiety or 'nerves', but I have learned that my technical proficiency in performance is about 80 per cent of what I am capable of in rehearsal. At a subconscious level, something is intervening in the neural pathways to my fingers. Interestingly, recording in a studio is even worse.

Many musicians use mild beta-blockers. These do the job, but at the expense of some mental sparkle. If Imperial's researchers could crack this one there would be many grateful musicians – and maybe a good few who wouldn't try to cope with it by resorting to alcohol or, even, illegal substances!
Dick Wolff
(Mining and Mineral Technology 1973)

Athlone memories

I thoroughly enjoyed reading the memories of the Athlone scholars (*Imperial 44*). I well remember one of those featured, Gary Elfstrom, as a PhD student in the Hypersonic Laboratory in the Department of Aeronautics. He researched on the gun tunnel in the laboratory and was a very hard-working young man – a joy to work with.
Jim Gibb (Aeronautics 1971)

Plastic fantastic?

Polyfloss (Test tube, *Imperial 43*): yes a novel way of redeploying many plastics and producing something useful, insulation in this case.

Please reassure me, however, that the development has taken account of the total cost of ownership (TCO). In particular, how are you going to recover the product at the end of its working life to ensure that it, like too much other plastic, does not end up in the food chain? Placing the product in a refugee camp subjects it to the vagaries of political stance, which could easily turn what appears to be a good idea into a major future problem: your children and my great-grandchildren ingesting the stuff!

An example is that of the current work going on to eradicate microbeads from toothpaste, which we urge children to use every single day. Good without the bead, dangerous with it. Some of it gets ingested by the child, the remainder goes down the sink, ends up in the sea and, with the next fish finger eaten, gets back into the child.
John Swallow

The superb *Imperial* magazine continues to be sent with a single-use plastic (polyethylene?) wrapper that will end up who knows where (ocean, landfill, or incinerated and then released as CO_2 etc to air?). How about switching your wrapper to paper or a biodegradable polymer?
Alex Scott
(MSc Environmental Technology 1993)

We agree! For the first time, this issue of Imperial *comes in a film made not from plastic, but potato starch. This is the most environmentally friendly film available, and is recyclable and compostable.*

Reader survey

The results of our latest reader survey are in, and we're thrilled to report that so many of you say you enjoy the magazine.

Eighty-six per cent of respondents agreed that *Imperial* magazine strengthened their personal connection to the College, principally by making them feel proud of Imperial and through the insights the magazine gives into the College's latest research. Readers also said that the magazine reminded them of their time at Imperial.

We were very pleased to hear that more than a third of you spend an hour or more reading your issue of *Imperial*, and that nearly all respondents (97 per cent) agreed that the magazine's content was excellent or good – the cover, layout, design and photography were particularly well received by readers.

We were also delighted to hear that more than a third of respondents used the magazine to actively engage with the Imperial community, contacting classmates or alumni friends, discussing or forwarding articles or recommending Imperial to potential students, colleagues or family members.

We're grateful to everyone who took the time to tell us what they thought about the magazine. If you would like to be involved in the next survey and be entered into a draw to win an Imperial-branded Lamy pen, visit www.imperial.ac.uk/be-inspired/magazine.

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

DIGEST

THIS PAGE PHOTOGRAPHY: MARTIN CARMACK. OPPOSITE PAGE ILLUSTRATION: MIKE LEMANSKI

CHILDREN'S HEALTH

New £25m Mohn Centre to pioneer children's health research

Imperial will establish a world-leading centre for children's health and wellbeing, education and community engagement, thanks to a £25m gift from alumna Marit Mohn (MSc Chemical Engineering and Chemical Technology 1973).

The Mohn Centre for Children's Health and Wellbeing at Imperial's School of Public Health at White City will support pioneering research, education and community engagement that will improve the diagnosis, prevention and treatment of childhood illness on both a local and global scale.

It will draw together its world-leading expertise in child and adolescent health to address childhood health challenges such as asthma, childhood obesity, malnutrition and infection.

Mohn says: "Imperial's academic excellence and ambition for White City is inspirational. We have the opportunity to change the lives of local young people in a way that will be felt for generations to come."

The Centre's flagship project will follow a group of White City children from birth into adulthood and old age to help deepen the understanding of how disease in old age is connected to early-life experiences.

Professor Alice Gast, President of Imperial College London, says: "We are profoundly grateful to Marit Mohn for this generous gift, which provides an unprecedented opportunity to transform the health and wellbeing of children in London and throughout the world. Marit is a talented and far-sighted philanthropist and it is a privilege to work with her to realise this vision."

Visit www.imperial.ac.uk/giving/transforming-health for more.

The new Mohn Centre for Children's Health and Wellbeing will draw together Imperial's world-leading expertise in child and adolescent health to drive discoveries and improve global understanding of childhood disease.

FROM THE PRESIDENT / PROFESSOR ALICE GAST

"The new White City campus is a rare opportunity to create a place that can really change the way things are done"

There are rare moments in history where new places are created that change the way things are done in the world. The Great Exhibition of 1851, co-organised by Prince Albert, was one of those moments. It brought the world to London to celebrate new inventions and it produced revenue that the Prince Consort used to purchase the South Kensington land that would become the great centre of art, music and science we know today. Prince Albert foresaw the need to work across disciplines, stating: *"We should ensure … that the different industrial pursuits of mankind, art and Sciences should not again relapse into a state of comparative isolation from each other…"*

Prince Albert's genius was to ensure that this happened through place-making. Imperial's creation of our White City Campus reflects this vision.

White City, West London, has a noble history. It was the site of the 1908 Franco-Britannic exhibition and Olympic Games, which attracted millions to Shepherd's Bush. The area acquired the name 'White City' because of the exhibition's beautiful white marble buildings. Later, White City became home to ambitious social housing developments and then a centre for worldwide broadcasting and production with the opening of the BBC Television Centre. More recently, Westfield Shepherd's Bush has become one of the most visited shopping malls in Europe.

Today, White City is a dynamic and rapidly changing part of London. Less than three miles from South Kensington and just 500 metres from Hammersmith Hospital, our new campus has excellent transport links to the rest of London and beyond.

Land in London is scarce. We have a rare opportunity to create a place where great academics work on leading research in close collaboration with corporate partners, entrepreneurs, venture funders and the community. We are creating a new paradigm to bring the disciplines and sectors together by making places for them to coexist and cooperate more closely than ever before.

Instead of creating an 'industrial park' outside our campus or a 'community centre' to work with the public, at White City we are opening up our campus to blend these groups from the start. Intermingling in buildings, sharing labs, collaborating on research as well as on educating the new generation of researchers is our mantra.

The White City Campus will expand and enrich Imperial's international connections and become another significant asset and attribute of London. It will create an exciting and rich environment for innovation, exploration, experimentation, risk-taking and growth.

In this issue you will read about a few of the many things going on at White City. The revolution in green chemistry is happening in the Molecular Science Research Hub, the new home of our Department of Chemistry. At the Centre for Blast Injury Studies, which will move into the Michael Uren Biomedical Engineering Research Hub in 2019, our medics, engineers and scientists work with military doctors to advance the treatment of blast injuries and improve the quality of life of its victims. Exciting breakthroughs in diabetes prevention and treatment are spearheaded by academics from our Faculties of Medicine, Engineering, Natural Sciences and Business. They can come together on the White City Campus where we are fostering multi-disciplinary collaboration and planning the new School of Public Health.

This ecosystem of spin-outs and startups working alongside Imperial academics has attracted corporate partners to the I-Hub as tenants with real growth potential. The next phase of our innovation spaces at White City is the creation of Scale Space to support, research and scale fast-growing businesses.

> **Prince Albert's genius was to make this happen through place-making. Imperial's White City Campus reflects this vision**

We believe that Imperial and its partners have a unique opportunity at this critical moment in history to help provide people with education, hope for the future and to build their trust in our institutions. We are doing this by being more open and involving non-academic partners in our mission. The makerspaces, hackspaces, Invention Rooms and other convening places at the White City Campus provide opportunities for the public to be a part of – and benefit from – our community.

Next time you are in West London, or whizzing by on the A40, please stop by and visit us at White City. ◆

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

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The Hitchhiker's Guide to the Galaxy declares 42 the answer. But what is the question? For Dr Jonathan Breeze, Research Fellow at the Department of Materials, it's about being on the right wavelength.

We've all heard of lasers, but what about masers? A made-up term? Absolutely not. Lasers have become an indispensable part of life since their introduction in 1960, featuring in everything from eye surgery to precision drilling. But masers – standing for 'microwave amplification by stimulated emission of radiation' – have only really come of age in the last year.

That was when Dr Jonathan Breeze, Research Fellow at the Department of Materials, and his team made the first maser to consistently work at room temperature (previously they only worked when cooled to -273°C, which meant they were impractical to use). "It's kind of a big deal," says Breeze. It's also central to his research interests. "Most of my work is about trying to understand how materials interact with electromagnetic waves."

His first attempt at a room-temperature maser, which can direct microwaves in a particular direction, used the organic material pentacene, but it became so hot it only worked for a fraction of a thousandth of a second at a time. Then, two years ago, he read about nitrogen-vacancy centres, a naturally occurring defect in diamonds.

"How the maser works is fundamentally about the interaction between microwaves and the special defects in diamonds." He created a synthetic diamond with the same tiny imperfections and placed it in a ring of sapphire, which stores the microwave energy. When lit by a green light to activate it, the maser emitted a continuous beam.

Breeze doesn't know exactly what the practical uses will be, but there are some exciting possibilities. "I'd like to see masers used in ground-penetrating radar or medical imaging tools." Because microwaves can travel through objects rather than bouncing off them like light does, they might be better placed to detect a tumour than a laser, for example. He's also happy to see what other people come up with – and doubts he'll be waiting long. "We're probably a couple of years away from a workable device that provides a source of coherent microwaves. It just requires a little bit of engineering by someone with an application in mind."

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

OVERHEARD ON CAMPUS

Lates
Imperial's 'after hours' programme of discovery evenings, exploring themes such as smart fashion and women in mathematics.

Curcumin
A study by Professor Francesca Cordeiro has found that this derivate of turmeric could be used to treat early glaucoma.

Sheepdog robot
A new algorithm has enabled this drone to herd birds without human input – saving aeroplanes and birds alike.

LEADERSHIP

New Provost

Physics pioneer and university leader, Professor Ian Walmsley FRS, has been appointed the new Provost of Imperial College London.

Formerly Pro-Vice-Chancellor (Research and Innovation) and Hooke Professor of Experimental Physics at Oxford, Professor Walmsley is no stranger to Imperial: he graduated from the College with a First Class Honours in Physics.

At Oxford, he led the university's research and innovation strategy, as well as directing the UK's largest quantum technology hub, developing the elements for a quantum computer.

Professor Walmsley says: "Imperial is a fantastic institution with a wonderful future. I look forward to working with colleagues to continue the trajectory of world-leading research, education and innovation for which the College is renowned."

ALUMNI

Imperial Plexus

Want to extend your professional network? Imperial Plexus is a new online platform that enables alumni of all career stages to search the global Imperial community for fellow alumni who share their interests, industry or simply live nearby.

More than 7,500 alumni have joined since the site launched in May. Most alumni will have received their unique activation link via email, but if you haven't, email alumni@imperial.ac.uk to join the platform.

ADVENTURES IN...

3D printing

A revolution in construction is taking place – right beneath our feet.

Words: **Helena Pozniak** / Photography: **Adriaan de Groot**

Next year a bridge will appear in the middle of Amsterdam unlike anything ever seen before. Sleek, undulating and futuristic, it is a world first: it was created by 3D-printing robots.

"We could never have imagined this would be possible, even a few years ago," says Professor Leroy Gardner (MSc Civil and Environmental Engineering 1999, PhD 2002) at the Department of Civil and Environmental Engineering. "3D printing opens up the opportunity to produce weird and wonderful shapes – you can put the material just where you want it. Nothing like this has been done before."

But while it has been fascinating to watch the molten steel take shape in an Amsterdam factory, the main priority for Gardner and his team has been to ensure that pedestrians and cyclists in the Dutch city will be safe on this radical new design.

Indeed, the team have been compressing the 3D-built steel to see if it buckles under the same loads as traditional steel, stretching it to understand how it deforms and loading containers with water on to the bridge to check the structure is sturdy enough to take the weight of pedestrians.

In the process, they have discovered that 3D steel has a rather curious property – it is anisotropic, which means its physical properties vary in different directions, because of the way layers are built up. "It has an inherent directionality, depending on whether you load the material parallel to the layers or across them. As an engineer, you need to understand that," says Gardner. By contrast, traditionally manufactured steel is essentially isotropic – with the same mechanical properties in all directions.

Meanwhile, data scientists at Imperial plan to measure the 12-metre bridge as never before, with a vast network of sensors. "We'll be able to gauge its 'heartbeat'," says Professor Mark Girolami, from the Department of Mathematics and an expert in how big data can be incorporated into engineering practice. He's based at the pioneering Alan Turing Institute, which specialises in data-centric engineering, and his team is working with engineers and the Dutch 3D-printing company, MX3D, which is behind the design and production of the bridge.

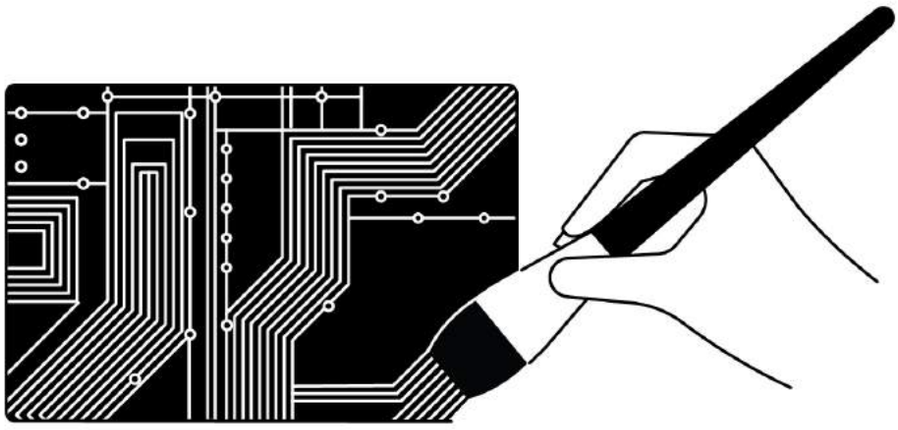
Sensors will measure vibrations, stress on different parts of the structure and ambient temperature – giving data scientists a wealth of information that they will use to inform a virtual model of the bridge and assess how it performs. Scientists will feed data from the real bridge into its virtual copy – created from a 3D laser scan. "We call it a 'digital twin'," says Girolami. "This is new material and there's a lot we don't know about its properties. Having one structure learn from the other – the real and the digital – could be revolutionary." In this way, scientists will be able to predict how the structure will behave in the future.

"What makes this exciting is that we will have a living laboratory on our hands," says Girolami. "We've not seen this level of integration of sensors and cameras before. We might also be able to measure social behaviour and what impact the bridge has on the surrounding area."

While printing a bridge in this way may not be the fastest or cheapest way to build, it has enormous potential.

"We are pushing the boundaries, and when it comes to 3D printing in construction, this may well be just the start," says Girolami. "Architects love this style of manufacturing. Normally we have to rein them in, but this gives so much freedom." ◆

Scientists from the Steel Structures Research Group at Imperial are undertaking structural testing on the 3D-printed steel, building a vast sensor network on the bridge to monitor its performance.



Test tube

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

WHO **MATT JOHNSON**

(MSc Industrial Design Engineering 2009)

WHAT Bare Conductive is a printed electronics company. That means we're interested in creating electronics on unusual substrates (underlying materials or surfaces) and putting them in unexpected places for a variety of applications, from sensing the presence of an insect to turning a wall into an interactive touch screen.

HOW We have a material called Electric Paint that looks like any other paint but when you apply it to a surface and let it dry, it conducts electricity. That's because it contains a conductor that forms a solid network when it dries, which allows electrons to travel. We also have hardware (circuit boards) that connects to the paint to enable all sorts of exciting functions.

INSPIRATION My co-founders also studied Industrial Design Engineering at Imperial: Chief Operating Officer Bibi Nelson (2009), Chief Creative Officer Isabel Lizardi (2009) and Product Manager Rebecca Pilditch (MEng Mechanical Engineering 2007, MSc Industrial Design Engineering 2010). We were working on a project about exploring electronics in unexpected places such as in textiles or architecture and we realised that the barrier to those applications wasn't conceptual, it was technical. So we thought, OK, how would you paint electronics onto things?

MOTIVATION Three things keep me going: selling the technology directly to consumers, engineers and designers, which provides tons of interactions with really smart people; the challenge and excitement of building relationships with large corporations; and working with a great team from different disciplines, which is fantastic fun.

THE FUTURE Short term, our goal is to help more companies build this technology into their products. Long term, we want to show that printed electronics as an industry is extremely valuable. We think it will have a role in the home and in the Internet of Things in general that hasn't yet been explored, because it allows profoundly low-cost devices to be made of materials that aren't usually associated with electronic products and that live in places other electronics can't live. There's so much potential.

> *Matt Johnson is CEO and co-founder of Bare Conductive, a design and technology company making products that integrate electronics directly into the environment.*

IN BRIEF

SCIENCE OF THE SUMMIT

Plasma physicist Dr Melanie Windridge (PhD Physics 2009) summited Everest in May to help inspire young people, especially girls, to reach new heights in STEM and business.

GYROGLOVE DEVELOPED

GyroGear, a startup founded by Dr Faii Ong (Medicine 2016), has used a €1.8m EU grant to develop GyroGlove, a device that helps stabilise the hands of people with tremors.

LKCMEDICINE FIRSTS

The first graduates of the Lee Kong Chian School of Medicine in Singapore have received Medicine degrees from Imperial and Nanyang Technological University.

ALUMNI WEEKEND 2019

Save the date! Next year's Imperial Festival and Alumni Weekend will take place on 29-30 June 2019.

BIOTECHNOLOGY

Infrared LEDs behind new process

A new form of photosynthesis which uses near-infrared light has been discovered by Imperial scientists.

The team discovered that the new type of photosynthesis, detected in cyanobacteria, allows the process to take place beyond the 'red limit' – the minimum amount of energy needed by the demanding chemistry that produces oxygen. The finding is "textbook-changing stuff" according to team lead Professor Bill Rutherford.

ILLUSTRATION: MIKE LEMANSKI. PHOTOGRAPHY: IMPERIAL COLLEGE LONDON

IMPERATIVE / DR MORENA MILLS, SENIOR LECTURER IN CONSERVATION SCIENCE AT THE DEPARTMENT OF LIFE SCIENCES

"We want to take 'saving the planet' out of the abstract and into reality"

Did you know that 35 per cent of global crop production depends, to some degree, on the pollination of birds, bats and bees? Or that the oceans have absorbed a third of the carbon dioxide produced by human activities to date? Or that hanging out in leafy parks reduces your risk of experiencing high blood pressure and depression?

These are the real, tangible benefits of protecting our planet; yet for many people, 'helping the environment' can seem an abstract concept. Despite billions being spent on environmental conservation projects, all too often they fail – and initiatives that would be certain to help sustain our planet come to nothing, simply because we don't want to adopt them or because adoption is just too difficult.

Yet every now and then, a conservation initiative goes 'viral', with rapid, widespread adoption that completely transforms the relationship between people and nature. This is fantastic, but also immensely frustrating – why do some ideas catch on while others don't?

At Imperial's Department of Life Sciences, we are trying to understand why only some environmental conservation projects gain traction in society. We believe adoption rate comes down to the interactions among three elements: the characteristics of the innovation; the adopters; and the socio-economic context. Essentially the likelihood of us adopting any idea comes down to what we value, how it benefits us and how easy it is to adopt.

For instance, people will be more likely to act if they can see, feel and benefit from the impact of a project. When rural Kenyan women reported their streams were drying up, affecting food supply and forcing local women to walk further and further to get firewood, the Green Belt Movement, founded by Professor Wangari Maathai, galvanised those women to work together to plant trees. These trees bound the soil, stored rainwater and provided food and wood locally. Restoring forests changed their lives.

The likelihood of somebody embracing new ideas and projects is also down to their characteristics and context – what's their status? Do they have money? What's their social network? Are they risk averse? Is there enabling legislation in place? Are there barriers preventing adoption?

We are finding that the theory we use stands up, even in very different environmental conservation projects across the world. When Tanzania adopted three different conservation initiatives – Community-Based Forest Management, Joint Forest Management and Wildlife Management Areas – each had the same basic aims. But the community-based forest management had the greater number of adopters because, although villagers shouldered most of the cost, it provided them with the most control over the resources and the benefits of participation – and therefore they were more likely to embrace it.

Similarly, a completely different innovation – Locally Managed Marine Areas – swept across the Pacific Islands, encouraging residents to collectively manage inshore waters. This initiative was rolled out over 500 villages across 15 island nations. The scheme thrived, especially in Fiji, where the locals greatly valued more autonomy over the management of their marine resources and the strengthening of their traditions.

We can use these examples to lobby politicians to implement government policy that can influence whether

> We are more likely to act if we can see, feel and benefit from the impact of a project

environmental conservation projects are adopted, by implementing the infrastructure needed to facilitate adoption, or implementing laws and policies that make them possible.

We are fortunate to have a dynamic and multidisciplinary team of great scientists here at Silwood Park Campus – part of the Grand Challenges in Ecosystems and Environment initiative – committed to exploring some of the greatest global environmental challenges. My lab's work on understanding how, when and why some environmental conservation initiatives spread so effectively, and why others don't, fills a critical gap in our knowledge of how to ensure the future of our planet. ◆

> ***Dr Morena Mills's*** *research focuses on biodiversity conservation, spanning marine and terrestrial systems on both a global and local scale.*

RESEARCH FOCUS / POLICY AGENDA
DR YVES-ALEXANDRE DE MONTJOYE
DEPARTMENT OF COMPUTING

“We can’t not use data. But we need to find new ways to protect people’s privacy”

THE PROBLEM

Twenty years ago, it was relatively easy to protect your data, but not anymore. Recently, for example, Australian researchers studying a database of 2.9 million ‘anonymised’ medical records (with names and addresses removed, for instance, among other things) were easily able to re-identify patients simply by comparing the dataset to other information in the public domain, such as athletes having operations or celebrity mums giving birth. In another study, fitness app Polar was used to identify names and addresses of soldiers and spies.

And at Imperial, Professor Yves-Alexandre de Montjoye recently found that 95 per cent of us can be uniquely identified from apparently anonymous datasets, using just times and places our phones show we have visited.

“Data anonymisation just doesn’t work anymore,” says de Montjoye, Head of the Computational Privacy Group at Imperial’s Data Science Institute. “There is no longer a guarantee of not being identified. We think of privacy in terms of the specific decisions we make in relation to privileges, but that’s no longer the case – we are identified by our movements, the places we visit, the things we buy or even the things our friends do, that link to us.”

THE ROLE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is changing every aspect of the way we live. AI works by machine learning through data – so if anonymisation is no longer practically possible, how can AI algorithms continue to learn from large-scale, sensitive datasets, while preserving our privacy?

“AI has tremendous potential for good,” says de Montjoye. “But we need to find a way to protect data.” An initiative led by the Data Science Institute at Imperial is doing just that. The Open Algorithms (OPAL) project is a secure platform that allows researchers to use datasets without actually getting a copy of them.

The aim of the project, which is currently being tested with phone firms Orange in Senegal and Telefónica in Colombia, is that instead of releasing large datasets, companies give governments access to interfaces that allow them to ‘ask questions of the data but without being able to access the raw files’.

OUTREACH

Summer school

Students from backgrounds under-represented in higher education had the chance this summer to experience university life and explore science, engineering and medicine at Imperial.

Imperial’s summer schools are part of a broader programme of on-campus outreach activities for young people that run through the year, including Pathways to Medicine and the Maker Challenge programmes in White City.

> *Visit www.imperial.ac.uk/outreach for more information.*

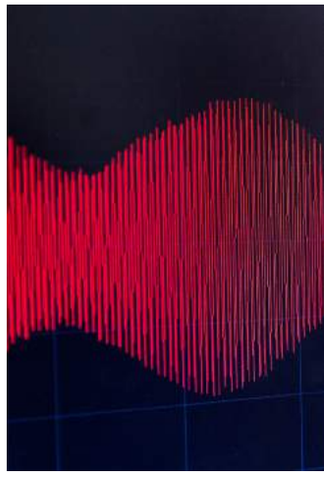
MEDICINE

Brainwaves

Dr Nir Grossman (PhD Neuroscience and Mental Health 2009) has been awarded the 2018 Science & PINS Prize for Neuromodulation for describing a technique which could hold the key to treating a range of brain disorders.

The technique, called temporal interference, stimulates the brain with electrical fields, and is far less invasive than other methods of electrical stimulation. It uses electrodes attached to the scalp to apply small, overlapping electric fields of different frequencies to subtly ‘nudge’ brain activity.

After succesful trials on mice, the next steps include testing the technique on patients with neurological conditions, to see if it can match the effectiveness of existing methods without the need for surgery.



KEEPING HOLD OF OUR DATA

"Just because data anonymisation doesn't work, it doesn't mean we can't still achieve privacy," says de Montjoye. "Essentially the idea is to put the data in a 'safe' and control what comes in and what comes out. We're not bringing the data to the code but bringing the code to the data."

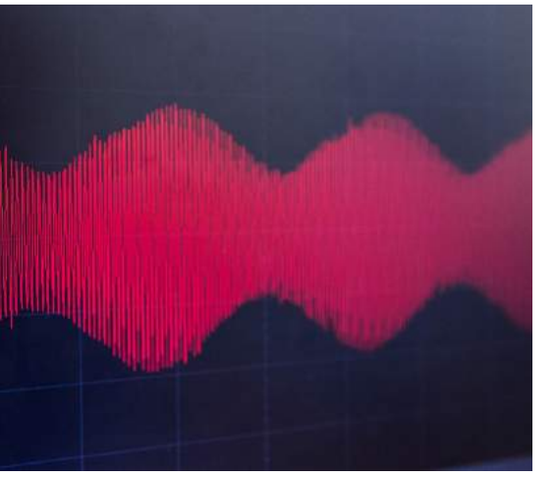
But de Montjoye says new legislation is also needed. "New technology has always challenged laws, and it always will," he says. "But too many current laws reflect outdated technology and, in this case, old notions about how people can be identified."

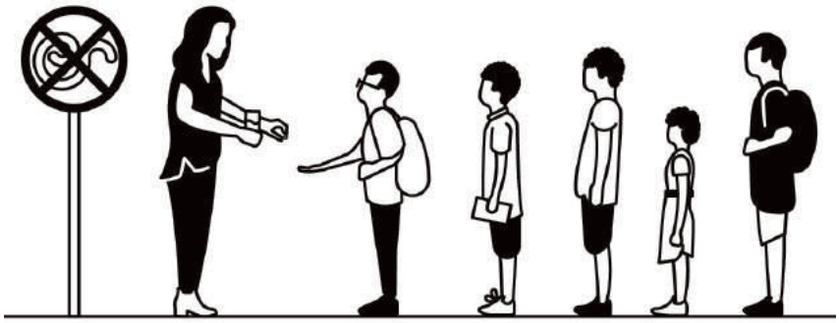
"We can't not use data – we have a moral responsibility to use it. But privacy is a need and a human right. So we need to stop pretending data anonymisation works and hold people accountable for how data is being collected and used.

"The OPAL project is a way we can do that, maintain privacy and use big data for public good."

> ***Dr Yves-Alexandre de Montjoye*** *is an Assistant Professor (Lecturer) and Head of Imperial's Computational Privacy Group.*

PHOTOGRAPHY: IMPERIAL COLLEGE LONDON. LLUSTRATION: MIKE LEMANSKI





A working life

As Executive Director at the Partnership for Child Development in the School of Public Health, *Dr Lesley Drake* says she is powered by the enthusiasm of foreign governments, deworming tablets – and a distinctly British soap.

For me, it all started with worms. When I worked in Vietnam and China, the focus of my PhD and postdoc years was on the effect of parasitic infections and their impact on health and child development. In Bihar, for example, one of the poorest areas of India, the Partnership for Child Development (PCD) supported the state government to deworm 17 million children in six months. Thanks to the model we developed, this has evolved into a national programme that now deworms 220 million children a year. My passion is to get these types of programmes to become policy, because otherwise as soon as the money runs out the programme stops.

The PCD helps countries use their own systems to support the development of children. We don't get involved with the politics, but we guide it with the evidence – as a scientist, it's all about translating evidence into action for me. We have had success in more than 50 countries and are especially impressed with what has been achieved, for example in Ethiopia, Ghana, Zanzibar and Nigeria, where the government has allocated money to provide a daily, well-balanced, locally-sourced meal for more than eight million schoolchildren as part of a national social investment programme. As they also pay small-hold farmers to grow the crops, it's win-win; children are fed and attend school and the rural communities benefit from a stable market.

Working in poor countries to benefit poor children is rewarding but it is also emotionally challenging. My way of coping after a challenging visit to a poor community is to catch up with *Coronation Street*. The reality/fantasy nature of a soap helps keep me grounded and in touch with my own sense of community as a northern woman. I am not sure my colleagues quite understand that in the same way!

I spend about half my time travelling, and I'm going back to Nigeria soon. Whenever I'm there and see the children washing their hands before they eat a locally produced nutritious meal with no worms in their bellies, it feels amazing to be a part of it.

Lesley Drake *(PhD Pure and Applied Biology 1992) has managed the Partnership for Child Development, which is based at Imperial College London, since 2007. She is also Deputy Director of the London Centre for Neglected Tropical Disease Research and founded the Deworm the World Initiative.*

Words: **Victoria James**
Photography: **David Gill**
Styling: **Vicky Lees**

SWEET SPOT

TEN YEARS AGO, DIABETES WAS A LIFE SENTENCE. TODAY, IMPERIAL RESEARCH IS TRANSFORMING THE LIVES OF DIABETICS THROUGH DATA, TECHNOLOGY AND PUBLIC POLICY.

Obesity and diabetes, the headlines tell us, are a 'national health emergency' that will 'bankrupt' the NHS within a generation and ensure that today's children 'die earlier than their parents'. The figures – 422 million worldwide living with diabetes, which directly causes 1.6 million deaths annually – suggest a health disaster of catastrophic proportions; one that has come out of nowhere to overwhelm the world's population. A trend we'll never be able to reverse. A fight we won't win.

Such pessimism would be challenged, however, by Imperial's numerous diabetes researchers – many of whom have been working in the field since long before it came to international attention. Indeed, their shared hope is that their professional lifetime may yet see the battle won.

Professor Sir Steve Bloom, Imperial's Head of Division for Diabetes, Endocrinology and Metabolism, now in his 70s, was born into the medical establishment's fight against diabetes. "My father was a doctor and my mother a nurse, and my father specialised in diabetes. When I was a boy I remember him testing urine in the kitchen," he recalls.

The use of insulin as a treatment for diabetes was pioneered in the 1920s by a team in Toronto, winning a Nobel Prize in 1923 for Frederick Banting and John Macleod. "Insulin was able to save lives," Bloom says. "And by the time my father retired it was unusual for children to die from diabetes, as they had done when his career began."

Bloom's father's small patients were living with type 1 diabetes (see box on page 18 for an explanation of the principal types), but today's diabetes discussion is focused on type 2, which is acquired from numerous risk factors, many – though not all – of which are avoidable.

"Globally, most cases of diabetes in adults – between 85 and 95 per cent – are type 2," says Professor Majid Ezzati, who holds Imperial's Chair in Global Environmental Health and in 2016 co-authored a major study in *The Lancet*, 'Worldwide trends in diabetes since 1980'. ▶

Opposite: A diabetes diagnosis used to mean a lifetime of daily testing and injecting. Today, while most reports focus on the rapid increase in cases of type 2 diabetes, at Imperial, researchers are accumulating the data, devices and drugs that could yet see the battle against diabetes won within their professional lifetimes.

That research, using data from 146 countries, laid bare the extraordinary advance of diabetes around the world. The number of adults living with the condition rose from 108 million in 1980 to 422 million by 2014.

"That's the story everyone talks about," says Ezzati. "Diabetes is going up." And on the face of it, it's a bleak story. One of the World Health Organisation (WHO)'s global targets for non-communicable diseases is, by 2025, to have held adult prevalence of diabetes at its 2010 level. Ezzati and his colleagues have found that even this modest goal looks unattainable. "If post-2000 trends continue," their study concludes, "the probability of meeting the global target is lower than one per cent for men and is one per cent for women. Only nine countries for men and 29 countries for women, mostly in western Europe, have a 50 per cent or higher" chance of doing so.

The bigger picture revealed by their work, however, is far more complex – and in some ways more reassuring – than these stark predictions suggest. In part, the rise in diabetes incidence is due to healthcare successes. Yes, you read that right.

"You hear a lot about obesity and fast food," Ezzati explains, "but the rise in population – and the ageing population – are actually the biggest drivers of rising diabetes costs to the NHS. In non-English speaking western Europe, diabetes is going up solely because of ageing. People are living longer. So, in many ways, that's actually a success."

Ezzati's research reminds us to beware lazy thinking about the modern lifestyles so often blamed for that post-1980 acceleration of diabetes prevalence. Take urbanisation, accused of causing people to lead sedentary lifestyles and consume poorer-quality diets of processed foods. The evidence suggests otherwise. "Access to diverse foods can be greater in a city," says Ezzati, "so that can be a benefit. Cities, rightly used, can be useful. Where we see westernisation and urbanisation, those countries are doing better."

Better access to healthcare is a crucial part of that, and Ezzati's Imperial team is working with WHO to look at coverage of treatment. "The sooner people are diagnosed, the sooner the chance of preventing complications. That's currently done very well in tackling HIV and very poorly with diabetes," he says.

Opposite: Professor Gary Frost's studies show that dietary supplements containing fermentable carbohydrate, like that found in legumes such as peas and beans, protects against body weight gain.

Those fighting obesity and diabetes are now looking back, keen to learn lessons from past public health achievements and failures. Dr Jonathan Pearson-Stuttard (MSc Epidemiology 2016), a Public Health doctor and National Institute for Health Research Academic Clinical Fellow at Imperial, is currently seconded to England's Chief Medical Officer (CMO), Professor Dame Sally Davies (herself an Emeritus Professor at Imperial). A recent paper on childhood obesity from the CMO and Pearson-Stuttard drew parallels with the public health response to smoking. Almost 70 years after a seminal study on smoking's grave health impact, the paper states, "it remains a leading cause of premature deaths in England". The fight against obesity, it concluded, must be "faster, and fairer, than our fight against smoking".

"Look at how long it's taken us with smoking," says Pearson-Stuttard. "The response has had to be multifaceted and sustained: redesigning packaging, restricting availability by age, reducing acceptability (not smoking in cars with children nor in public spaces) and persistent taxation. Despite these efforts, inequalities still persist. And that's the challenge for public health on obesity and diabetes – that it's complex. You can't take a pill and sort it. One's risk of obesity and diabetes is influenced by family history and diet, all the way to your living conditions and economic circumstance – the environment around you is immensely important."

Building an evidence base and communicating such messages takes time. "The link between being overweight and cancer has been around for many years," says Pearson-Stuttard. ▶

DIABETES PREVENTION IS MOVING OUT OF THE LAB AND ON TO OUR PHONES

"But the link with diabetes is much more recent. We recently quantified the cancer burden – in 2012 – attributable to diabetes for the first time."

Pearson-Stuttard was the lead author of a June 2018 paper in *The Lancet Diabetes & Endocrinology* that, for the first time, estimated the global cancer burden attributable to diabetes and high body-mass index combined – and also isolated that caused by diabetes alone. Examining the 12 cancers known to be linked to high Body Mass Index (BMI), it found that 804,100 new cases were attributable to the combined effect, with nearly 300,000 cases due to diabetes alone. "We're only just beginning to see what a complex condition diabetes is as a risk factor for other chronic illnesses and the implications for management and prevention measures," he says.

And there are further startling new insights to come from Imperial's network of diabetes researchers. While it may seem unsurprising that a patient's diabetes will influence their health in other ways, striking evidence is emerging of how one type – gestational diabetes, experienced during pregnancy – affects not only the mother's own health but also that of their child, even after birth.

"Diabetes in pregnancy is associated with a number of risks to the mother and baby, including a greater risk of pre-term labour, stillbirth and congenital malformations," explains Dr Karen Logan (PhD Clinical Medicine Research 2016), Honorary Research Associate at Imperial's Department of Medicine. "More recently, associations have been demonstrated between diabetes in pregnancy and longer-term health risks in offspring. Our research showed that diabetes in pregnancy is associated with greater fat deposits in early infancy."

The mothers in Logan's study all had their condition well controlled during their pregnancy, but the study's findings showed that diabetes in the mother can trigger changes in the baby at a very early stage. And that's worrying, because it throws the problem forward to the next generation. "Long-term health can be influenced in the womb and in early infancy, and diabetes in pregnancy may contribute to the worldwide epidemic of obesity and diabetes," Logan says.

This deepened understanding of the complex causes and consequences of diabetes only heightens the urgency around effective intervention and prevention. Indeed, the two go hand in hand. And this is where Imperial's network of expertise is leading the way in delivering a whole new range of diabetes interventions, arising from interdisciplinary collaborations.

For example, Gary Frost, Professor of Nutrition and Dietetics, is working on clinical trials of a cheap food ingredient that works in the same way that appetite-supressing legumes do, and has the potential to prevent weight gain in adults who wouldn't naturally eat peas and beans by becoming part of their everyday diet. He is also working with clinician and Professor of Practice, Anne Dornhorst, on innovative approaches to gestational diabetes. "Using novel food supplements, we hope to offer women new ways to improve their pregnancy outcomes and long-term health," says Dornhorst. The sort of interdisciplinary working enabled by Imperial's collective expertise is, she says, "quite simply essential".

Professor Bloom enthuses about the range of work being conducted across the university's departments. "We have a division that looks at metabolic engineering which developed small artificial pancreases; a bariatric arm that can predict who will respond to surgery; a wing studying complications of diabetes; nutritionists looking at the kind of food that will protect us from diabetes; and geneticists working out who's susceptible. We cover everything from the most basic biology to translational use, doing patients good here and now."

'Patients', however, isn't a word you'll hear Professor Chris Toumazou using often. Toumazou is Regius Professor of Engineering, and among his innovations are an artificial pancreas for type 1 diabetics and an intelligent neural stimulator that provides a drug ▶

alternative for obesity. His latest venture, though, is taking diabetes intervention out of the realm of hospitals, research labs and policy makers' offices. Instead, Toumazou and colleague Dr Maria Karvela are the co-founders of a spin-out company, DNA Nudge, that is taking diabetes prevention and intervention into supermarkets and high streets – and directly to 'consumers' via their smartphones.

"We now have the ability to sequence DNA on a microchip," Toumazou explains. "And we know that a DNA-based diet will improve health." The device offering the help is a blue plastic disc the size of a compact mirror, from which juts a microchip. "This replaces an entire lab," Toumazou says. "It removes the stigma of it being anything medical." Karvela adds: "The test helps glucose management, and hypertension goes down. So, the idea is to help people use their genetics to nudge their eating decisions for them."

The consumer provides a saliva sample from which the chip sequences their DNA and creates a profile of their body's particular susceptibilities – how well it processes fat, sugar and salt, what foodstuffs are craved, and how the body manages weight and appetite. It then empowers them to go and do something about it. The chip's results are uploaded into a smartphone app and a wearable smartband that lets shoppers scan any grocery barcode and get an instant thumbs up or down as to whether it's a suitable purchase for them.

It assists consumers in the course of their everyday life, 'nudging' them to make healthier choices that can prevent obesity and diabetes before they ever arise. "It's not about telling people to eat grapes instead of biscuits," says Toumazou. "It's about what biscuits are better for you."

Imperial expertise is opening up a new front in diabetes prevention, using cutting-edge technology to solve the oldest conundrum of public health: how to reach 'consumers' before they become 'patients'. The future of the fight against diabetes just got personal. ◆

Opposite: Professor Chris Tomazou's revolutionary DNA Nudge device uses smartphone technology to advise consumers whether particular products are healthy or not.

> *In June 2018, Imperial launched the campaign for the School of Public Health to develop a state-of-the-art hub for health and wellbeing research at the College's White City Campus. To find out more, visit www.imperial.ac.uk/giving/transforming-health*

UNDERSTANDING DIABETES

TYPE 1 – an autoimmune disease that prevents the body from producing enough insulin to regulate blood glucose levels. The cause is believed to be a combination of genetic predisposition and potentially an environmental 'trigger'. Usually diagnosed in childhood but may start in adulthood.

TYPE 2 – a metabolic disorder in which the body either uses insulin inefficiently or is unable to produce enough to regulate blood glucose. Risk factors include being overweight/obesity, unhealthy diet, physical inactivity, smoking, genetics and ethnic predisposition.

GESTATIONAL DIABETES – usually develops around weeks 24-28 of pregnancy, caused by insulin-resistant hormones made by the placenta, coupled with foetal growth. The condition occurs in 3-5% of pregnancies and typically disappears after the baby is born.

PREDIABETES – a metabolic condition closely connected to obesity, in which blood glucose is higher than normal but not yet classifiable as diabetes. An estimated one in three people in England live with prediabetes, which can be prevented from developing into type 2 with intervention.


POTATO CHIPS *
NUTTY NOUGAT *
BLT SANDWICH *
CHOC ECLAIRS *
PEANUTS *
LEMONADE *
JAM DOUGHNUT *
TOTAL
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MERCHANT : 46267192
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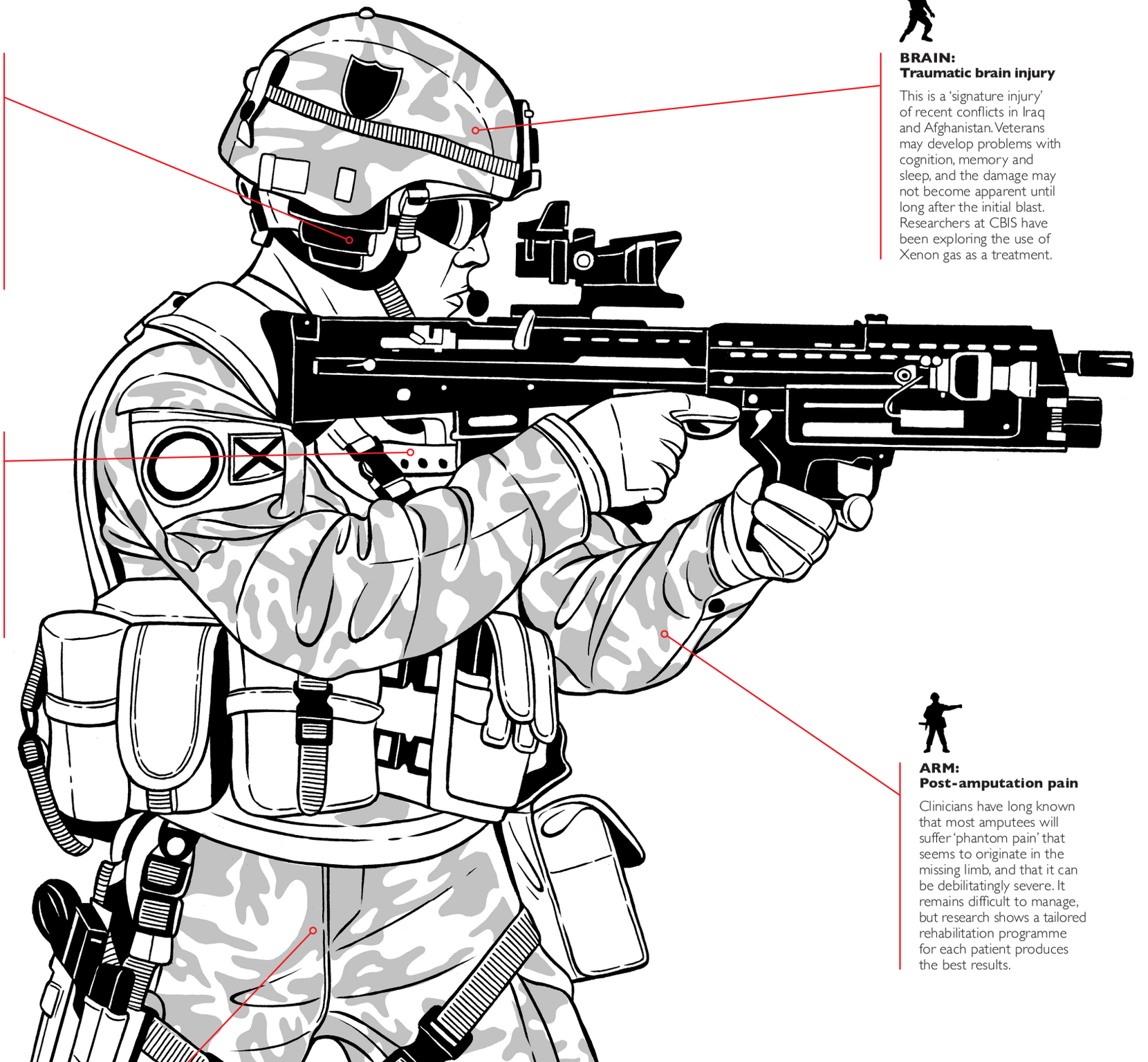


HEARING:
Auditory processing disorder (APD)

Veterans exposed to blast have a high incidence of APD, a brain disorder that affects perception of sound – particularly the ability to understand speech whenever there is background noise. The Centre for Blast Injury Studies (CBIS) is working on a mind-controlled hearing aid that can isolate and boost the voice being listened to.

CHEST:
Blast lung

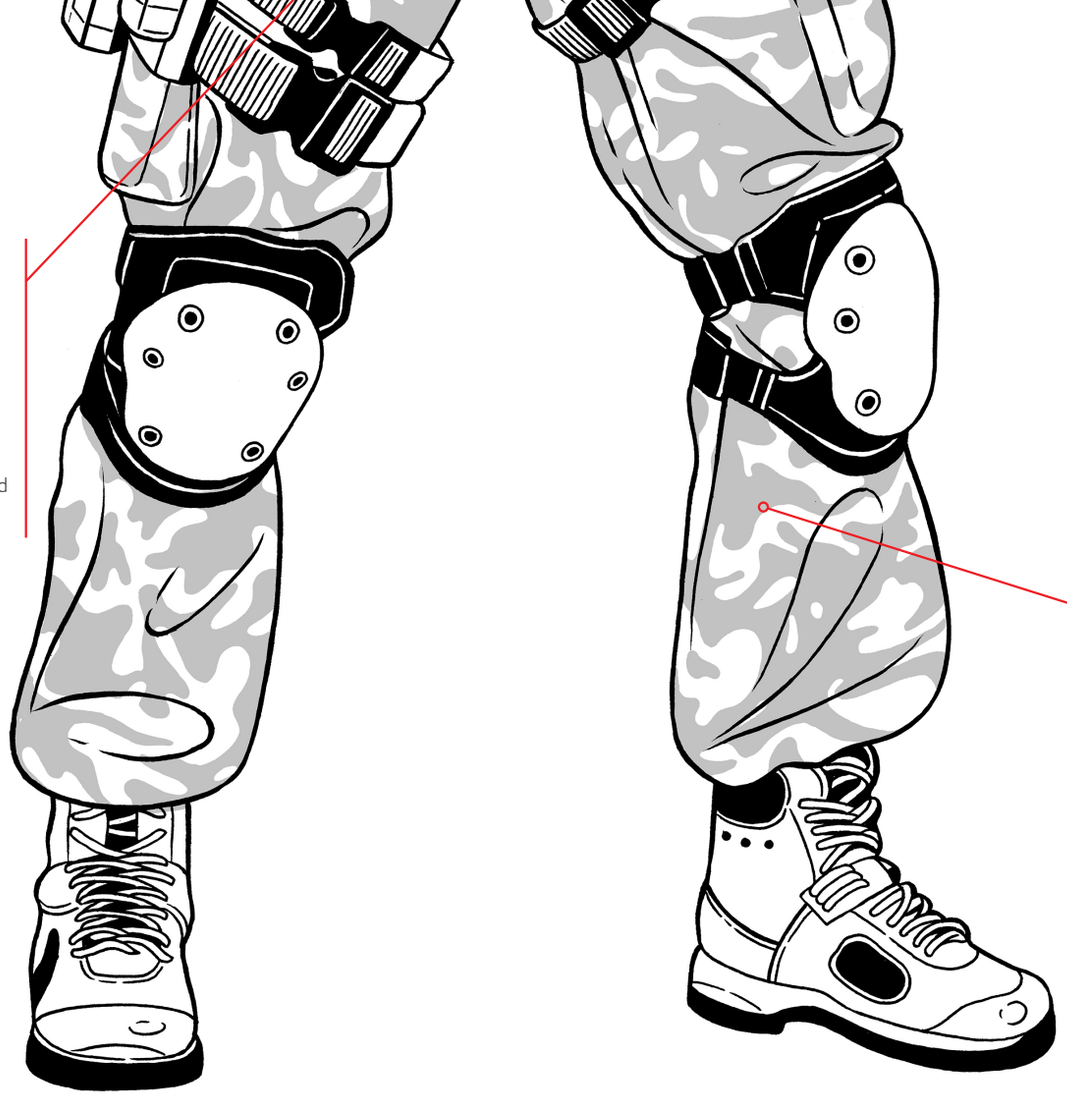
For soldiers who survive an initial explosion, blast lung is the most common cause of death. Its symptoms include internal bruising, blood vessel damage and haemorrhage – often without obvious external signs. Effective treatment and protection is among CBIS's clinical priorities.

BRAIN:
Traumatic brain injury

This is a 'signature injury' of recent conflicts in Iraq and Afghanistan. Veterans may develop problems with cognition, memory and sleep, and the damage may not become apparent until long after the initial blast. Researchers at CBIS have been exploring the use of Xenon gas as a treatment.

ARM:
Post-amputation pain

Clinicians have long known that most amputees will suffer 'phantom pain' that seems to originate in the missing limb, and that it can be debilitatingly severe. It remains difficult to manage, but research shows a tailored rehabilitation programme for each patient produces the best results.



PELVIS:
Open blast fractures

When an explosion causes the pelvis to open up – something often encountered in open-field combat – a pelvic binder is used to strap it together. Work at the Centre shows that in blast injuries, the binder should be positioned differently than in civilian cases such as car crashes.

LOWER LEG:
Heterotopic ossification

One of the strangest long-term effects of blast damage is the growth of abnormal bone tissue at the site of an amputation. This can affect the load-bearing ability of the stump, preventing prosthetic limbs from being used. CBIS is researching ways to slow down and reshape this bone growth.

INVISIBLE KILLERS

Blast injuries can devastate lives. But a unique centre at Imperial is providing hope for the future. ▸

Words: **William Ham-Bevan** / Illustration: **Stuart Patience**

BLAST

injuries have been called the 'invisible killer', as prevalent in modern warfare as when they caused so much devastation in the First World War more than a century ago. Indeed, in the recent conflict in Afghanistan, roadside bombs or improvised explosive devices (IEDs) were the leading cause of death and injury for UK forces personnel. Of the individuals who survived the initial blast, 291 required the amputation of one or more limbs.

"Blast injury is where physics meets human biology," says Dr Emily Mayhew (MSc History of Science, Medicine and Technology 1999), Historian in Residence at the Department of Bioengineering. "Explosions generate very fast, very powerful increases in air pressure as an invisible wave outward and away from the site of the blast. The shockwave passes through the tissues, causing differences in pressure at all sites in the body where gas and liquid are contained."

The effect is immediate and devastating, but it can also have serious implications months and years afterwards. She says: "Perhaps the most serious threat to blast injury casualties is our inability to consolidate research gains made during wartime. Medical history shows that we are always efficient at treating the immediate emergencies of wounds but have not been able to sustain work to resolve the broader issues, like pain in its various forms."

Finding out how to aid the recovery of affected individuals and improve their subsequent lives – and protect against such injuries in future operations – is the mission of the Royal British Legion Centre for Blast Injury Studies (CBIS) at Imperial. It's the only centre of its kind in the UK and was founded in 2011 with the financial backing of the Royal British Legion and support from the Ministry of Defence. It brings together military medics and civilian engineers and scientists from around the world. Professor Anthony Bull (Mechanical Engineering 1992, PhD 1995), Head of the Department of Bioengineering and Director of the Centre, says: "There were people who were good at designing vehicles and protective equipment, and there were military medics who were good at saving lives. But they were not really learning from each other about how to do a better job.

"We realised there was a lot we could achieve by putting these people together, with people in the middle to make it all work. We now have: clinicians; rehab specialists; hardcore engineers who do materials engineering; and then people like myself who look at the tissues of the body, how they respond to load and how we can reconstruct and repair them."

The participation of the military – from both UK and allied forces – is essential in allowing CBIS to pursue its long-term goals. Its clinical lead is Professor Jonathan Clasper, a colonel in the Royal Army Medical Corps who spends one day a week at the Centre; military surgeons from both sides of the Atlantic come to Imperial on collaborative projects. "It's important that we have access to military incident data," says Professor Bull. "We need to know things like where every blast victim received their injury, the size of the blast, and the medical outcome."

The shockwave from an explosion passes through human tissue at all sites containing gas and liquid

Mayhew was involved with CBIS while researching her book *A Heavy Reckoning: War, Medicine and Survival in Afghanistan and Beyond*. She says: "There is a tremendous similarity between the injuries of the First World War and 21st-century conflict. A lot of the research threads that we've picked up in the Centre were laid down a century ago, but the medical establishment didn't want these new disciplines to be developed. They were worried that if you had this whole new section of orthopaedic surgeons and specialists, then general surgeons and general practitioners would lose fees; so they shut them down. All the ability and knowledge learned in the early 20th century was lost.

"However, we know about these soldiers' needs because some of them didn't die until the 1970s, and we have their complete medical records. Unfortunately, many of them lived lives of misery and pain."

Large-scale cohort studies track the progress of today's veterans. CBIS has been collaborating with King's College London and the Defence Medical Rehabilitation Centre at Headley Court on a 20-year follow-up of 600 soldiers with very severe injuries. Bull says: "Every three to five years, we'll physically measure various indicators of musculoskeletal and cardiovascular health, comparing them with a control group who were exposed to the battlefield but not injured."

Musculoskeletal damage may be the most visible consequence, but blast can affect every

system of the body. Dr Mazdak Ghajari (PhD Mechanical Engineering 2010), a Lecturer at the Dyson School of Design Engineering, specialises in the biomechanics of traumatic brain injury. Outside CBIS, his research has been concerned with single-impact events such as those found in road-traffic accidents, but blast injuries are both more complex and less clearly understood. Sometimes there is little outward sign of damage, and symptoms such as amnesia, confusion and personality change can take weeks or months to show themselves.

He says: "We have a combination of different forces. Initial blast is a pressure front travelling at supersonic speed, but after this you have something called blast wind – a negative phase that's more like a suction action. Some researchers even think this second phase causes the brain injury, though that's controversial."

If finding out how these forces interact with the brain to cause injury is challenging, working out how to protect against them is tougher still. In collaboration with the Division of Brain Sciences at Imperial, Ghajari has been working to improve the design of helmets and other impact mitigation devices.

He says: "With something like shrapnel, you just make the helmet stiffer so that it can't be penetrated or deformed. With blast, the situation is different: you have a pressure wave that can be transmitted through the material. It's difficult to imagine how to protect against this. It may be that it's not even possible with one helmet, and we need a more complex protective system."

INJURY

from a more specific brain condition under investigation at CBIS is auditory processing disorder (APD). "It's a problem with the neurocircuitry that's responsible for sound processing," says Dr Tobias Reichenbach, the Senior Lecturer in Bioengineering who specialises in the condition. "We don't just hear with our ears, but with our brain. People with APD typically have difficulty understanding speech in noisy situations. So, if you're in a busy pub, you may find it difficult to focus on the particular person you want to talk to."

The exact nature of the neuroimpairment that causes APD remains elusive, but he believes that its appearance in blast victims is a result of structural damage to the brain caused by the pressure wave. To alleviate the condition, his team at CBIS has developed technology that uses electrodes to decode brain activity and determine what the wearer is trying to listen to, with a view to using it in a mind-controlled hearing aid.

Another typical consequence of blast injury is heterotopic ossification. This is the abnormal growth of bone in the affected limb, appearing as deposits in muscle, tendons and other soft tissue. It affects around 65 per cent of British military amputees and can cause severe pain, making the use of prosthetics difficult or impossible.

"The research into it is complicated," says Reichenbach. "We have to recreate a blast wave in an experimental model to see if we can recreate this kind of bone by shocking human cells, and we've been doing complex computer modelling of how bone grows. This helps us work out how to change early treatment to slow down the rate of bone formation or change its shape so that it can bear load, rather than appear as a nasty spider's web in the limb."

Perhaps the most intractable problem for the Centre's researchers is chronic pain among amputees. In *A Heavy Reckoning*, Mayhew contends that the past century has seen very little headway in alleviating it. "You'll have pain at the amputation site, in the stump," she says. "But then you have this extraordinary thing called phantom limb pain. That's where you feel pain in the limb that has gone, and there's still very little we can do for this. We know that the rate of it is very similar to 100 years ago."

Despite being established only seven years ago, CBIS is already having a significant impact both in academic research and its practical application. Professor Bull says: "We don't treat our funding as a grant to allow us to retreat into an ivory tower and do our thing. We're very milestone driven, and it takes a certain type of academic to want to engage with that – not everyone does.

"As for specific goals, I'd like us to come up with an effective therapy for auditory processing disorder, and I'd like us to discover a treatment for heterotopic ossification. There are other things in the pipeline – we've created an orthopaedic implant for above-the-knee amputees that will change the way they can bear load. That has been tested and is now going through the approvals process, and there are patients lining up to use it."

"We're dealing with a real emergency," says Mayhew. "We have to keep focused on the victims of blast injury and work out who we need to gather around them to make improvements to their lives." ◆

Clean reaction

From farming and pharmaceuticals to transport and communications, chemistry underpins modern life. But it is also an industry that is too often dirty, dangerous and wasteful. We meet the people who plan to change the world with green chemistry. ▶

Words: **Becky Allen** / Photography: **Sophia Spring** / Styling: **Vicky Lees**

Dr Florence Gschwend, creator of BioFlex, which turns waste wood into valuable raw materials.

BioFlex can turn any waste plant material – such as wood – back into raw materials that can be made into new plastics, glues, bulk chemicals and fuels

Dr James Wilton-Ely is finding new ways to reuse precious metals such as palladium.

Dr Florence Gschwend
Recycled wood

When Dr Florence Gschwend (MRes Chemistry 2013, PhD Chemical Engineering 2017) arrived at Imperial, she knew she wanted to use her science for sustainability. But she never anticipated inventing a new process – BioFlex – that could "transform today's waste into tomorrow's raw materials", as she puts it.

In the EU and US alone, around 100 million tonnes of waste wood go unrecycled every year – a major economic loss and an untapped resource. By using ionic liquids as solvents, BioFlex turns waste wood that would otherwise go to landfill into valuable raw materials that can be made into new plastics, glues, bulk chemicals and fuels.

It means that, in the future, BioFlex could be used in anything from biodegradable plastic cups to flat-pack furniture and paints. The process was developed by new spin-out company Chrysalix Technologies, founded by Gschwend (now a Research Associate at the Department of Chemical Engineering) with colleagues Dr Jason Hallett and Dr Agnieszka Brandt-Talbot (PhD Life Sciences 2011).

"Decarbonising the world's economy means more than ditching fossil fuels in favour of renewables like solar and wind energy," explains Gschwend. "We need huge quantities of raw materials to produce everyday items and much of this still comes from a barrel of oil.

"Our two innovations are using a cheap solvent and a cheap raw material. The added benefit of using our solvent is that it can extract the heavy metals used as wood preservers, and which remain one of the main barriers to its recycling." And because the BioFlex process uses no sulphur, the output materials it generates are free from the rotten-egg smell that prevents the paper industry doing anything useful with its major by-product, lignin.

But what makes BioFlex so special is that it works with any plant material, not only waste wood. "Plants are made of varying proportions of cellulose, hemicellulose and lignin, but our process works regardless of which plant species you use," says Gschwend. "At the moment we're piloting waste wood, but it could be applied equally well to agricultural residues or invasive species."

> *www.chrysalixtechnologies.com*

Dr James Wilton-Ely
Palladium metal

Forget gold and platinum: the precious metal we should all be talking about is palladium, a silvery metal used in catalytic converters for many of the 1.2 billion vehicles on the road. But despite being a precious metal, an awful lot of it ends up on the (literal) scrapheap.

Dr James Wilton-Ely (Chemistry 1994, PhD 1997), Reader in Inorganic Chemistry at the Department of Chemistry, wants to find new ways of recycling these and other extraordinarily useful metals, not least because they are globally scarce and costly to extract. "Mining is hazardous to workers, local communities and the environment – and palladium mining is no different – so instead of more mining, we need to reuse more of this precious metal," he says.

Despite its value, recycling palladium from old catalytic converters to make new ones is too expensive. But together with Professor Angela Serpe at the University of Cagliari, Wilton-Ely has developed new ways of reusing this palladium for catalysts in other industries.

Serpe and her colleagues have pioneered a new process capable of separating old catalytic converters into palladium compounds. Rather than using huge amounts of energy to reduce palladium back to the metal, the process uses mild chemicals and small amounts of energy to yield palladium in molecular form. Wilton-Ely's idea was to find new ways to reuse these valuable compounds.

He's already discovered that they can be used as catalysts in pharmaceutical research. Here, they perform just as well as existing catalysts – with the added benefit that the palladium is recycled, not newly mined. And having proved they work, Wilton-Ely has extended his work into the myriad reactions based on palladium.

"It's probably the most catalytic of metals, so it's widely used in lots of applications. And with some modification, we've applied it to lots of routine and industrially important processes that make large quantities of chemical products," he says. "It's a new approach, but in future Angela's methods could be widely used in industry – and our research will be ready to be rapidly adopted on an industrial scale." ▶

Returning palladium used in catalytic converters to metal is resource-intensive. Instead, the new process uses mild chemicals and small amounts of energy to yield palladium in molecular form

Henrik Hagemann
Cellulose granules

Next time you drink a glass of water, think carefully about what may have gone into it – every day, millions of people globally are exposed to toxic, manmade chemicals called per- or polyfluoroalkyl substances (PFAS).

Seeing first-hand how industrial chemicals like PFAS have polluted natural environments was part of what motivated Henrik Hagemann (MEng Bioengineering 2015) to find better ways of removing micropollutants from wastewater. "Travelling through very low-income parts of the world made me want to reduce the impact these chemicals have by tackling the problem at source," he says.

Together with Gabi Santosa (Life Sciences 2016), Ben Reeve (PhD Bioengineering 2016), Amanda You (PhD Materials 2016) and Shayne Petkiewicz (MSc Chemical Engineering 2016), Hagemann has developed a new way of selectively removing PFAS and other pollutants from wastewater, and set up a new company, CustoMem, to bring it to market.

Their invention is based on simple cellulose. Found in bacteria, algae and across the plant kingdom, it is the most abundant natural polymer in the world. By processing the cellulose and using supramolecular chemistry – how compounds or building blocks are held together by intramolecular bonds – they can produce porous, non-biodegradable granules that can be tailormade to mop up specific pollutants.

"The granules are hard, non-wetting and look a bit like sand," explains Hagemann. "Compared with the activated carbon that's currently widely used, our materials are novel because not only can they be targeted, they can also be regenerated, so you can reuse our granules on site with a simple non-hazardous liquid wash."

The end result is a system that is more effective, produces less downstream waste and is much less expensive. "We're targeting chemicals that are so persistent that in some cases people currently incinerate water to deal with the problem. When you compare using our cellulose-based granules with burning water at 1,100°C, you get an idea of the difference we can make."

> *www.customem.com* ▶

From left to right:
Henrik Hagemann, Shayne Petkiewicz, Ben Reeve and Amanda You of CustoMem.

Instead of having to incinerate water, the team use cellulose-based granules to remove pollutants

Professor Tom Welton works on real-life, world-changing applications for ionic liquids.

Solvents are often highly hazardous to health and the environment. Ionic liquids – salts that are capable of dissolving almost anything – could be the answer

Professor Tom Welton
Ionic liquids

If you've ever painted a wall, taken your clothes to a dry cleaner or simply made a cup of tea, you'll have come into contact with solvents. But these essential liquids are often hazardous to health and the environment, and we urgently need to find greener alternatives.

For almost 30 years, chemists have wondered whether ionic liquids – salts that are liquid at room temperature and capable of dissolving almost anything – could be the answer. Despite being hailed as 'designer solvents', tailormade for a specific purpose by varying their ions, chemists discovered that behind the hype, the chemistry of ionic liquids was far more complex.

"When I started studying them in 1985, you could put everyone working on ionic liquids in one small room. I know that because it happened – and there were about 30 of us," says Professor Tom Welton, Dean of the Faculty of Natural Sciences. "Now there are thousands of researchers in a field that's become very large and hugely exciting."

What most excites Welton isn't just that our theories still cannot adequately explain how ionic liquids behave, but that his discoveries have so many potentially world-changing applications. "By developing the tools to study them, we are finding out how ionic liquids actually behave. Knowing that means that we can manipulate them to achieve a desired outcome," he explains.

Welton is working on real-world applications for ionic liquids alongside his research, such as solutions to the challenges of recycling textiles (it's currently impossible to recycle polycotton mixtures) and ways of using ionic liquids to dissolve wood, as an alternative to using food crops, which could open up totally new ways of producing biofuels.

"That's very exciting," he says. "We're not there yet, but ionic liquids show huge promise. Something like making biology-based replacements for the oil refinery without using plant foods – now that would have massive global implications." ◆

Mice find Lego so interesting, they will stay awake to play with it. This has enabled researchers to examine the probable overlap between the brain pathways that induce natural sleep and those worked on by sedatives

A good night's sleep

WHAT DO LEGO, MICE AND FRUIT FLIES HAVE IN COMMON? AT IMPERIAL, THEY ARE ALL PLAYING THEIR PART TO UNLOCK THE MYSTERIES OF SLEEP.

Words: **Lucy Jolin** / Illustration: **Andy Martin**

We spend a third of our lives doing it – more than on any other activity. We know that we need it: if we don't get enough, the consequences can be far-reaching and even fatal. And we know that the drive to do it is irresistible: however much we fight it, it will eventually come. Sleep: one of the great unsolved scientific mysteries of our time. And working out ways to unravel its secrets is as complex as the act itself.

"Ask people what sleep is for, and they will say: 'Getting some rest.' But that is not really a satisfactory answer from the biological point of view," says Professor Giorgio Gilestro, a lecturer in the Department of Life Sciences, who believes an over-emphasis on studying brain signals has compromised sleep research. "Compare sleep with feeding. We know, at the biological level, what feeding is for. We know that when you ingest food you do so because your body needs calories to function. We know exactly how sugar transforms itself in order to give you fuel. We don't have a conceptual equivalent for sleep."

But there are two new secret weapons in the battle to uncover sleep's mysteries from a genetic standpoint: fruit flies and mice. ▶

Like humans, *Drosophila melanogaster* (the common fruit fly) have around 20,000 genes, 70 per cent of which they share with humans, making them a perfect model for studying how genes affect sleep.

"We now have tools that allow us to destroy the genes one by one and then check each one for a given pattern or phenotype," explains Gilestro. "We recently found the gene that, when mutated, will make flies sleep less. We proposed that it's important in merging together circadian rhythms, which regulate the time of the day when you have to sleep, together with sleep homeostasis, which regulates how tired you are." They called the gene *Ninna nanna*, Italian for lullaby.

AWAKE TO THE DANGERS

Along with genetic technology, automation has been key to allowing proper investigation of sleep. In Gilestro's lab, 70 specially built robots take on repetitive tasks formerly performed by students: they move the flies' jars to wake them up when they start sleeping, puff odours in to sexually arouse them, and record their levels of movement.

Any experiment predicated on a student's ability to shake a jar at exactly the same time and with the same force over an extended time period is never going to give accurate results. Research performed in this way in the US, aimed at seeing how long flies could go without sleep, found that some died after 60 hours. Gilestro replicated the experiment with his robots. After five weeks of sleep deprivation, giving the flies no more than 20 seconds of consecutive sleep, none had died.

"And this opens up new hypotheses – one of which is that sleep is not a vital necessity, at least for flies," says Gilestro. "Or another is that animals enter episodes of sleep whether they want to or not. We keep them awake and they have microsleep episodes in order not to die." These episodes have far-reaching implications for humans: for instance, an investigation found that Alfred Dorris probably drifted into a microsleep in 2016 while driving a tram in Croydon, London: the resulting crash killed seven people and injured 62.

Professor Nick Franks and Professor William Wisden's work also involves keeping things awake: in their case, mice, who are sufficiently excited by a piece of Lego popped in their cage every hour or so. Their research into sleep has thus far focused on the probable overlap between the brain pathways that sedatives work on, and the brain pathways that induce natural sleep.

"There's interest in sedative drugs or anaesthetics used in investigative or therapeutic procedures that produce a sedative state, but that don't have side effects," says Franks. "You always feel better after a good night's sleep, but not after a sedative. Having a sedative drug that puts you in a deep but rousable sedative state, and that might even give some of the restorative benefits of natural sleep, would be very attractive clinically."

Their new project, however, is founded on the observation that almost every neurological disorder – Alzheimer's disease, schizophrenia, depression – presents with bad sleep. Are those conditions causing bad sleep? Or is the bad sleep itself causing the disorder? This is the question that their new research, funded by the UK Dementia Research Institute, will investigate: whether sleep is helping toxins such as beta-amyloid proteins, which have been associated with Alzheimer's, get cleared from the brain. "The idea is that if you have healthy sleep during your lifetime, it may lower your risk of dementia," says Wisden.

It's one thing to study a jar of sleeping flies or a mouse; quite another to study a sleeping human. Studying how individuals sleep is vital not just for research, but also for diagnosis of a particular sleep problem. Dr Parviz Habibi, co-founder with Dr James Di Pasquale (PhD Clinical Medicine Research 2017) of the Imperial College London Centre for Paediatric Sleep Science and Medicine at St Mary's Hospital, are trying to find a solution. Their lab consists of two spacious bedrooms connected by an observation room. Every night, from around 7pm, children with a range of sleep problems – from respiratory difficulties such as obstructive sleep apnoea (OSA) to night terrors – and their parents arrive to have the child's sleep observed.

Polysomnography sensors are attached to the child's scalp and face to collect a sample of the brain's electrical brain signals (EEG). If the child has breathing problems, they may also need: a nasal pressure cannula to detect airflow through the nose; a heart rate monitor; a respiratory effort band, which is like a belt; and a pulse sensor on the finger. Then they have to have a restful night's sleep. It's a less than ideal method, says Di Pasquale, especially for paediatrics. "A three-year-old often can't understand or be convinced that this is a good idea."

To that end, he and Habibi are researching a new innovation developed by Colin Sullivan at the University of Sydney: the Sonomat, a mat designed to fit over a mattress, which contains sensors similar to stethoscopes. These record sounds during sleep such as coughing, sneezing, wheezing, crackles, scratching and snoring, all of which could indicate a sleep problem. However, it can't measure some indicators, such as oxygen levels, and it can't be used to diagnose neurological sleep disorders. Something else is needed, and Professor Esther Rodriguez Villegas, Chair of Low Power Electronics in the Department of Electrical and Electronic Engineering, may have the solution.

"When you affect behaviour by studying it, you are not going to get the best conclusions," she points out. "This happens not just in research, but also in diagnosis. To study sleep, you have to have sensors attached to the body that don't detach, or change position, or affect sleep behaviour. You need wearable technology that people forget they are wearing."

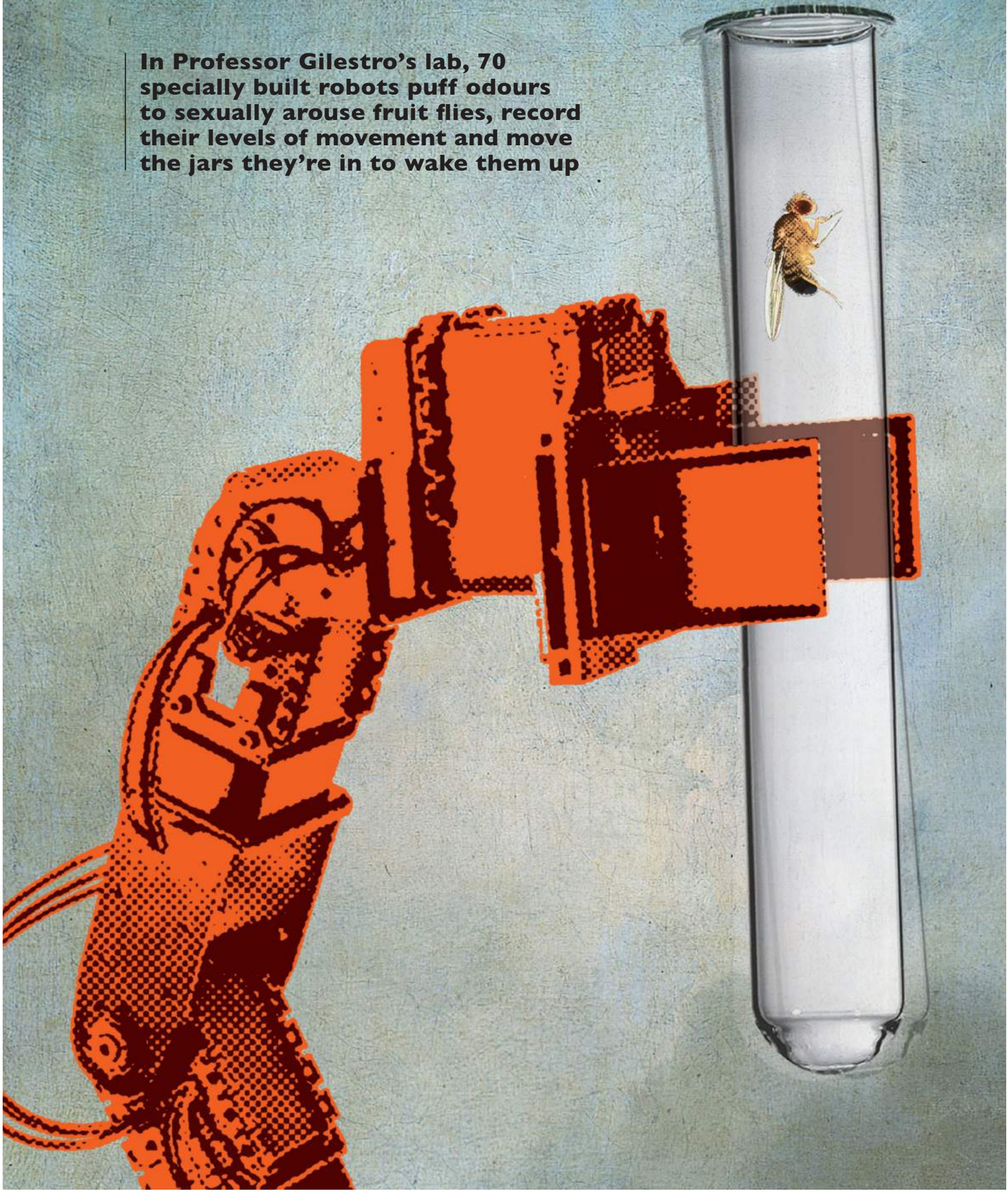
CREATING A NEW PLAYING FIELD

Villegas and her team have come up with a wearable sensor that will be on the market in 2019 – again, for diagnosing OSA. They are currently working on the next bit of tech, which monitors brainwaves while algorithms detect different stages of sleep – the first stage, the rapid eye movement (REM) stage of deep sleep, and episodes known as sleep spindles, which correlate with a number of neurologically based conditions such as epilepsy, currently diagnosed in hospitals using EEG.

Villegas hopes that these wearables will open up many different areas of research. "It's going to allow easy signal acquisitions," she points out. "We know that sleep spindle activity changes in people with depression but we don't know if that's caused by depression, or the other way around. The question now is how we acquire more than one physiological parameter for sleep, from just one location in the body. We are not going to be able to detect respiration and brainwaves from the same location, but for everything else, there's nothing that makes it physically impossible. What is that place?"

So many problems, so many questions: it might seem that the conundrum of why we sleep is insurmountable. However, with disciplines from engineering to paediatrics coming together to find answers, it may well be that sleep starts to yield its secrets soon. "I wouldn't be so ambitious or naive to say we are close to solving it," says Gilestro. "But I'm very proud of the fact that we are creating a new playing field. We are creating new rules and questions and a new way of looking at the problem." ◆

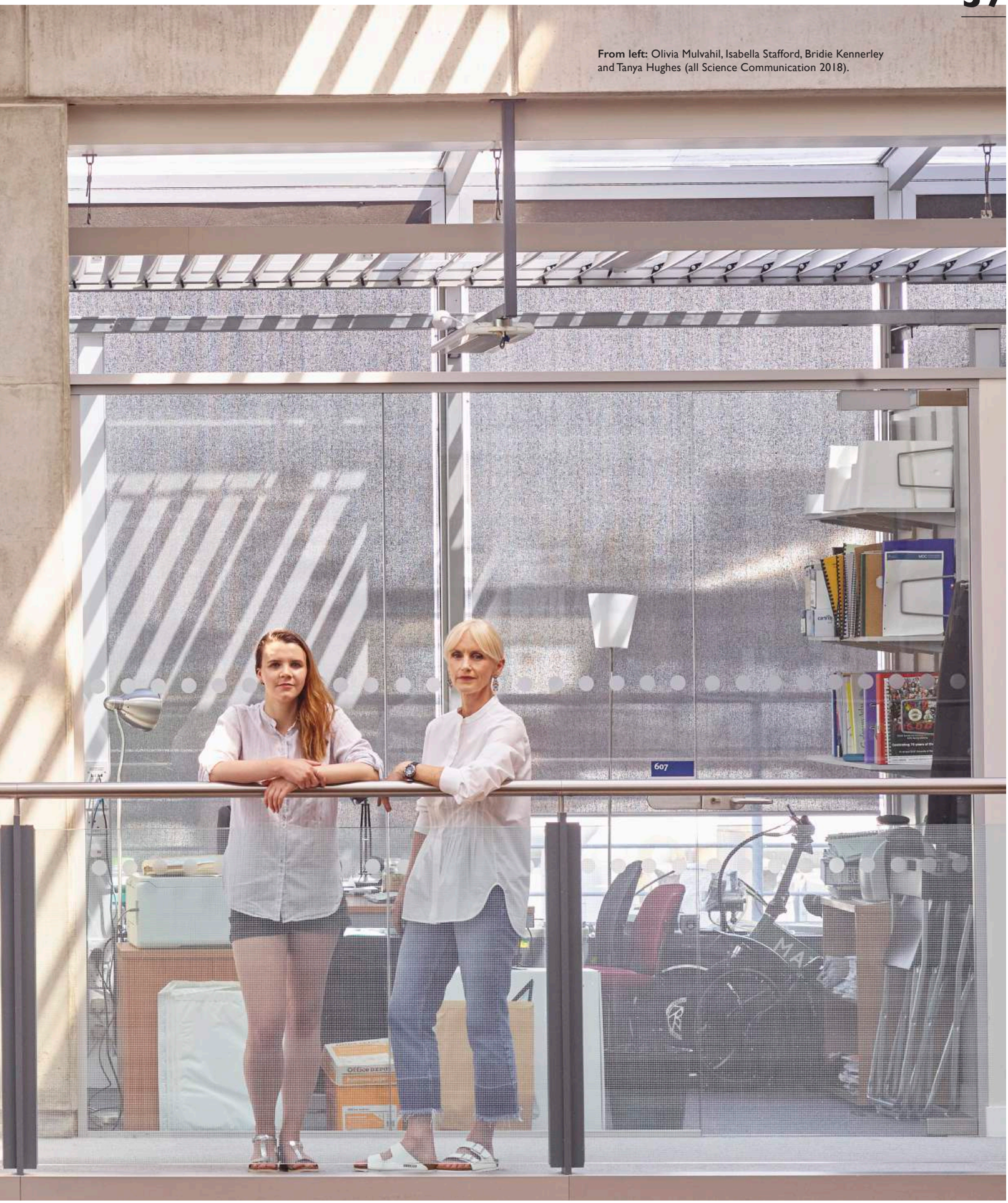
In Professor Gilestro's lab, 70 specially built robots puff odours to sexually arouse fruit flies, record their levels of movement and move the jars they're in to wake them up



Words: **William Ham Bevan** / Photography: **Angela Moore**

THE WONDER OF SCIENCE

WHAT IT REALLY TAKES TO COMMUNICATE SCIENCE IN 2019



From left: Olivia Mulvahil, Isabella Stafford, Bridie Kennerley and Tanya Hughes (all Science Communication 2018).

IT HAS THE

potential to unlock some of the most important discoveries in the universe and is the world's largest and most complex piece of scientific kit. We've all heard of the Large Hadron Collider (LHC) at CERN – the proton beams and the Higgs boson, the so-called 'God particle' – but who really understands what it's all about?

The task of keeping the public informed about the mind-bogglingly complex developments at CERN falls to Kate Kahle (MSc Science Communication 2004) and her team. As Head of Editorial Content Development, she is responsible for publishing news of the LHC across websites and social media channels and says it's all about finding stories that will make people care. "We're pushing the boundaries of technology, so the story isn't just about what the physicists are searching for, but the accelerated development of technology to achieve it," says Kahle. "And then there are the human stories – the people behind the science. Above all, we need to reach out to the public, so the first thing we ask is this: what's the audience for the story?"

Communicating science in the public sphere is a complex task that comes with some misleading preconceptions, says Katherine Mathieson (MSc Science Communication 1999), Chief Executive of the British Science Association. The first assumption to be challenged, according to Mathieson, is the idea that communicators simply 'translate' science into a more accessible form.

"I think that's how people used to see it," she says. "There was this idea that we should turn this hard stuff into something that the lay person could understand. But when I came to Imperial, I realised this was wildly over-simplistic. It's actually less of a translation job and more about bringing together people and skills from different sectors to ensure that as many people as possible build up a positive relationship with science."

And for all the controversy about whether the public has 'had enough of experts', science content has lost little of its audience. Carlo Massarella (Physics 1995, MSc Science Communication 1996) is Creative Director of Windfall Films – a TV production company he joined straight from the MSc course – and an Emmy-award-winning executive producer and documentary director. "I think it's a great time for science," he says. "Global broadcasters are looking to British producers because they have a very good skill set in making science accessible in an entertaining way."

A current project is *The Fifteen Billion Pound Railway*, three series of BBC documentaries about the construction of Crossrail underneath London. Massarella says: "You have a whole wealth of people coming together to make the project possible, from people doing heavy engineering to soil scientists, geologists, electrical engineers and designers. We've been trying to convey the passion of those people with the skill and expertise to make it happen."

SPRINGBOARD TO SUCCESS

Like many who represent the public face of the world's greatest scientific establishments – and countless others who report on them – Kahle, Mathieson and Massarella are graduates of the Imperial College London MSc in Science Communication. Earlier this year, the 25th intake of students received their degrees in the Royal Albert Hall, pushing the number of alumni past the 800 mark.

Since 2000, Imperial's Science Communication Unit has offered two MSc programmes: the original MSc degree, and one in Science Media Production. Although the latter is more geared towards documentary film-making, the content across both is similar. Dr Stephen Webster, Director of the Unit, says: "In all cases, we're trying to get the students to look in to science and look out to society. We want them to take a broader perspective on how science fits with the wider world."

The core syllabus includes five types of professional skill: writing, TV and film-making, museums, web design and radio. However, students also take a wide range of courses in the humanities and social sciences – something they may not have done since choosing A-level options at the age of 16. Webster says: "What I mostly do, for example, is teach philosophy of science. That's really to undermine the beliefs of the students that science is a bunch of facts that everyone would love, if only we could explain them more clearly.

"We tell them that it's not like that: science is not about certainty. What do we even mean by scientific progress? And is it really true that the public are ignorant of science, and that's why they resist ideas? We look at all these things from a humanities perspective."

Graduates of the MSc programmes are highly sought-after in all areas of science communication and journalism. Webster says: "About 50 per cent go into communications teams at scientific institutions, working on websites, public outreach, press releases, videos and so on. About a quarter go into print journalism, TV, documentary films and radio. Then we have a steady minority – perhaps five in every group of 50 – who go into museums and exhibitions. Finally, there's a small stream who go into policy, such as in think tanks."

It's a fast-changing world, and many alumni end up taking on a multitude of different roles. Since graduation, Alok Jha (MSci Physics 1998, MSc Science Communication 1999) has variously worked as a science correspondent for *The Guardian* and ITN, a TV and radio

Reporting on tomorrow's world today...

Dr Stephen Webster
Director of the Imperial College London MSc in Science Communication.

Kate Kahle
(MSc Science Communication 2004)
Head of Editorial Content Development at CERN

Carlo Massarella
(Physics 1995, MSc Science Communication 1996)
Creative Director, Windfall Films.

Katherine Mathieson
(MSc Science Communication 1999)
Chief Executive of the British Science Association.

Alok Jha
(MSci *Physics 1998, MSc Science Communication 1999)*
Author and science correspondent.

... and into the future

Olivia Mulvahil
"David Attenborough first got me hooked; I'm fascinated by the natural world as there's still so much to learn and I'd love to be part of the teams that bring it into people's homes."

Isabella Stafford
"The unlimited nature of knowledge keeps me excited – alongside being part of an emerging sphere focused on protecting and preserving nature's wonders."

Bridie Kennerley
"I'm inspired by the natural world itself – fascinated by the interactions that take place between organisms, from animal behaviour right down to deep sea bacteria."

Tanya Hughes
"My holiday reading – Steven Pinker, Thomas Kuhn, Simon Singh – reveals a love of science that has been deeply buried under a 30-year career in fashion and lifestyle."

presenter for the BBC, and an author of books including *How to Live Forever* and *The Water Book*. He says: "Before new media came along, journalism used to change once a generation. Now it seems like the format changes with every generation of iPhone.

"When I started, I'd have a day or so to write and edit a news story, or perhaps several days for a feature that would appear in the paper some days later. Today, it's so much faster. Often, you just have hours to try to do the same thing. But the fundamentals of the journalism are still the same: you take into account what your audience wants to know, you speak to expert people who know what they're talking about, and you make sure what you produce is accurate."

So, has the rise of social media, and the ability for anyone to broadcast their opinions to an audience of millions, fuelled a reaction against scientific expertise in favour of a post-truth free-for-all? Imran Khan (MSc Science Communication 2008), Head of Public Engagement at the Wellcome Trust, is not so sure.

He says: "One of the things we're looking into at the moment is the narrative around vaccines and how social media may amplify poor debate. But we shouldn't be too quick to make assumptions. It may be that while the quantity of poor information being shared is significant, people are actually quite resilient to it.

"It's something we're trying to test, rather than jump to conclusions. And we've got plenty of examples of poor debate and misinformation from before social media arrived – like the MMR vaccine, or controversies around BSE ('mad cow disease') and GM crops – so we should be careful of imagining a pre-Twitter golden age of scientific debate."

TIME TO CONNECT

Mathieson (who succeeded Khan as Chief Executive of the British Science Association) likewise thinks the 'backlash against experts' narrative is too simplistic. "My view is that experts are not less trusted than they were," she says. "But public audiences have become more sophisticated at understanding the nature of expertise.

"I don't think it's the case that, 30 years ago, everyone just accepted what scientists said. I just think those conversations are now in public rather than private spheres."

It all comes back to the idea of science communication as a conversation, rather than just a megaphone to amplify research findings. Webster queries the idea that any scientist can remain in a hermetically sealed laboratory and expect not to get tied up in real-world debates about the consequences of their research.

He says: "Students often want to believe that science is above politics, but is there really any science that's not political? It's a wonderful idea, the researcher locking themselves in the lab trying to understand nature. But because science is so anxious to be useful and have a role – not least so that its funding remains secure – it's inevitable that it will get mixed up with politics."

And ultimately, the greatest lesson for students on the MSc is that the public should not be seen as passive consumers, to be handed down digestible morsels of wisdom from the high table of science, but as active participants.

"The organisation I work for was formed in 1831," says Mathieson. "At the time, there was no such thing as a scientist as we now understand the word – research was done by amateurs. In the transition to a professional science environment, perhaps we've lost that ability to connect with scientific method to understand the world about us. We feel that science only belongs to the professionals.

"Trying to bring back that connection is an important objective for me. Yes, there will always be professionals, who know their stuff best and do most of the work; but that's true of music or sport as well. It shouldn't stop the rest of us having a relationship with science and making it part of our lives." ◆

ICE HOCKEY SOCIETY

Skate expectations

Ice hockey demands long hours and late nights – but when it comes to team spirit, it can't be beaten.

Words: **Sarah Woodward** / Photography: **Joe McGorty**

So, you want to play ice hockey – but can't skate? That didn't put off Parth Khullar (MSci Physics 2018), last year's Imperial Devils ice hockey club president. "I'd watched the Sochi Games on TV and thought the ice hockey looked amazing. The minute I arrived, I signed up for the club and then I just went for it." That meant long hours down at Queensway ice rink, often late at night when rink hire is cheaper – and watching a lot of YouTube.

The club can't afford a coach, so beginners rely on the more experienced players to teach them their stick and puck work, but learning to skate is down to them. 'A' team player Ben Lakey, who is taking his Master's in Biochemical Engineering, grew up in Edmonton, Canada, and was "practically skating before I could walk. But the new players will be down the rink at 11.30 on a Monday night. Their level of dedication is crazy."

Lakey appreciates the team spirit, brought home to him recently after the Humboldt Broncos were involved in a fatal coach crash in Saskatchewan. "Four of the players were from my city. Parth

and others organised a fundraiser; they didn't know the Humboldt Broncos, but they shared their passion for the sport."

That passion has not dimmed for recently qualified doctor Trent Allen (Medicine 2018), a member of the Devils for six years. "My parents are Canadians and taught me to skate, but I played field hockey at school. When I started at Imperial, I didn't know whether to play field or ice hockey. I went for the ice and never looked back. I love the finesse and physicality of the game. The highlight of every year is our varsity match against the UCL Yetis, though I missed my first chance to play in it three years ago because I had broken my leg, embarrassingly, in the warm-up of a practice session."

Everyone gains their place on merit and, as Khullar says, "it's a long learning curve and the spectrum of ability in the society is enormous. Ice hockey demands a unique set of skills and everything happens so much faster." That is what Lakey loves about the game – "it's quickfire, you come off the bench on to the ice with a full head of steam". At 6ft 4ins and "quite heavy", he is aware that his team members "like having me around – they reckon the other team are less likely to run into them when I am in the way".

Size helps, although a mixed team means that women get the chance to shine. "The most beautiful move I've ever seen was a full-on, old-fashioned hip check by one girl on another at Nationals," says Allen. "She turned her opposite number upside down."

All three players agree practice is the key. "Skating is 80 per cent of ice hockey – it doesn't matter how good your stick and puck work is, the faster skater on the rink will still beat you if you can't skate," says Allen. New society members can expect to spend long hours at the rink and their reward might be a league game at 11pm, sometimes on a Sunday night, sometimes far away.

The annual Eindhoven tournament in the Netherlands brings its own hardships, as Khullar remembers: "We were sleeping on the concrete floor of the sports hall and there was great competition for the 'goal hammock'. It's not always glamorous. But from the moment I started playing ice hockey it was all I imagined it to be – and more." ◆

Clockwise from left: A-Team captain Karl Zimmerman (PhD Clinical Medicine, second year), far left; Amir Sadikov (MEng Biomedical Engineering, third year) on the attack; Andreas Siagris (MEng Civil Engineering, fourth Year), left, and Karl Zimmerman; goalkeeper Shu Shiotani (MEng Mechanical Engineering, third Year).

WHAT'S ON AT IMPERIAL

November 2018 – March 2019

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

14/NOV
The Vincent Briscoe Security Lecture 2018

Commissioner of the London Metropolitan Police Service, Cressida Dick, discusses digital policing and technology in law enforcement.

Sir Alexander Fleming Building, South Kensington Campus

21/NOV
Alumni and friends reception in London

Join President Alice Gast and Professor the Lord Darzi of Denham at this special reception in London.

28/NOV
Eradicating malaria: A journey down the lens of a microscope

Jake Baum, Professor of Cell Biology and Infectious Diseases, discusses his own journey, interfaced with that of the malaria parasite, focusing on how the microscope has become such a central member of his team's science.

South Kensington Campus

30/NOV
Imperial College Symphony Orchestra Concert

A performance of Bernstein's Candide Overture, Prokofiev's Violin Concerto No 1 and Holst's The Planets.

Holy Trinity Church, Sloane Square, London, SW1X 9BZ

05/DEC
Zinc fingers: From gene switches to gene therapy

Professor Mark Isalan will tell the story of gene editing that spans the discovery of DNA, from Franklin, Crick and Watson through to Franklin's colleague Aaron Klug – who discovered zinc fingers – and up to the present day where these technologies are turning the potential for DNA and genome editing into a reality.

Lecture theatre G16, Sir Alexander Fleming Building, South Kensington Campus

06/DEC
The Professor Roger Sargent Lecture 2018

Professor Babatunde A. Ogunnaike, University of Delaware, gives the annual Professor Roger Sargent Lecture where he will provide insight into how physiological life is made possible by control.

Lecture theatre 3, Roderic Hill Building, South Kensington Campus

06/DEC
Imperial Lates: Xmaths

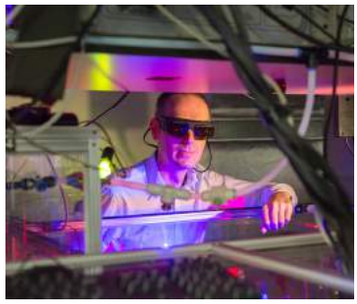
A festive celebration of maths, from its fundamental role in science and its application to all elements of our lives.

College main entrance, South Kensington Campus

30/JAN
Inaugural lecture: Toby Wiseman

Toby Wiseman, Professor of Theoretical Physics in the Department of Physics, presents his inaugural lecture.

South Kensington Campus



06/FEB
Molecule movies: Capturing the ultra-fast structural dynamics of life

We are astonishing miracles of molecular complexity. And yet, through that complexity comes the ability to direct the simplest everyday movements that sustain all life on Earth. So how do we, and all living things, move? Professor Jasper van Thor, Department of Life Sciences, presents his inaugural lecture.

Lecture theatre 200, City and Guilds Building, South Kensington Campus

19/FEB
The Schrödinger Lecture 2019

Michele Dougherty, Professor of Space Physics and Head of the Department of Physics at Imperial College London, will discuss her work on the Cassini Mission to Saturn which came to a spectacular end on 15 September 2017.

Great Hall, Sherfield Building, South Kensington Campus

21/FEB
Imperial Lates: Smart fashion

A collection of fashion, future clothing materials and wearable tech innovations and projects presented as part of London Fashion Week.

College main entrance, South Kensington Campus

02/MAR
Imperial College Symphony Orchestra Concert

A performance of Shostakovich's Piano Concerto No 2 in F Major Op 102

Cadogan Hall, Sloane Square, London, SW1X 9DQ

06/MAR
The Sir Ernst Chain Lecture 2019

Richard Henderson, recipient of the Nobel Prize for Chemistry in 2017 for electron microscopy of biological molecules, will present the 2019 Sir Ernst Chain Lecture.

Lecture theatre G16, Sir Alexander Fleming Building, South Kensington Campus

07/MAR
Imperial Lates: XX Factor

A celebration of the achievement of women in science and engineering past, present and future.

College main entrance, South Kensington Campus

13/MAR
President's Address

Professor Alice P. Gast presents her fifth annual President's Address.

Lecture theatre 200, City and Guilds Building, South Kensington Campus

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

DATASET / PROFESSOR DAVID MILES
AND PROFESSOR JAMES SEFTON

“What is the one thing that would make the biggest impact on the housing crisis? Transport infrastructure”

CONTEXT

Houses have become ever more expensive – relative to other living costs – since the mid-1970s, and are now proportionately three times as pricey in the UK as they were in the mid-1980s. In London, prices have risen far faster still. What's driving the market? And will house prices continue to rise faster than the cost of living, or could they eventually fall?

BACKGROUND

Over the past 50 years, housing has become remarkably expensive, but this hasn't always been the case. Imperial College Business School's David Miles, Professor of Financial Economics, and Professor James Sefton, Chair in Economics, have been taking a longer than usual view of property prices, examining the market and factors from the mid-19th century onwards, across a sample of developed economies. For about 100 years (1870-1970), house prices rose only in line with the wider cost of living. While recent studies might look back at the last decade or try to predict the next five or ten years, Imperial College Business School has taken a historical view, and casts more than a century into the future.

METHODOLOGY

Miles and Sefton used diverse data to build an economic model to help understand what drives property prices. They've pieced together information from some 65 historical, geographical and economic sources, looking at the cost of transport, the pace of improvements in commuting speeds, the cost of land, building materials and housing, and population growth rates. Using this data from developed countries, they have built economic simulation models suitable for a long horizon and have focused on a 250-year period (1870-2120).

FINDINGS

One of the major reasons housing didn't become more expensive from the mid-19th to the mid-20th century is the dramatic improvements in transport – trains, trams and roads and aeroplanes to a limited extent – during that period. "Our model suggests this was a leading factor in keeping property costs down, even as populations and real incomes grew substantially," says Miles. But a slowdown in transport improvements from 1970, and the subsequent effect on commuting times, has had an impact on the cost of land.

"Two other key parameters also affect prices. One of these is how willing we are to live in more housing built on less land – high into the sky or beneath the ground – which would increase supply. The other is how willing we are in the future to save on our lifestyles – holidays and restaurants, for instance – and spend more of our incomes on housing."

OUTCOMES

"Many US economists believe planning restrictions are responsible for high property prices," says Miles. "But our research suggests if we could return to similar rates of improvement in transport infrastructure that we saw from 1850 to 1950, we could make a big difference to the evolution of prices in the future.

"But if transport doesn't improve and commuting times remain the same, if future generations don't want to live in high towers or underground and they're still willing to sacrifice lifestyles to afford the kind of house their parents or grandparents lived in, then we can expect housing to become ever more expensive." ◆

> ***David Miles** is Professor of Financial Economics and **James Sefton** is Professor of Economics, both at Imperial College Business School.*

WORDS: PETER TAYLOR WHIFFEN

Giving back, looking forward

Volunteering is a great way to stay in touch with Imperial – and help students and your fellow alumni. Three Imperial graduates explain why they decided to volunteer.

OLIVER WOOLLEY

(MBA 1992) is the CEO of Envestors, a private investor network, and sits on Imperial's governing body, the Court

Q. What first encouraged you to volunteer?
It wasn't until my two sons started growing up that I decided to reconnect with Imperial. Looking at them, aged seven and ten, I realised the importance of education and the value of my Imperial MBA. After losing touch for about 15 years, I re-engaged with the College a decade ago and haven't looked back. Initially, we employed two interns from Imperial at Envestors, which was a useful experience, and as a result I joined the Business School's Alumni Advisory Board. Then I was very flattered to be invited to join the Court, which is a fascinating, diverse group of people – quite different from the 'male, pale and stale' boards I often encounter.

Q. What are the benefits?
Last year I was making a business trip to China and got in touch with the Imperial College Alumni Association (ICAA) for South China. They set up a drinks party, which I hosted and gave a talk at – it was well attended and gave me a fantastic opportunity to meet alumni. Not entirely without self-interest – we are always on the lookout for new investors. I have a huge fondness for Imperial and choose to support the College with my time (and in mine and my wife's wills) regardless of any benefits to myself and my business. But through volunteering I have met so many interesting people that it is definitely two-way traffic.

Q. What outcomes can you expect?
I see the Imperial Court as having two roles – providing a sounding board for the College's strategy and acting as ambassadors. Currently, I am encouraging the College to support its own investment community and in June this year I put together a panel for a sell-out talk on crowdfunding versus angel investing. I hope it will result in greater investment in spin-outs from alumni and so I may have done a bit of good in 'giving back' – the evening was also great fun!

WORDS: SARAH WOODWARD

DONG PING ZHANG (MSc Computing 2006, PhD 2010) is senior quantum architect at PsiQuantum and co-founder of Learnpool

Q. How did you reconnect with Imperial?
I was born in a small village in China and I feel I turned a corner when I went to Imperial – it's where I truly grew up. I didn't just learn about specific technology subjects, I acquired a whole new way of thinking, to be creative in problem-solving and use my ingenuity. A few years after I left, I became interested in making connections with other alumni who had naturally similar ways of thinking. I met a wonderful couple, David (Mining 1961) and Mary Goodman (Aeronautics 1961), who had been running the alumni association (ICAA) here in northern California for decades but were now retired and ready to hand over. I just thought it was my time.

Q. What do you get out of your volunteering?
Becoming President of the ICAA of Northern California was a bit daunting at first. It is a lot of work but I feel very rewarded. I am constantly inspired by meeting all these awesome people who have a connection to Imperial and it can also be very useful to know what is going on in current research. The College alerts me if a member of the teaching staff is coming here who might be able to give a talk, so we hear from experts in many different fields. We also have social events, such as potluck dinners and English afternoon tea. I hosted the most recent at my house, so it helps that my partner Lee Howes (MEng Computing 2005, PhD 2009) is also an alumnus.

Q. What motivates you?
I'm driven by the desire to create a platform through which like-minded people can meet and mentor each other both personally and professionally. When I first moved to north California I really could have done with such a network, so am delighted to be able to create it with Imperial. And I get to meet people who have been in Silicon Valley since the 1970s! These opportunities are very enriching to my life.

DR ZAHRA KADOM (Medicine 2013) is currently mentoring two medical students through the Careers Service Alumni Mentoring Programme

Q. Why did you sign up to be an alumni mentor?
There is a big gap between the six years you spend as a medical student, where you are protected to a degree, and suddenly launching into being a doctor. When I saw an email about the mentoring programme, which is especially aimed at those from disadvantaged backgrounds, I saw it as an opportunity to share my own experiences. At the first get-to-know-you meeting, many of the mentors were older than me and it was inspiring to see them reconnecting with Imperial.

Q. How does it work?
The Careers Service matches you to your mentee based on your backgrounds – for me they did a good job. All three of my mentees to date have been women, which is not something I particularly chose. But women often prefer to see a female doctor, whatever your background, and it helps to talk woman-to-woman about my own area of specialisation: women's health. I was quite active as a student, and my mentees were members of some of the same College societies as me, including the Imperial College Medical Education Society, so we started off with plenty in common. After an initial face-to-face meeting, we keep in regular virtual touch via email and WhatsApp.

Q. What are the benefits – on both sides?
I give my mentees an insight into my everyday life as a GP, and also talk about what to expect if they choose a different career path, working in a hospital. As the relationship progresses it becomes more colleague to colleague, especially as I am quite close in age to my mentees. For me, it is a nice link back to Imperial. It's only five years since I left but so much has changed and there are so many new opportunities available to medical students. One of my mentees is currently on an exchange at the Lee Kong Chian School of Medicine in Singapore, so it's great to find out what she is getting up to!

DISRUPTOR / AIMEE MORGANS, PROFESSOR OF THERMOFLUIDS AT THE DEPARTMENT OF MECHANICAL ENGINEERING

"Fixing thermoacoustic instability could significantly reduce global emissions"

When Neil Armstrong, Buzz Aldrin and Michael Collins launched their Apollo 11 mission to the moon on 16 July 1969, it was the result of an extensive and hugely expensive testing programme. But that still didn't completely calm the nerves of the team watching them.

Among the many unknowns about this dangerous potential end to the Space Race was the well-known instability of the F-1 rockets that were powering the spacecraft – what was termed thermoacoustic instability caused by the complicated combustion process.

It's an instability issue that persists across engineering today, but which the work of my team is hoping to 'design out'.

Thermoacoustic instability is the inevitable result of unsteady combustion – a flame, for instance – meeting acoustic waves. It's always been difficult to solve because such instability is impossible to predict from a design on paper. The only way we can work out what will happen is to build full-scale working models. That is, unless we can find a method of designing out the instability at an earlier stage.

Our research is working to do just that. With the help of a €2m European Research Council grant, I and my team of three postdoctoral researchers and two PhD students are aiming to develop a way of computationally predicting thermoacoustic instability that is both fast and accurate enough to enable the instability to be designed out earlier than ever before.

Our work – the AFIRMATIVE project – uses a multi-scale treatment, combining mathematical models for the acoustic waves with simulations on super-computers to extract models for the unsteadiness of the flames. We then bring these together to work out whether the two-way interaction between the waves and the flame will result in instability.

As you'd expect, many other academics across the world are working to solve this. Our research is unique because we retain key-flow physics (such as the mean flow passing through the combustor) and are able to use this to improve the modelling of how acoustic waves pass through the combustor.

We are also able to capture the flame response faster than other approaches. This means we can, crucially, combine accuracy with computational efficiency in a way that is unique to Imperial researchers.

The project is not only hugely exciting, but enormously significant for a whole range of reasons. Most people accept that to ensure our planet's sustainability, we need to produce fewer emissions. We are certainly making further advances to achieve this than ever before, but even with a (mostly) universal political will, the actual science of reducing emissions continues to throw up immense challenges.

In my field of research, for instance, we have always faced a clear conundrum. Gas turbines, such as those used in aircraft and power stations, are essential for long-term energy, being flexible, fast and able to burn renewable-derived fuels. The downside, however, is that they produce nitrogen oxides (NOx) emissions, which cause air pollution.

The problem is that to reduce these emissions you need to operate at conditions that are highly vulnerable to thermoacoustic instability. So gas turbines can't further reduce NOx emissions without the damaging instability, and this is preventing further reductions in NOx emissions. The hope is that our work will break the chain, if you like, and create some viable options, with huge industrial and societal impact.

> **AFIRMATIVE aims to develop computational predictions that will design out thermoacoustic instability earlier than ever before**

Now that we are able to accurately forecast instability in lab combustors, we are extending our tools to industrial combustors. That gives us a very real chance of the gas turbines, and aeroplane engines of the future, being free of all instability – greatly reducing the NOx emissions and significantly improving the health of our planet. ◆

> ***Professor Aimee Morgans** aims to make energy generation and transport more environmentally friendly by modelling thermoacoustic instabilities in gas turbine combustors.*

INTERVIEW: PETER TAYLOR-WHIFFEN / PHOTOGRAPHY: IMPERIAL COLLEGE LONDON/THOMAS ANGUS

MY IMPERIAL

On the water

Mara Kont (MSc Public Health) says the Paddington canal basin is a hidden treasure.

Words: **Diane Shipley** / Photography: **Angela Moore**

I like to be surprised by places, and the Paddington canal basin never disappoints. It's a beautiful, relaxing place, but there's always something new going on and things to discover. During the FIFA World Cup, I watched some of the matches on the big screen outside. And I've just heard there's a weekly farmers' market. They don't really advertise these things, you tend to discover them by word of mouth. That might sound inconvenient when everything is usually online, but I like it.

I discovered the area when I was flat-hunting before I came to Imperial, and I've got lovely memories of coming here at lunchtime or after class with the friends I've made on my Master's, especially on sunny days when we could sit outside. It has a really lively atmosphere and makes such a change from being indoors like we normally are.

It's a quick walk from the St Mary's Hospital Campus, which is quite small and remote, so it's fantastic that we've built such a close community there, not just with the students but the staff as well. The friends I've met have made this year so special, and it's been the perfect place to escape from the daily coursework. We had a lot of classes together over the first two terms, so we would go there for lunch or after class. During the summer term, we mostly don't have classes but we still go there for lunch if we are on campus during the day or sometimes in the evening – it's a nice place to relax and catch up.

I was doing research at the World Health Organisation (WHO) archives in Geneva a few weeks ago, which was really interesting – my dissertation is about malaria elimination. I'm hoping to do a PhD next but, ultimately, I'd love to work somewhere like Médecins Sans Frontières or the WHO. Geneva is quite a quaint city, full of lovely places like the basin, but it's more of a surprise to find something like this in a bustling city like London. It's tucked away – more a winding path than a definite street – and not really that well known, but that's just how I like it! ◆

TEST YOUR BRAIN POWER

Fresh from regular slots on Radio 4's *Puzzle for Today*, Imperial's best minds set the ultimate puzzle challenge.

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1: HARD

Joe the milkman has a 4x6 rectangular crate that can hold 24 milk bottles, with each cavity being capable of holding a single bottle. He only has 18 bottles (and nothing better to do) so he is wondering how many ways he can put these in the crate so that each row and each column has an even number of bottles.

Dr Lynda White, Principal Teaching Fellow in Experimental Design, Department of Mathematics

2: VERY HARD

A maths professor of my acquaintance has noticed that the long number N on her credit card has ten digits. The first digit of N is the number of zeros in N, the second digit is the number of ones, the third digit is the number of twos, and so on until the last digit is the number of nines in N. wWhat is her credit card number?

Dr Lynda White, Department of Mathematics

3: FIENDISH

Aluna, Bruce and Cora each have a different positive whole number written on their head, and can see the numbers on the other two people. They are told that one of the numbers is the sum of the other two. Without prior communication, the following truthful statements are made. Aluna: "I don't know what number is on my head." Bruce: "I don't know what number is on my head." Cora: "I don't know what number is on my head." Aluna: "My number is 50." What are the three numbers on their heads?

Melissa Lee, Research Postgraduate, Department of Mathematics

HOW TO ENTER:

Senders of the first ten correct solutions for two or more of the puzzles will receive a copy of the *Today Programme Puzzle Book*, featuring 280 cryptic, linguistic and numerical brainteasers from Dr Lynda White, other Imperial researchers, and contributors from around the world. Solutions and winners will be printed in *Imperial* 46 in May 2019, and online at www.imperial.ac.uk/be-inspired/magazine from January 2019.

THE WINNERS AND ANSWERS FROM ISSUE 44:

Congratulations to the first ten respondents who contacted us with two or more correct solutions from the previous issue:

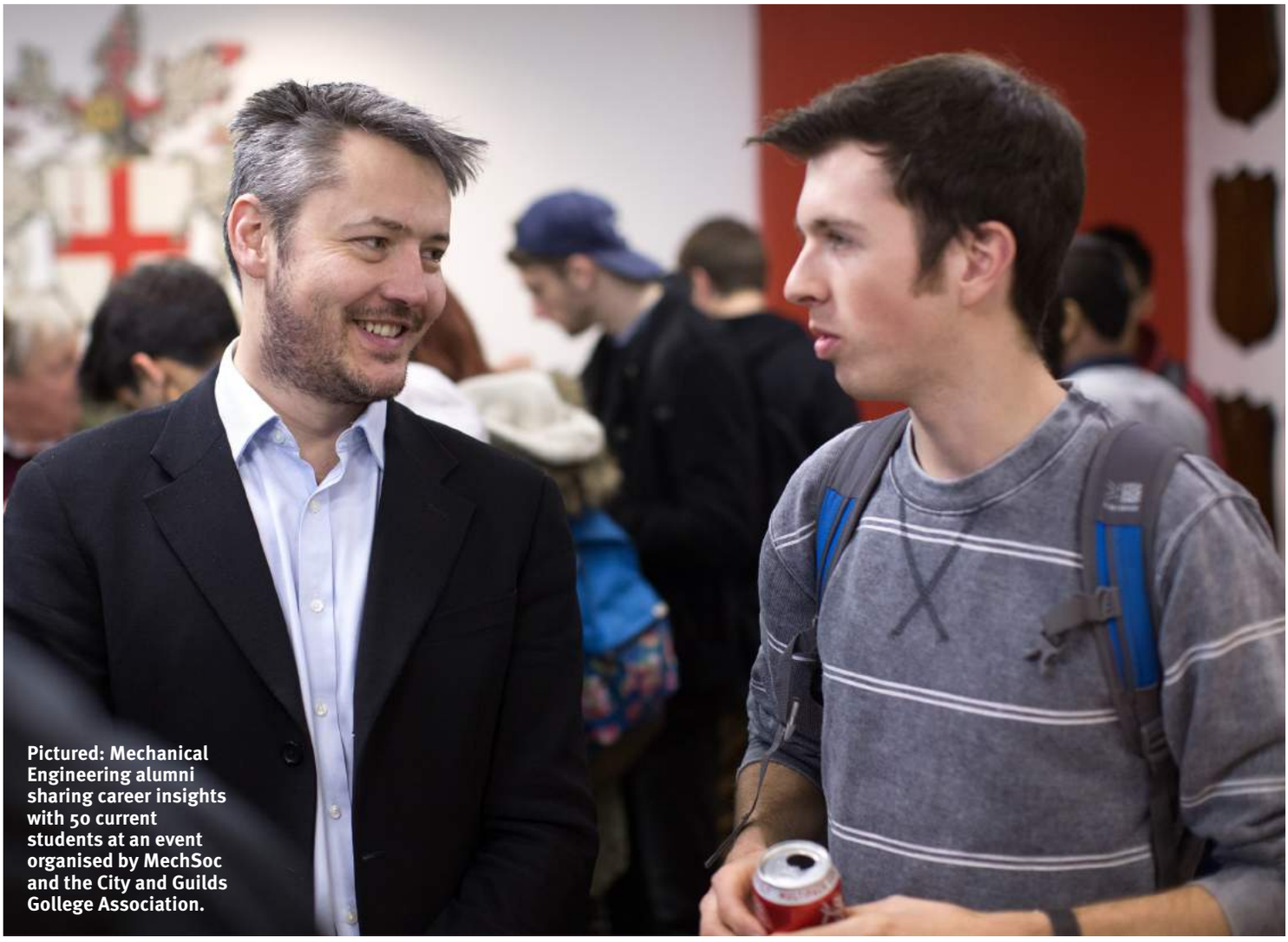
Caterina Buizza *(MSci Mathematics 2015)*
Hugh Strafford *(Wye College 1979)*
Nick Andell *(Physics 1995)*
Martin Marriott *(MSc Civil Engineering 1981)*
Paul Rowland *(Electrical Engineering 1991)*
Bob Thomas *(MSc Mineral Resources Engineering 1992)*
Peter Webb *(Chemistry 1968)*
Devendra Patel *(Charing Cross and Westminster Medical School 1994)*

1: HARD: However you break the chocolate, you will take 11 cuts to separate it because at each stage you increase the number of pieces of chocolate (which may consist of more than one square) by one until they are all separated.

2: VERY HARD: There may be any number of soldiers of the form 58+105k, where k is an integer greater than or equal to zero (eg, the first few valid answers are 58, 163, 268 and 373).

3: FIENDISH: There are infinitely many primes, even though the fraction becomes tiny for larger numbers. The simplest way to see that there is no largest prime number is to assume that this is the case and then show that this leads to a contradiction. If you multiply all the prime numbers, from two up to the hypothetical largest prime, and then add one to this product, you'll have found a number that is not divisible by any of this list of primes. But that means that it must be a prime number itself; as it is clearly larger than the hypothetical largest prime that hypothesis is contradicted. So, there must be infinitely many primes. (Not that large primes are easy to find: there was a press release in late 2017 when researchers found 2^77,232,917; one, a number with 23,249,425 digits, was shown to be a prime.)

ILLUSTRATIONS: MIKE LEMANSKI.



Pictured: Mechanical Engineering alumni sharing career insights with 50 current students at an event organised by MechSoc and the City and Guilds Gollege Association.

What can you do?

IN LONDON, THE UK AND AROUND THE WORLD, ALUMNI VOLUNTEERS ENHANCE THE IMPERIAL EXPERIENCE FOR ALL.

More than 1,000 dedicated alumni volunteers enrich our global community. An increasing number of you are choosing to give your time and energy to support Imperial – an effort which has an impact on current students, the alumni community and the College.

As volunteers, alumni help shape the student experience from the very start, providing expertise, inspiration and advice to current and future Imperial students. Alumni support students as mentors, speakers and champions for diversity, and offer career advice, work placements and, often most importantly, a reassuring voice of experience.

Once you graduate, the benefits continue: alumni volunteers support the broader alumni community by leading our professional networks and dynamic global groups. They organise events, reach out to new members and foster a sense of community. And as they give back, they also benefit: volunteers learn new skills, enhance their CVs and meet new people who, in turn, inspire their fellow alumni.

- Ask an Alumnus career advice scheme
- Alumni Mentoring Scheme
- Champions for neurodiversity in STEM
- Career champions
- International student recruitment ambassadors
- Speakers and panellists
- Event hosts and group coordinators

Read about the impact volunteering for Imperial has had on three alumni on page 45, or to find out more, visit: www.imperial.ac.uk/alumni/volunteer