Imperial/43

PHOTOSYNTHESIS

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Imperial/43

THE MAGAZINE FOR THE IMPERIAL COMMUNITY

WINTER 2017/18

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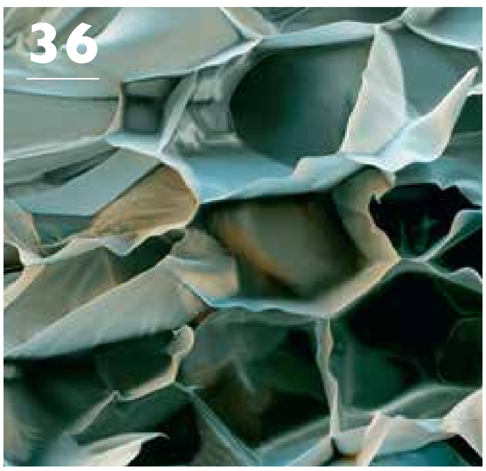
Features



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Letters

WRITE TO US

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

Interesting and varied

Your article about the student relay race (*Imperial 42*) brought back memories of my time with Imperial's Cross Country Club, while studying at RSM in the early 1960s. Even then Loughborough was the team to beat! Your article mentioned some famous names – one to add is an Australian freshman at Cambridge by the name of Herb Elliot, probably the world's greatest middle distance runner of his era. He participated in the 1961 relay, having destroyed the opposition in the 1,500 metres at the Rome Olympics the previous year; he gave up competitive athletics in 1962.
Richard Burt
(Mining 1963)

Thank you for another interesting issue of *Imperial*. I must say it's still good to have solid paper to read in a comfortable armchair rather than sitting up in front of a screen. And the varied contents make good reading.
Alec Hester
(Physics 1949, 1952)

As a 1971 Physics alumnus, I continue to receive the magazine. Although I can't say I feel a close connection to Imperial any more, I did appreciate Issue 42 – both the attractive presentation and, in particular, the articles on Blockchain, the brain and the Standard Model 3.0. Well done!
Viktor Steiner
(Physics 1971, 1974)

I am at a loss to understand why the In Memoriam pages have been omitted from the new *Imperial* magazine. While I know a lot of alumni have been enjoying the new format and the articles in it, it seems to me that it now gives no information about what might be happening to (or have happened to) those known to us many years ago.
Christopher Lumb
(Electrical Engineering 1961)

Thank you to those who have written to express concern about the decision to remove the In Memoriam pages from the magazine. We are continually reviewing the content of Imperial *magazine, and we will take your views into consideration. In the meantime, we continue to publish obituaries online: please visit www.imperial.ac.uk/alumni. We also welcome updates and news from alumni and we are happy to share these widely with the community.*

Chemistry memories

I have so many fond memories of Imperial from my earliest days as an 18 year old Chemistry fresher in October 1950: many rewarding analytical chemistry sessions under LS Theobald; postgraduate research on mixed metal oxides under AJE Welch; cricket at Harlington; lubrication at '22 Club' meetings; and mixing with chaps from other disciplines – there were only about 3,000 undergraduates then, three of whom were women, who largely kept a low profile.
John Ault
(Chemistry 1953, PhD 1955)

Erratum

In Issue 42's profile of Professor Joanna Morgan's work at the Chicxulub crater, we referred to the three domains of life as bacteria, ucerota and arcaea. John Barnes (Agriculture 1956) wrote to point out that two of the terms were unfamiliar to him – they were in fact spelled incorrectly and should have been eukaryote and archaea.
We apologise for this mistake.

More from the mailbag

We are delighted many of you followed John Ault's lead (left) in sharing your Chemistry memories with us.

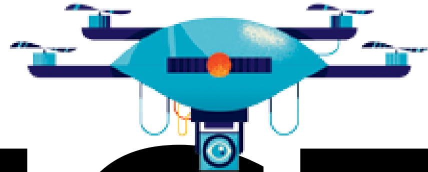
Peter Dayton (Chemistry 1953), reminds us that when he joined in 1950, rationing still applied for special chemistry, so students were never far from their jar of Sucrose Analar, which they used to sweeten their tea. "Later, with sugar available, I was informed that some who actually had to use sucrose in experiments preferred to use Tate & Lyle granulated as it was much more convenient," he writes.

Professor Tony Wickham (Chemistry 1968) recalls the accidental origins of his first published paper on vibrational spectroscopy – partly the result of a timely mug of tea and a slip up in Bill Griffith's lab.

And Vernon Parker (Chemistry 1960) shared wonderful memories of his three years spent at the Royal College of Science. Academic highlights included studying under three professors (Wilkinson, Barrer and Barton) who would later go on to be awarded Nobel Prizes for Chemistry, but there was plenty of time, it seems, to enjoy Wednesday afternoons (and evenings) with the College 1st XV rugby team, and a couple of light-hearted run-ins with mascot cars and steamrollers.

To read these memories – and more – in full, please visit www.imperial.ac.uk/be-inspired/magazine.

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



DIGEST

GIFT

Next generation drones get new arena

Imperial's new testing ground for the next generation of aerial robotics puts the UK at the forefront of a billion dollar industry, says its new director.

Speaking at the opening of the Brahmal Vasudevan Multi Terrain Aerial Robotics Arena, Dr Mirko Kovac said the applications are endless. "We see aerial robotics as a way to improve all our lives," he said.

The researchers in the Arena can simulate different terrains in the air, the ocean and on land, and create extreme conditions to mimic how the next generation of drones will perform in harsh environments.

The development of the Arena is thanks to a £1.25m gift from Brahmal Vasudevan (Aeronautics 1990), who flies drones as a hobby.

"I was very excited to hear from Dr Kovac how drones could have a positive impact on the environment, industry and our way of life," said Vasudevan. "Now our shared vision is a reality and it is great to see the Arena open for research, teaching and industrial development."

The applications are endless – we see aerial robotics as a way to improve all our lives

The Brahmal Vasudevan Multi Terrain Aerial Robotics Arena at Imperial is testing the use of drones in areas as diverse as extreme weather, water sample collection and 3D printing.

ILLUSTRATIONS: THIS PAGE: ADAM AVERY. OPPOSITE PAGE: MIKE LEMANSKI

FROM THE PRESIDENT / PROFESSOR ALICE GAST

We must achieve enduring excellence in research and education, and use that for the good of society.

Our mission at Imperial is to achieve enduring excellence in research and education in science, engineering, medicine and business for the benefit of society. Our mission is more than an aspiration. It is what guides us in all that we do.

Imperial magazine provides a glimpse of some of the ways that the Imperial community of staff, students and alumni fulfil this mission to benefit society. They do this in a variety of ways and in a wide range of places.

In this issue, for example, we learn how research in synthetic biology helps pave the way for new drugs and new materials. We see how in Liberia, and back in the UK, Imperial scientists and alumni responded to the Ebola epidemic. We are impressed that two of our recent graduates started a company that could revolutionise the building industry. We are thankful that the work of an Imperial team in Borneo may help save rainforests. We are excited about the power of our Imperial 'hackspaces' to unleash curiosity.

These are but a few examples of how every day – both on campus and throughout the world – Imperial uses our excellence in research and education in science, engineering, medicine and business for the good of society.

In addition to excellence, it is our commitment to collaboration, patience and sharing that helps us achieve great things. These four attributes are the characteristics of a great university in changing times.

Society's demands on universities have never been greater. The opportunities for Imperial staff, students and alumni to contribute abound. We are fortunate to be a part of a great university that can meet society's demands.

Yet, as good as we feel about our work and our association with Imperial, we also know that there is a divide between those who believe that research and teaching brings great value to society and those who feel that they have been left behind and are not reaping the benefits of investment in higher education.

We live and work in a time when universities are viewed by some as part of the problem rather than a source of solutions. Some think that universities are elite institutions that are not relevant to them.

> We look beyond the immediate to advance the frontiers of knowledge

Collaborating with others to improve the world is one of the characteristics of a great university, and it is more important than ever. We need to share our innovations and discoveries more broadly and in ways we have not shared them before. We must continue to address global issues while paying increased attention to the ways these issues are manifest close to home in our neighbouring communities.

Our new campus at White City provides us with an opportunity to do this. In late October, Imperial welcomed our neighbours in the White City community to the opening of The Invention Rooms, the first facility of its kind in the UK. It provides workshops and interactive spaces called 'maker spaces' and 'hackspaces' that give community members of all ages a place to come together to work personally and directly with our staff, students, alumni and partners to test out their creative ideas, and share in the excitement of research and innovation.

The opening of The Invention Rooms is an important beginning to a strong, respectful and lasting relationship between Imperial and our neighbours in White City. We will benefit from one another's presence.

Imperial and other great research universities educate tomorrow's leaders, provide solutions to pressing problems, and look beyond the immediate to advance the frontiers of knowledge.

Imperial will continue to rise to the challenge of the times. It is a challenge that requires the collective expertise, strengths and goodwill of the worldwide Imperial community. We are very grateful for your support and encouragement.

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

PHOTOGRAPHY: IMPERIAL COLLEGE LONDON/THOMAS ANGUS

CASSINI MISSION

Last data received

After 13 years capturing unique images and data from Saturn and its environment, the Cassini spacecraft mission has come to an end. Some of the last data received was from Cassini's magnetometer instrument, which was built and is led by a team from the Department of Physics at Imperial.

One highlight of the mission was the magnetometer's role in discovering an atmosphere at the moon Enceladus. A surprise 'bending' of Saturn's magnetic field around Enceladus spurred Principal Investigator for Cassini's magnetometer Professor Michele Dougherty to suggest they fly closer to the moon on the next pass, where a strange atmosphere was detected, produced by jets of water escaping the icy surface. Enceladus now represents one of the best prospects for finding life in the solar system.

> *To find out more about the Cassini mission, visit NASA's dedicated website at https://saturn.jpl.nasa.gov.*

PHOTOGRAPH: NASA/JPL-CALTECH

OVERHEARD ON CAMPUS

Martian mudstones n: *Sedimentary rocks discovered on the surface of Mars, obtained by the Curiosity Rover, the first on-the-ground evidence that there was once sustained river flow.*

Diatoms n: *Pinhead-sized algae that play a uniquely important role in our oceans, producing a quarter of our planet's oxygen and absorbing zinc from seawater.*

Closthioamide n: *The antibiotic that has, for the first time, successfully treated lab samples of gonorrhoea, a previously untreatable antibiotic-resistant infectious disease.*

Immunomodulation n: *An adjustment of the immune system – currently the focus of research by the National Heart and Lung Institute's Dr Susanne Sattler on improving regenerative therapies after a heart attack.*

42

According to *The Hitchhiker's Guide to the Galaxy*, 42 is the answer. But what is the question? Professor Roy Taylor muses on the future of fibre lasers.

Thanks to a rise in laser pointer attacks on planes and helicopters, the humble laser has been getting a bad press of late. But don't be fooled. Lasers, and specifically fibre lasers, underpin a whole range of essential technology. Indeed, for Roy Taylor, Professor of Ultrafast Physics and Technology, the question is just how far fibre lasers can go in transforming our lives.

"Even up until 20 years ago, lasers were quite primitive," says Professor Taylor. "Technological advances in semiconductor pump lasers and in innovative fibre designs over the past 20 years have helped make the fibre laser break into areas such as welding, materials process, medicine and defence. Fibre lasers are compact, more stable, with a higher beam quality, getting ever-more powerful and are very efficient and easy to cool. The applications of greatest influence are in industrial processing such as cutting, welding and manipulation of metals and polymers, where laser fibres are having a truly transformative impact."

Taylor established the first Femtosecond Optics group at Imperial. Rather than focusing on power scaling, where it was impossible to compete with commercial development, the group looked at the generation and application of supershort pulses and femtosecond lasers , which emit optical pulses with a very short duration. It is a technology that underpins many recent developments in medicine and engineering.

As to the future, fibre lasers have potential in a wide variety of areas, from counteracting chemical attacks and monitoring gas content in underground systems to advancing disease diagnostics in developing countries. Taylor predicts that "everything ultimately will be done by semiconductor lasers".

In May, Professor Taylor was elected a Fellow of the Royal Society for his work on laser systems and their application.

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IMPERATIVE / PROFESSOR FRANCO SASSI

I wish my children ate fewer treats – but not all government intervention works.

I know from my own personal experience just how difficult it is to keep your family eating healthily – I have three children aged seven, nine and 13, and it's a constant struggle to keep them away from sugary snacks and drinks. But I'm not the only one to wish that my children ate fewer treats – government is also keen to encourage us all to eat more healthily both for our own good and to reduce the burden on our health service. The interesting question for researchers such as myself at the Centre for Health Economics and Policy Innovation is finding out what actually works.

We know, for example, that taxes – such as the 'soda tax' of one peso per litre on sugar-sweetened beverages introduced by the Mexican government in 2014 – can indeed be effective. (Research has found a six per cent reduction in the consumption of sugary drinks in Mexico in the first year.) But taxes cannot be seen as a magic bullet in the fight against obesity.

The single most important contribution taxes can make is in sending a message to both consumers and the entire food system. The landscape is changing – only 10 years ago you couldn't even talk about taxing food for improving health. But taxes are not simple tools, and designing them to engineer an improvement in people's diets is especially complex.

My team and I create advanced computer simulation models to demonstrate the impacts of public policy on human health. If you introduce a sugar tax, as the UK government is currently considering, you first need to be able to demonstrate to policy makers the likely results. There is a danger the models we economists work on are seen as simply black boxes – the policy makers don't understand what goes in and what comes out. It's my challenge to make our very complex research models, whether it be on the economics of obesity or the widespread effects of harmful alcohol abuse, relevant.

The work of my team was instrumental in supporting the development of Mexico's anti-obesity strategy, today one of the best examples worldwide.

Our model predicted that Mexico would have gained more than 1.3 million life years in good health from a similar strategy in 20 years. (We also predicted that England would gain more than 1.7 million life years in good health, despite having a much smaller population than Mexico.)

When it comes to chronic diseases linked to behaviours such as poor diet, lack of physical exercise, smoking and the abuse of alcohol, 'epidemic' is not too strong a word.

The important difference between this epidemic and those caused by infectious diseases is that chronic diseases spread through social transmission networks. Which is something governments, with the help of economists, can do something about – provided they have the will. Our predictions can help.

At the Centre we have an explicit goal of influencing government policy. If your behaviour only affects your own wellbeing, there is very little that governments can do, other than make sure you understand the consequences of your choices. But if others share the consequences of your choices, or your unhealthy habits are passed on, then governments can, and should, intervene further. To do so effectively, they first need to understand patterns of behaviour and how they can be changed.

> Many people's perception of what is good or bad for you is entirely misguided

Our behaviour is only to an extent down to individual choice. We are all affected by the behaviour of those around us and by the environment in which we live, and that is particularly true when it comes to children.

Many people's perception of what is actually good or bad for you is entirely misguided, which is not surprising given the mixed and often conflicting messages they receive from various sources.

It's my team's task, through our economic models, to show policy-makers the ways governments can help reduce the burden.

Franco Sassi *is Professor of International Policy and Economics at the Centre for Health Economics and Policy Innovation, part of Imperial College Business School.*

The Imperial alumni network, stronger than ever

The Imperial global network has never been stronger. Over the past year, almost 6,000 of you have registered for one or more of our 260 events or joined one of our 35 recognised alumni associations, geographic groups and professional interest networks.

That success comes as no surprise: when Imperial alumni come together, ideas, contacts and innovation abound – alongside a wonderful keenness in the community to help other alumni and the College, with more than 1,300 of you volunteering this year alone.

A perfect example of that spirit of shared community has been in evidence in south-east Asia recently. In Singapore in September, more than 300 alumni and friends gathered to celebrate 40 years of the Imperial College Alumni Association of Singapore (ICAAS), which was founded in 1977 by Professor Phua Kok Khoo (DIC Physics 1967).

As Jayson Goh (Electrical and Electronic Engineering 1998), current President of ICAAS, points out, the Association provides a vital connection between graduates and the College. "ICAAS continues to be the link between Imperial and our many graduates who are pushing the innovation frontiers."

Across the South China Sea, in Hong Kong, the Imperial College Alumni Association of Hong Kong (ICAAHK) held a special gala with President Alice Gast for more than 150 alumni. The October gathering put collaboration and innovation centre stage, with speakers including Dr Paulina Chan (PhD Electrical and Electronic Engineering 1977), champion of ICAAHK's mentoring programme, Professor Maggie Dallman, Imperial's Associate Provost (Academic Partnerships) Susannah Morley, Director of Programmes and Partnerships at the British Council, Michael Kwok (Civil Engineering 1984), chair of Arup East Asia and Dr Paul Cheung (Electrical Engineering 1973, PhD 1978), a biomedical engineer and computing professor at the University of Hong Kong.

There are myriad ways to benefit from your lifelong Imperial connection – participate and get involved.

> *To find out how, visit the alumni website www.imperial.ac.uk/alumni or get in touch with us via alumni@imperial.ac.uk.*

THE NETWORK IN NUMBERS

35
Alumni associations around the world

Statistics: 2016/17

1,373
Alumni volunteers

5,989
Alumni registered for events

13
Alumni and friends receptions with President Alice Gast

39
International events with academics or speakers

260
Alumni events

IN BRIEF

The James and Gloria Borley Memorial Scholarship fund will be used to offer an annual PhD scholarship to researchers in neurological research at Imperial's Division of Brain Sciences.

Chen Jining (PhD Civil Engineering 1993) who has served as China's Minister of Environmental Protection and Mayor of Beijing, was elected to the 19th Central Committee of the Communist Party of China in October.

ThinAir, the brainchild of four Imperial undergraduates, has been crowned Enterprise Nation's first ever Student Start-up of the Year for its water-condensing biomembrane to provide clean water.

Three new Deans have been announced: Professor Francisco Veloso is Dean of Imperial College Business School; Professor Nigel Brandon is Dean of the Faculty of Engineering; and Professor Jonathan Weber is Acting Dean of the Faculty of Medicine.

A new study on obesity from Imperial and the World Health Organisation (WHO) suggests the world will have more obese children and adolescents than those classified as underweight by 2022.

COMMUNITY
Invention open day

The Invention Rooms at Imperial's White City Campus opened its doors to the community for an open day in October.

The new space, the first of its kind in the UK, brings the local community together with Imperial academics, students, alumni and partners to test out creative ideas, build real prototypes and share in the fun of making and discovery.

> *Visit www.imperial.ac.uk/the-invention-rooms to find out more.*

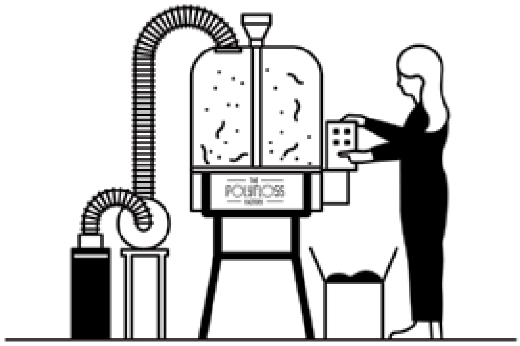
MEDICINE
LKCMedicine opens its doors

A state-of-the-art new medical school has opened in Singapore, a partnership between Imperial and Nanyang Technology University (NTU).

The Lee Kong Chian School of Medicine (LKCMedicine) welcomed its first students in 2013, but with the completion of the School's brand new 20-storey Clinical Sciences Building, will admit 120 students a year. The first cohort of fully qualified doctors is due to graduate in 2018.

Speaking at the opening ceremony, Professor Alice Gast said: "Our collaboration has generated innovative teaching approaches that provide a rich source of improvements to medical education in Singapore, the UK and beyond."

PHOTOGRAPHS: LKC SCHOOL OF MEDICINE. DANNY FITZPATRICK. ILLUSTRATION: MIKE LEMANSKI



Test tube

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

WHO Audrey Gaulard (MSc Innovation Design Engineering 2012).

WHAT The Polyfloss Factory processes plastic waste on a local scale to give it a new life. Along with co-founders Nick Paget, Christophe Machet and Emile De Visscher (all MSc Innovation Design Engineering 2012), we came up with a machine that transforms waste plastic into a floss-like fibre material with multiple and varying uses.

HOW We use a rotating oven with holes in the walls to spin the plastic. When the material is molten we use centrifugal force to create fibres similar to candyfloss, but made out of plastic. We think it's the first time that plastic has been used as a craft material rather than in industrial factory terms.

INSPIRATION The humble candyfloss machine was our inspiration. For our final project at Imperial we were very inspired by the history of the Industrial Revolution in England. We always had a playful approach to our design, and the result was our machine.

MOTIVATION We are focused on sustainability and climate change, and an amazing opportunity came in the form of a call from Andrew Lamb, the Innovation Manager at Field Ready, a humanitarian supplies organisation. He had seen our machine and wanted us to take it to refugee camps to create insulation for emergency shelters.

THE FUTURE We are at the beginning of the process of taking our equipment into refugee camps and creating an on-site micro industry – the first machine has arrived in Kathmandu and it worked well. We hope to teach people how to create their own insulation to improve their shelters.

> ***Audrey Gaulard** is co-founder of The Polyfloss Factory (thepolyflossfactory.com). She is also a senior tutor and Advanced Hackspace Fellow at Imperial.*

SOCIETY

En garde!

Imperial's Fencing Club is successful – and sociable. *Imperial* met the team.

Ella Rice (fourth year MSci Chemistry) admits that "fencing is not necessarily the coolest sport". But who cares about being cool when you captain Imperial's officially most successful club (in terms of BUCS points)?

With two women's teams and three men's, the Fencing Club is competitive as well as social. Rice and her teammate, Ailsa Morrison (third year Chemical Engineering) both took up the sport at a young age (aged eight and 11 respectively) and fenced at national level before coming to Imperial. Morrison enjoys the fact that men and women fence at an equal level, meaning that everybody trains together – but she concedes it is "sometimes difficult if my opponent is twice my height".

Both use a foil as their weapon of choice, but the club offers beginners training sessions with all three types of sword: foil (the most common); épée (heavier and stiffer); and sabre (the edge of which can be used to slash and score points – "think Zorro," says Rice).

These days the tips are electrified but, according to club secretary Ben Fry (third year PhD Mechanical Engineering), "we often break our swords in the process of scoring".

Rice has even shed the odd tear when she loses. "Fencing is a very emotional sport. You are looking your opponent right in the eye as you lunge and parry."

Happily, however, instead of a fight to the death, these days a bout is more likely to be followed up with a friendly race to the nearest café or bar.

PHOTOGRAPHY: JOE MCGORTY.
ILLUSTRATION: MIKE LEMANSKI

A working life

The international conductor Daniel Capps says his passports – and his composure – are key to daily life.

Many people might think the one thing I need to do my job is a baton. But I can easily conduct without a stick – and some conductors prefer to do so. So the one essential ingredient to make my life possible is my passport.

I have two, as one is always in an embassy awaiting a visa. For six months of the year I am based in New York City, the rest of the time London is home. One time my passport was stuck at the American Embassy for nearly three weeks due to a technical glitch. The organisers of the festival I was booked to work at were desperate; there weren't many other conductors who were familiar with the repertoire. Luckily, my passport was released 24 hours before my flight.

One of my most memorable experiences was in Cuba, where I travelled in 2009 with the Royal Ballet, the first foreign company to visit for a long time. Ballet is as popular there as football and one of the principal dancers, Carlos Acosta, is Cuban, so the crowds outside the Grand Theatre in Havana were enormous. Afterwards, I had to travel to the US. Thankfully, although I work a lot in the US, I am not actually American so I didn't have to worry about the Cuban stamps in my passport.

I travel a lot, although not as much as some of my peers. Most of the works I conduct are productions involving a stage and a fixed set, so tend to be a series of performances rather than a one-off concert. But I still spend a lot of time on planes and trains. I enjoy the peace of travelling as well as the privilege of being paid to go to extraordinary places. No phone, no email – I dread W-iFi on planes. Nowadays, though, I often travel with my two small children so it is less tranquil than it once was!

My passport is the only thing I really check on before I leave the house, apart from my wallet, and I have three of those. I also take my composure with me. I need my passport to get to my job but without my composure I'd be largely useless when I get there. The orchestra is playing a feeling that I transmit, and I need to be in a state of calm to do that. It's pressured, but an incredible privilege.

Daniel Capps (Physics 1996) is Resident Conductor at the Lincoln Center, home of New York City Ballet. He is also Music Director of the University of London Symphony Orchestra, London Mahler Orchestra and the Sirius Ensemble. During his time at Imperial and the Royal College of Music, he founded and conducted the Imperial College Sinfonietta.

Game changer

PHOTOSYNTHESIS UNDERPINS ALL LIFE ON EARTH, BUT UNTIL NOW LITTLE WAS KNOWN ABOUT HOW IT ACTUALLY WORKS.

Words: **Becky Allen** Photography: **Victoria Ling** Styling: **Vicky Lees**

Flabbergasted. That's how Bill Rutherford, Professor of Biochemistry of Solar Energy at Imperial, feels when he looks at all the "amazing stuff" going on in photosynthesis research. "One of the main things I find amazing, having worked my whole career on this, is that I'm floored every year by new things that come up which you'd never have predicted," he says. Some 40 years on from his PhD, he still uses words like "fun", "beautiful" and "joy" to describe his research.

Rutherford has spent the past four decades teasing apart photosystem II, the water-splitting enzyme that – despite its prosaic name – is key to photosynthesis and to life itself. "This enzyme changed the whole planet," he explains. "Before photosystem II, there was no oxygen on the planet, life was unicellular. Hard UV was coming in, so life was lived under rocks and energy was in short supply."

The evolution of photosystem II was a game changer. Able to rip water apart to harvest the energy in its electrons, it put oxygen into the atmosphere, forming the ozone layer that shielded living things from harmful UV. It also meant respiration could occur, a far more energy efficient process than anything that had gone before, allowing multicellular organisms to evolve. "This one enzyme is key to all that," says Rutherford. "It's the reason this planet is the way it is."

At its heart, photosynthesis explores the way chlorophyll captures energy from the sun to turn carbon dioxide and water into glucose and oxygen. Except of course it's more complicated than that; so complicated, in fact, that at the beginning of the 21st century there is much about photosynthesis that we still don't understand.

Thankfully, however, some of the finest minds are working hard to crack the code. Greater understanding of the process could help us discover and harness new sources of energy, create new types of fuel and feed our growing population. This is dynamic science that will make a very real difference.

Rutherford and other colleagues at Imperial – including Emeritus Professor James Barber and Professor So Iwata, who in 2004 obtained the first refined crystal structure of ▶

Left: Under Professor Peter Nixon at the Department of Life Sciences, students such as Joshua Osayemi (Biochemistry 2017) are involved in world-leading research, using cyanobacteria on an agar plate to study the effects of drought and high light on photosynthesis.

photosystem II – have been central to advancing our understanding of photosynthesis. And like Rutherford, Professor Jasper van Thor is also interested in the initial stage of photosynthesis – the so-called light reaction. "What I find fascinating is the astonishing efficiency of the light reactions – they're at least 90 per cent efficient, that's almost a miracle," he says.

Until recently, however, there were two possible theoretical explanations of the very fast physics involved, but researchers lacked the experimental tools to prove which was correct. "A photosynthetic machine is hugely complex. If we strip down the core of just one of the reaction centres – photosystem II core complexes – it still has 74 different chlorophyll pigments and each is differently positioned," van Thor explains. "It's also really fast – we're talking femtoseconds to nanoseconds – but we recently revealed dynamical images of the process by developing a new experimental method.

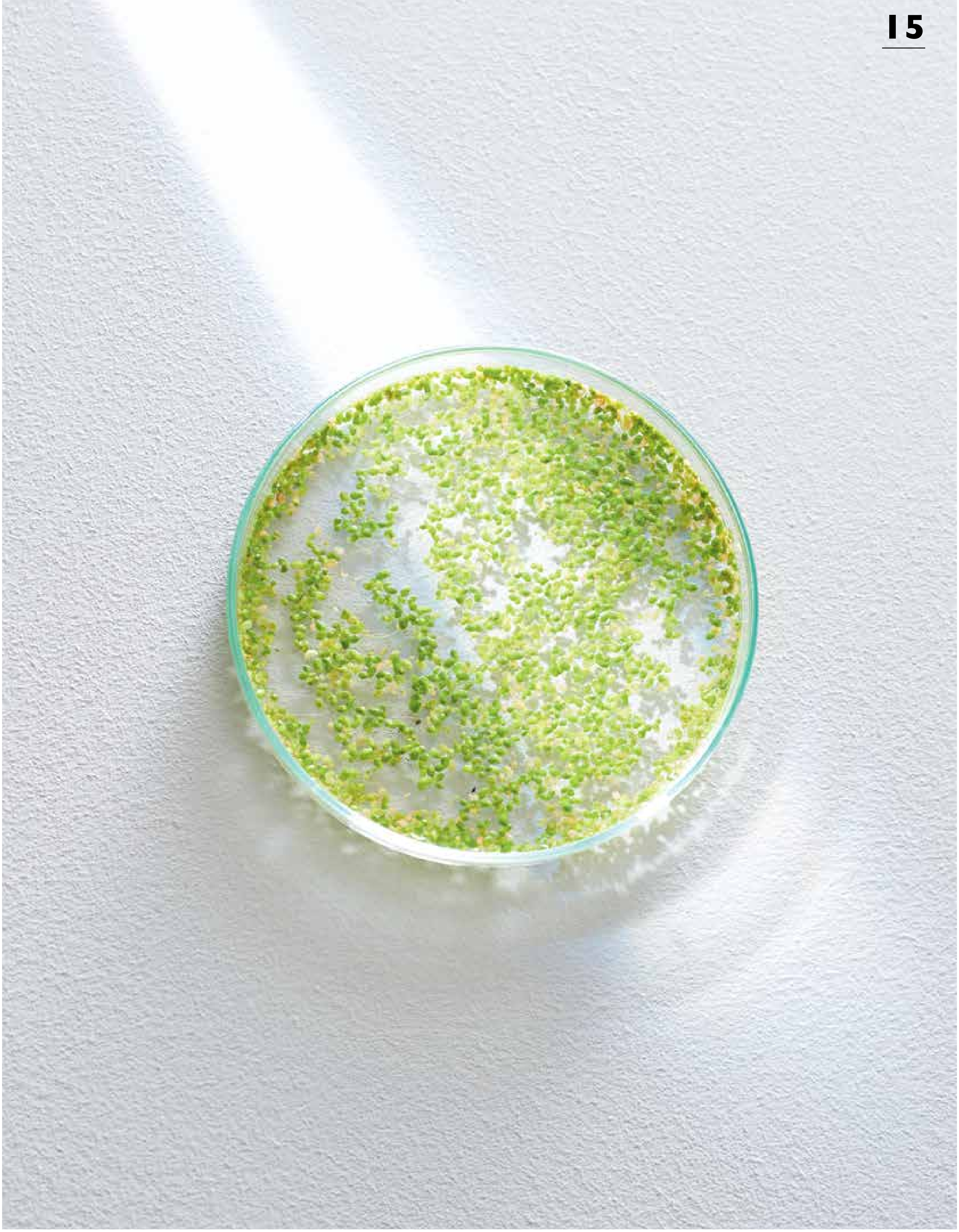
THE METHOD INVOLVES FIRING SHORT PULSES OF LASER LIGHT AT CRYSTALS OF PHOTOSYSTEM II, PURIFIED FROM SYNECHOCOCCUS ELONGATUS, THE BLUE-GREEN ALGAE HE GROWS IN THE LAB

"Using these methods we can make a movie of the reaction so that we can see what's happening in time and space," he says. "It's this new ability to watch where the energy flows that bridges the gap between the static picture and first principles theory."

For van Thor, it's pushing the boundaries of science, rather than their immediate applications, that matter most. "That's my first motivation. We do science that does not yet exist and by generating more detailed understanding this provides new methods. It's fundamental science," he says. "But looking at the fundamental physics of how energy is developing on very fast timescales could lead to applications that we can't even imagine today."

Elsewhere at Imperial, researchers are looking at other parts of photosynthesis to address critically important global challenges. A physical chemist who began her career using lasers to study photosynthesis, Dr Laura Barter is trying to find ways of making photosynthesis more efficient to increase crop yield. "I'm very aware how rapidly the population is expanding, and how we need to provide food, fuel and fibre for that population. Enhancing photosynthesis is one potential way of addressing that challenge," she says. ▶

Right: At the Department of Life Sciences, Professor Jasper van Thor fires laser light at crystals of photosystem II, purified from lab-grown algae. He is investigating the initial stage of photosynthesis – the 'light reaction' – which happens at astonishing speed and efficiency.



Barter's work focuses on the dark reaction or Calvin cycle, the part of photosynthesis that builds food in the form of sugars and where – unlike the super efficient photosystem II – there is plenty of room for improvement. "A network of enzymes makes organic carbon from carbon dioxide in the air and these reactions are strikingly inefficient," she explains. "Typically, only one to two per cent of the sun's energy is converted into biomass, so I got interested in where those inefficiencies lie, and one culprit is an enzyme called RuBisCO, which is really lousy."

Part of what makes RuBisCO such a lousy enzyme is its chemical promiscuity; it reacts with both oxygen and carbon dioxide. So Barter thinks that by increasing local concentrations of carbon dioxide, RuBisCO will work better, in turn boosting crop yield. "To do that I'm guided by nature," she says. "I'm looking at other enzymes that can help."

STUDIES HAVE ALREADY SHOWN THAT YOU CAN INCREASE YIELD BY GROWING PLANTS UNDER GLASS WITH HIGH CARBON DIOXIDE LEVELS – BUT BARTER THINKS THERE IS A SIMPLER WAY OF ACHIEVING THE SAME END

Working with synthetic chemists, she's making a suite of catalysts that mimic the way carbonic anhydrase works and looking at their impact on crop yield. She is also working with another group on the rules that govern how substances move across plant membranes, so that once they find the best catalysts, they can deliver them to the right place in the plant.

Improving photosynthesis to boost crop yield, however, is only one possible benefit of better understanding this process. James Durrant, Professor of Photochemistry, is trying to learn from nature to develop artificial photosynthesis – chemical systems that use sunlight to make molecules that, rather than meeting plants' energy needs, produce the alternative energy sources we urgently require.

His work addresses three key challenges: "Firstly, while we are now making progress in decarbonising electrical energy generation, we lack a scalable pathway to sustainable fuels. Secondly, our transition to more renewable electrical power generation means we need to store energy, and the most energy-dense way of doing that is in chemical bonds. We have solar cells, but when the light goes, so does the power. If we could make fuels during the day and ▶

Left: Dr Laura Barter, at the Department of Chemistry, is working with synthetic chemists to make a suite of catalysts that mimic the way carbonic anhydrase works and improve crop yields. Her aim is to simplify the process of growing plants under glass and improve efficiency.

turn them back into electricity at night, that would solve the problem. Thirdly, we're emitting too much carbon dioxide. If we could synthesise fuels out of carbon dioxide, this would be a great way to create a market for it."

But doing artificially what plants do naturally is, of course, hard. "The chemistry of making fuels is complicated, even producing hydrogen and oxygen from water," Durrant explains. "So it's really challenging chemistry and the catalysis is hard. Often if you try and oxidise or reduce water to make fuels, you end up destroying the materials you're using."

Plants face the same challenge, which they overcome by replacing the enzyme they use every half an hour, which is as long as it lasts before burning out. Durrant is looking to some very basic materials to try and make fuel from sunlight: rust. "The stuff we study most are things like rust, because it's cheap, it's stable and it's brown – so it absorbs light," he explains. "It can oxidise water, it just doesn't do it very well, so we're trying to make it better."

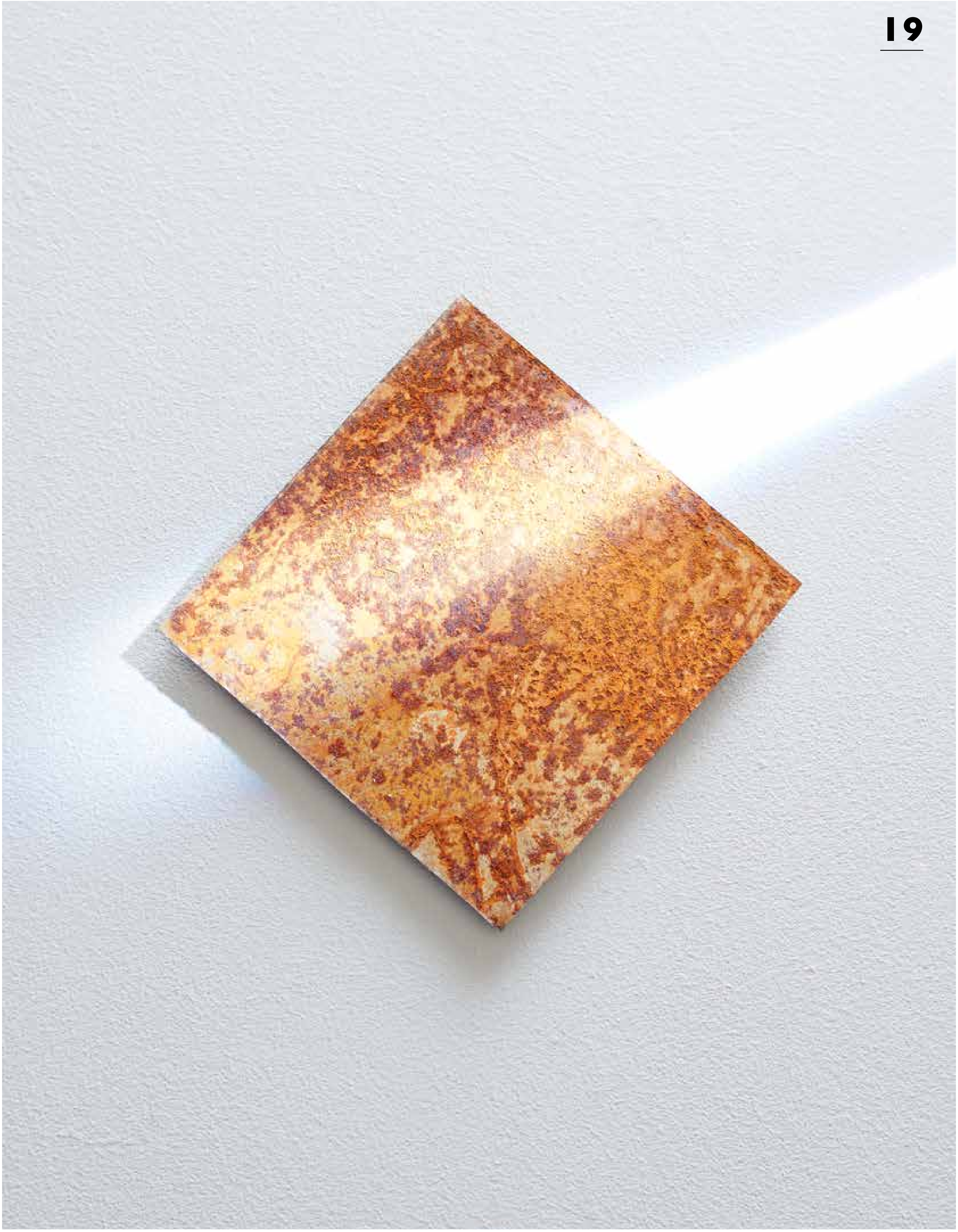
And they're generating some interesting results. "We're learning how to do surface treatments to make it work much better, and we're learning about the molecular

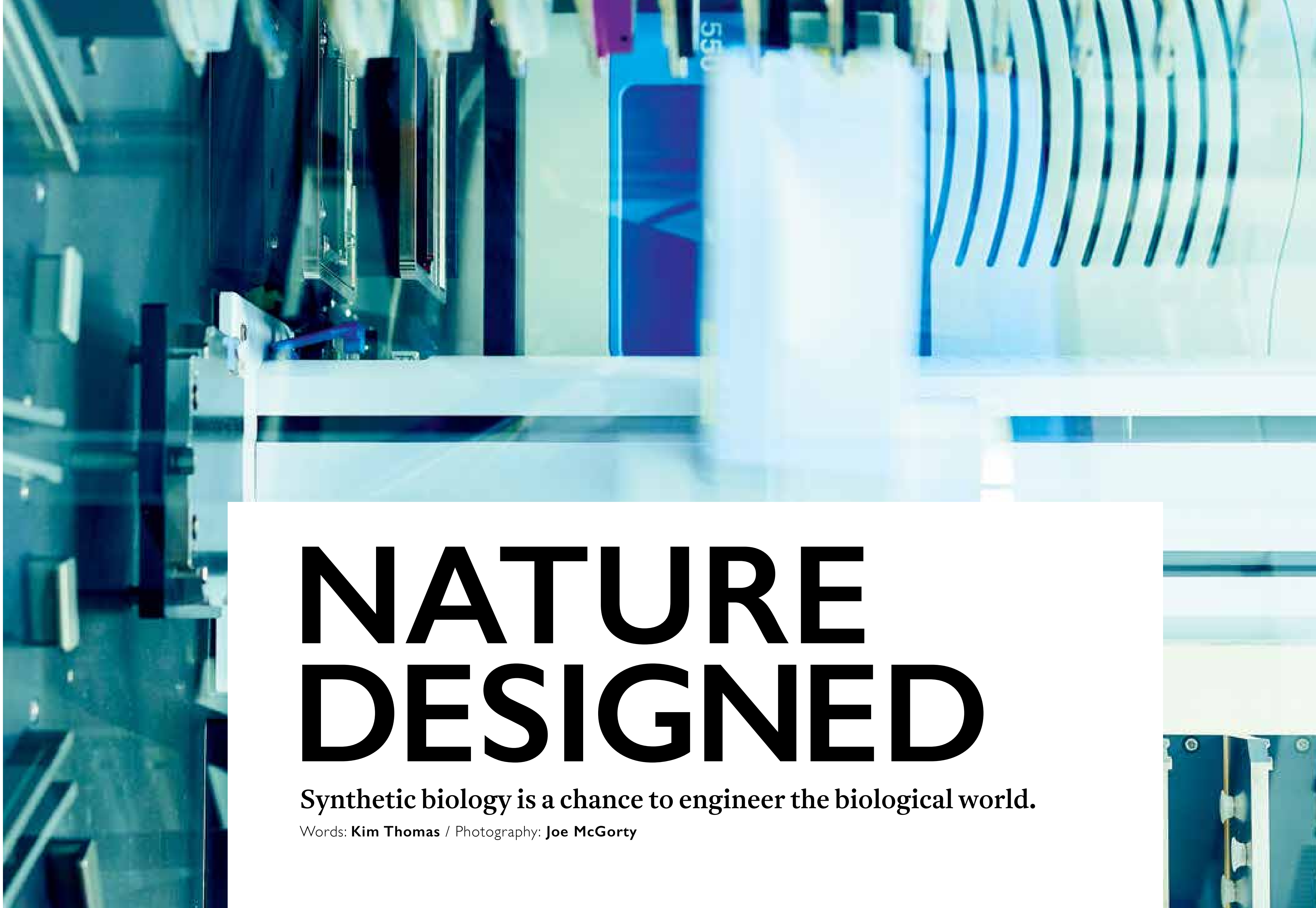
IN THE LAB, DURRANT FIRES SHORT LASER PULSES AT PARTICLES OF HEMATITE (RUST). THE AIM? TO WORK OUT HOW TO MAKE THE CHARGES LAST LONG ENOUGH TO DO SOMETHING USEFUL.

mechanisms," says Durrant. "In some ways, rust appears to oxidise water in quite a similar way to plants, which surprised us. You wouldn't think plants and rust have much in common, but they have more in common that we expected."

He's optimistic, however, that these approaches will help us find new sources of energy. "To make something useful it must be cheap, efficient and stable. Most materials are one of those, a few are two, but none are all three. That's the big challenge," he concludes. "Whether we'll get something that competes directly with fossil fuels I don't know. Biofuels will have an important role, but have limited scability. There are many forms of transport, such as aeroplanes, where if we want to de-carbonise, we'll need sustainable fuels. If we could make fuels from sunlight, water and CO_2 cheaply and sustainably, this could be truly transformative." ◆

Right: At the Department of Chemistry, Professor James Durrant is examining artificial photosynthesis, firing laser pulses at hematite (rust) to better understand the oxidisation process and, ultimately, make fuel from sunlight.





NATURE DESIGNED

Synthetic biology is a chance to engineer the biological world.

Words: **Kim Thomas** / Photography: **Joe McGorty**

Left: Automated experimentation using state-of-the art robotics enables rapid mass-testing. **Above:** Bespoke experimentation at a lab bench using 'traditional' techniques – the lifeblood of synthetic biology R&D.

Imagine you could program a living cell in the same way you currently program a computer. Cells could be made to convert carbohydrates to fuel – or to detect disease-causing bacteria. Plants could be programmed to create new, life-saving drugs. Welcome to synthetic biology – less than 20 years old and already making an impact. Its logic is irresistible: take engineering principles – breaking material down into modules and combining them in different ways – and then apply them to biology.

It's a bit like turning living cells into little manufacturing factories: and the diversity of things these factories can produce and the precision you can apply is endlessly exciting. "Humans have been using biology for more than 5,000 years," says Professor Paul Freemont, Co-Director of the EPSRC Centre for Synthetic Biology and Innovation (CSynBI), "but synthetic biology now offers the opportunity to rationally engineer biology for the first time." ▶

In practical terms, scientists take sequences of DNA and put them together in different combinations within a cell, thereby programming cells to behave in new ways. "The whole field is about how you write DNA within the context of a particular cell type, to make the cell produce something you want according to human design," says Professor Richard Kitney, fellow Co-Director of the CSynBI.

As well as anti-malarial drugs and modified yeast-producing biofuels, Kitney believes one of the most promising applications is vaccine production. It normally takes nine months to produce a vaccine, but with synthetic biology they can be produced in only one month in plant cells: "You take the plant cell, modify its DNA and then get the plant to produce the vaccine. Harvest the plant and grind it up – then the liquid that comes out of that grinding process is the actual vaccine."

Speeding up process is also at the heart of PhD student Loren Cameron's work. She is developing a revolutionary new biosensor – a piece of biological material that converts a biological response into a detectable signal – to help sufferers of cystic fibrosis, a chronic disease caused by a genetic mutation. Sufferers are highly susceptible to respiratory infections such as *Pseudomonas aeruginosa* and, currently, it can take 24 hours or more for patient sputum sample cultures to detect the presence of the *Pseudomonas* bacterium and other pathogens.

What's special about Cameron's biosensor is that it uses cell-free synthetic biology to shortcut the process and detect *P. aeruginosa* more quickly and more cheaply. "You take all the cellular machinery out of the context of a living cell, so it's a non-living system," she explains. Living cells are highly complex, making them difficult to engineer.

And the great advantage of a cell-free system is that it can be freeze-dried and reactivated: "There's no issue of molecules crossing a cell membrane because everything is open and exposed and ready to sense whatever is in your sample."

Early testing with clinical samples has shown that the biosensor works, and can quantify *P. aeruginosa*-specific molecules with reasonable accuracy compared to analytical methods. The research demonstrates the potential of cell-free biosensors in the diagnosis of bacterial infections, particularly, says Freemont, in low- and middle-income countries that cannot afford sophisticated diagnostic equipment. Longer term, he says, the technology could be used to build "low-cost diagnostic sensing devices that could be used to detect viral infections, bacterial infections and environmental pollutants".

Whether it's creating vaccines or detecting *Pseudomonas*, the holy grail for synthetic biologists lies in a greater understanding of genomes – the complete set of genetic material in a living cell. We can already 'read' a genome – that is, break it into its component parts, consisting of thousands of tiny pieces of DNA. But Imperial is part of a project that goes one step further: it is helping to write a genome.

Anyone who appreciates bread or beer knows how important yeast is, particularly its ability to convert carbohydrates to carbon dioxide and alcohols through fermentation. Now, an international collaboration, known as the Synthetic Yeast Genome Project, aims to build a synthetic version of the entire yeast genome, an accomplishment that is centrally important in modern cell biology research.

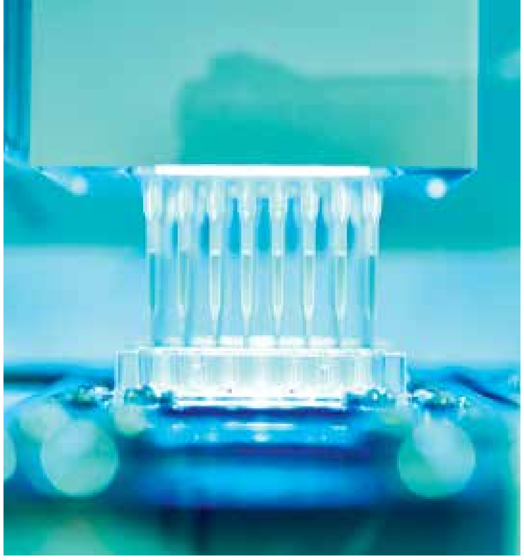
Each of yeast's 16 chromosomes has been allocated to teams of scientists across the globe. The Imperial team, led by Dr Tom Ellis, has been working on chromosome 11, a middle-sized chromosome with 700,000 bases of DNA. Their work consists of editing synthetic DNA sequences into chunks then introducing them into yeast cells, where existing cellular machinery finishes building the chromosome. Eventually – possibly as soon as the end of 2018 – all 16 chromosomes will be brought together to make an entire genome.

If the project was just about replicating the existing yeast genome, then its usefulness would be limited. But the scientists are making slight changes as they go, removing some unnecessary genetic ▶

For the very first time, it is possible to harness the biological sphere according to human design

Clockwise from top: Precision biology in the SynbiCITE labs; computer-controlled robotic liquid handling; a 96-well plate – the carrier commonly used in automated experimentation; an example of hand-made biological components used in experiments; biology hand-in-glove with lab R&D.


Access



Clockwise from far left: A skilled researcher using a pipette (taking, perhaps, more than a week to test, analyse and characterise a single plate); a computer-controlled automated platform which can perform up to 10,000 experiments a day; automated liquid handling machines, doing the job of 48 pairs of hands; robotic liquid handling machines; standard 50ml Falcon tubes – where most bespoke experiments in synthetic biology begin.

material and adding features that might improve on the original, says Ellis. "We've done a lot of learning by breaking down the natural systems – let's see if we can learn even more by building up a new version of the natural system based on the knowledge we have."

As a result of the changes to the genetic code, the finished yeast chromosome will have what Ellis calls "special powers" – new strains which make the bread-making or beer-making process more efficient. But the project is also improving scientists' understanding of how to program yeast to produce, for example, medicines or fuels. The process of building the yeast genome will also make it easier to build other genomes, such as those of plants or animals. Finally, because yeast shares a quarter of its genes with humans, understanding how yeast works will also help us understand the human genome better.

OWNING LIFE

Synthetic biology is not without challenges. It's all very well using yeast or bacteria cells to make a medicine in a lab, but scaling it up to a factory process is much harder. And there are ethical questions about the potential harm of rewriting genetic code, as well as concerns about intellectual property and whether a living organism can be 'owned'.

The government's Synthetic Biology Leadership Council (SBLC), which decides priorities and recommendations for synthetic biology research in the UK, is looking specifically at the ethical and regulatory issues. Companies that provide DNA sequences on request to researchers have monitoring programmes to ensure that no-one submits a design that could inadvertently cause harm. But the complexity of what's involved should not be underestimated.

However, it is wrong to imagine that scientists are able simply to put DNA sequences together to build a new biological system. The term BioBricks (standardised pieces of DNA sequences), gives the misleading impression, says Freemont, that they are "like bricks of Lego you can stick together". A living organism is "a very constrained volume of chemical reactions" which creates context dependencies: "You can't just say: 'If I put these parts together it's going to work'."

A growing, open access database now exists of those DNA sequences, known as the Registry of Standard Biological Parts, which contains information about every BioBrick (or biopart, to use the term preferred by Imperial scientists). "When a particular biopart is defined, it goes through a detailed experimental procedure to describe exactly how it operates under various conditions," says Kitney. Once that has been determined, all the details are put into the Registry.

Truly understanding the interaction between different biological components is far from being a short-term project. The team led by Dr Guy-Bart Stan, Head of the Control Engineering Synthetic Biology group, is developing mathematical models that more effectively predict what happens when new DNA is inserted into a cell. "That will allow us to increase the reliability and the predictability of what will happen before we perform the experiment," he says.

"When engineers design a new aeroplane on a computer, the information about how the different elements interact and behave is so reliable that the computer modelling can be used to build a single prototype that is instantly successful," says Stan. "So they don't build 10,000 planes and then select the one that flies correctly. It's totally cost-ineffective to do that. The long-term vision is to reach a stage where we can design or engineer living cells in a way akin to what we do in manmade systems when we build a plane."

It's still a young field, and that vision is some years off. But the potential is undoubtedly vast and, as Kitney says, it represents a huge leap forward in what is scientifically possible: "For the very first time in the history of the world, it's possible to begin to harness the biological sphere to operate according to human design." ◆

We were lying patients on the floor. It was dire. Four patients died in two hours and by the end of July it was out of control

PHOTO: NIAID

Professor Neil Ferguson plays an active role in informing disease control policy-making by public and global health institutions.

Imperial scientists, in the lab and on the ground, are working to defeat Ebola.

Words: **Megan Welford**
Portrait photography: **Joe McGorty**

Ebola. The word alone implies a death sentence, and for 11,310 people in West Africa between March 2014 and April 2016 that is exactly what it was. In 2014 the world wasn't ready: previous outbreaks, such as in DR Congo in 2012, had caused a maximum of 36 deaths. Being unprepared was part of the problem, but the sheer scale of the disaster means that Imperial scientists are more ▶

determined than ever to make sure the lessons are learned.

One of those at the very forefront of the battle, both then and now, is clinical research fellow in the Department of Medicine, Dr Nathalie MacDermott. She travelled to Liberia in early July 2014 with one of the first disaster response teams, through the charity Samaritan's Purse. "At that time no-one in the international community was really concerned," she remembers. "The World Health Organisation (WHO) and other experts were still saying it would burn itself out. But when we got there, Médecins Sans Frontières were already overwhelmed, and asked us to take over the treatment centres in Liberia."

Those treatment centres had not been designed for an epidemic. "We were lying patients on the floor. It was dire. We had to knock through the partition wall of the treatment centre in Monrovia – ELWA 2 – to add beds. While we were doing that four patients died in two hours. Ebola is a horrific, febrile illness transmitted by direct contact with the bodily fluids of infected people. There is diarrhea and vomiting. Some people bleed from multiple sites and die from that, others have high fevers or seizures before they die.

"By the end of July the epidemic was out of control – every day people were coming from a new area, so we could see it spreading throughout the whole country. Our morgue was overflowing." At that point two of MacDermott's American colleagues contracted Ebola and, subsequently, the whole team was evacuated.

ANALYSING DATA IN REAL TIME

At the same time, Professor Neil Ferguson of the School of Public Health volunteered the services of Imperial's MRC (Medical Research Council) Centre for Outbreak Analysis and Modelling to the WHO. The largest of its kind in the world, the centre analyses data in real time during disease outbreaks to help inform policy at a strategic level, working with governments, the military and NGOs.

"Our aim was to analyse how rapidly Ebola was spreading across each country and what the variations were within," explains Ferguson, "in order to assess the incubation period, for example, and to answer specific questions such as how many beds were needed in treatment centres. The problem was, the

> **Our aim was to assess the incubation period, and answer specific questions such as how many beds were needed in centres**

data was incomplete, so trying to analyse the case-to-fatality ratio, for example, gave wildly diverging estimates."

That is the problem of a disease outbreak in countries without adequate healthcare systems or accurate data recording. MacDermott describes the 'perfect storm' that allowed Ebola to spread so rapidly throughout Liberia, Sierra Leone and Guinea. "The three countries border each other to the north of Liberia, and people travel across those borders all the time – for trade, for medical treatment or to visit family. There was no contact-tracing in place, nor proper burial facilities, and corpses are highly infectious.

"This part of the world had never seen Ebola before so health workers weren't trained, and in any case there's a lack of health infrastructure in these countries, still reeling from civil wars. Some of the areas were urban, which meant disease spread quickly." ELWA 2, for example, received patients from the West Point slum, with its high population density and limited hygiene, such as communal latrines.

Then there were the beliefs and behaviour of the local population. "People were rioting outside the compound," explains MacDermott. "They were afraid. They didn't want the treatment centre there, because it would mean sick people coming. There was also a widespread belief that Ebola didn't really exist, that it was a hoax by the government to gain aid money, or that people were being taken to treatment centres for organ

IMPERIAL ALUMNUS LEADS THE WAY

Imperial specialists have been at the very heart of Ebola treatment in recent times, and none more so than Dr Sir Michael Jacobs (PhD Clinical Medicine 1998), a member of the Royal Free Hospital team that treated high profile Ebola cases of the British nurses Pauline Cafferkey and Will Pooley, in a specialist isolation unit. "The Royal Free had maintained a unit to look after Ebola patients and other infectious diseases for a long time, so for us it was almost business as usual. The frequency of the cases was exceptional – normally we'd expect one patient every few years – and it was very high profile, with a lot of media attention on us. The team functioned fantastically, though. We were prepared and trained because we knew that it would happen sometime. We didn't know that it would be Ebola and we didn't know when, but we knew it would happen. We knew so little about the disease and we were learning as we went, using new treatments, things that had never been used in humans before."

harvesting. In West Point, families were taking sick relatives away from the holding centre on infected mattresses."

Ferguson says one the biggest lessons learned by the MRC centre from the outbreak is the "importance of the behaviour of individuals in stopping the spread of a disease. Where you have distrust of authority and government, for example, imposing control can be counter-productive." The centre, he says, has since brought social scientists into its work, to try and model behaviour. "We can't yet do it reliably," he says. "You can count cases of hospitalisation, but quantifying behaviour is much more difficult."

Since the Ebola outbreak, he says, the centre has also developed more sophisticated data processing tools. "The data [in 2014] was so noisy and full of errors that it took time to clean up. We are developing open-source tools that can do it more efficiently. Silicon Valley software engineers are also working on this in their spare time." And his team is developing better criteria for resource allocation. "The World Bank's new pandemic emergency funding facility, backed by insurance policies, aims to improve the way money is allocated to tackle these types of epidemics. We've helped develop the quantitative criteria for pay-outs used by that scheme."

Comprising around 130 staff, the centre had previously worked on SARS, swine flu and MERS (Middle Eastern respiratory syndrome) coronavirus outbreaks, but Ferguson says Ebola took them, like everybody else, by surprise. "We hadn't done significant research on Ebola prior to 2014," he says. "It didn't cause much concern. It was lethal but outbreaks had always been contained; no-one thought it would cause a large epidemic. That is one lesson: don't dismiss a pathogen because you think you know it."

TREATMENT AND VACCINATION

The MRC centre works on the full range of infectious diseases, with the world's biggest killers – HIV, tuberculosis and malaria – commanding the biggest research groups. "But a lot of the methods are shared with other diseases, such as Ebola," Ferguson explains. "Machine learning tech [where computers can learn without explicit programming] is a big thing and we are employing professional programmers for the first time. A lot of our work focuses on retrospective analysis of epidemics like Ebola."

The aim for both Ferguson and MacDermott is disease treatment and vaccination. "HIV and malaria vaccines are challenging to develop because of how those diseases evade the immune system," says Ferguson. "Zika, MERS coronavirus and Ebola have a range of candidate vaccines but the problem is testing them. We are exploring how you would employ a vaccine; for example, if you stockpiled five million doses how would you deploy it in an outbreak? During a crisis there is a political desire to do something but interventions need to be effective. We need to produce cost-effective vaccines in a timely manner."

Ironically, MacDermott says, the scale of the 2014 outbreak makes this kind of research possible in a way it wasn't before. "Genetic studies require thousands of participants, which we didn't have before," she explains. "We've recruited 2,529 participants in Sierra Leone, for example: survivors – those who were living in a house where someone was sick but they themselves didn't get sick, or controls – where no-one was sick in the house. We're looking into how these people differ genetically and also if there is a genetic disposition to the kinds of problems survivors have – joint pain, eye inflammation and cataracts, even blindness, and neurological and fertility problems. We are looking at possible sexual transmission, whether how long the virus can survive in semen is genetically determined.

"We are just getting the results of the antibody tests – whether participants tested positive or negative for the disease antibodies – and by next summer we hope to have completed exome sequencing and genotyping. We will genetically profile all participants and study single nucleotide polymorphisms (the building blocks of DNA) to look for mutations in receptors or differences in immune response. This will help us to understand the virus – how it enters cells and interacts with the immune system. Differences in DNA can lead to developing treatments and identifying targets for vaccination, which can be useful in other infectious diseases such as Marburg virus disease [another virus from the Ebola family] and other viral haemorrhage fevers."

Overall, however, the most important lesson, according to both scientists, is not a scientific one. "I hope the international community has learned the importance ▶

People were rioting outside the compound. They didn't want the treatment centre

Dr Nathalie MacDermott has taken time out from paediatric training to do a PhD looking at genetic susceptibility to outcome from Ebola virus infection in Sierra Leone.

of responding quickly," says MacDermott, "particularly in countries where there are weak health systems."

Ferguson agrees. "There was a structural, political and logistical failure to act early enough in 2014." He says this is a lesson relevant to other diseases, so the MRC centre works on mapping geographical risk and vulnerabilities. "Take MERS coronavirus," he says. "There have been outbreaks in Saudi Arabia which have so far been contained. But there are migrant workers in Saudi Arabia from the Indian subcontinent – Bangladesh, for example – and were they to take it back with them to such a resource-poor country, then an outbreak there would be much more difficult to control." ◆

Curiosity

How can we reduce the drag
power the future of water
market be worth $127bn by
vaccines end hay fever forever?
stop a heart attack? Can tunable
optical properties of materials?
fields help predict extreme-
asthma at work? Can inherited
gene expression? Should all
Do descendants of Holocaust
trauma? Could hypothermia
What can plasma tell us about

THE SIMPLE DESIRE TO KNOW MORE IS SCIENCE'S ROCKET FUEL. WHICH IS WHERE, SAYS PROFESSOR OSCAR CES, IMPERIAL'S HACKSPACE COMES IN. ▶

on a Formula One car? Is pedal-
purification? Could the drone
2020? Could synthetic peptide
How can wave intensity analysis
nanoparticles change the
Could the study of kinematics
wave events? How can we limit
disorders be reduced by altering
surgeons be using the iKnife?
survivors cope less well with
help reduce deaths in newborns?
the future of space travel?

How do we plan for the next
be eliminated? What can
us about the solar system? How
Why should society care about
hybrid electric cars the answer?
a thing of the past? Can
predict tomorrow's weather?
computer algorithms to
molecular basis of

As humans, we are hard-wired to be curious. Whether it's a child asking 300 questions a day, or adults just trying to find out the latest gossip, a curious mind is an integral part of what makes us, us.

And curiosity is what drives everything we do at a university. It's a desire to make connections between apparently unrelated phenomena, and to see the world in a new way. But it's also a call to action – a force that compels us to push forwards, make new discoveries and generate solutions to important societal problems.

It's become commonplace to run creativity sessions where walls end up covered in sticky notes, each with the nugget of an idea; but in many cases, they progress no further than the wall. Tantalising ideas that remain bound by the frames they were written within. To me that's frustrating, as curiosity is bound up with creativity. Unlocking the process of moving from concept to execution is as exciting as having the idea in the first place: not just having the eureka moment but proving it works and then doing something useful with it.

True curiosity refuses to be contained within a silo. It is often multi-disciplinary. It encourages us to leave the comfort zone of our own specialism and collaborate across boundaries. Many of the big challenges that lie ahead – everything from discovering new drugs and therapies through to developing artificial life and novel materials – require a mix of expertise from different fields.

My own department, Chemistry, is a perfect example. As we take up residence in a new building at the White City Campus – the Molecular Sciences Research Hub – we hope to promote a networked approach to science where chemists will sit alongside other molecular scientists and engineers to take on problems that demand that fusion of disciplines. The Hub will be a magnet for curious minds wishing to meet, discuss and swap ideas.

Proper collaboration requires time, resources and commitment. When a chemist starts talking to a medic, each will have a very different perception of the challenge to be tackled, even down to different scientific vocabulary. Finding common ground is a big deal.

It's this ethos that has led to initiatives such as the Imperial College Advanced Hackspace, a community-operated prototyping workspace which has now been running at Imperial for three years. True curiosity demands a place where the means to collaborate, innovate and create working prototypes are available to anyone – whatever their department, and whether they are undergraduates, PhD students, post-docs or staff. The Advanced Hackspace imposes no rules on how the space is used and aims to give everyone the means of innovation; turning a population of stakeholders into a population of innovators. Today it has 2,400 members, drawn from every faculty in College, and more are joining at a rate of 100 every month. It brings together people with common interests in everything from computers, digital art, synthetic biology, robotics, healthcare, automation and machining. Its aim is to be the best place in the world to turn ideas into a reality.

But operating in a vacuum benefits no-one, so it's important that collaboration extends beyond the College. The Hackspace community has extended to encompass alumni, SMEs and industry. In order to foster this growth and allow members of the local community to come together with our staff, students, alumni and partners to test out their creative ideas, the College recently founded The Invention Rooms. This venture houses an exciting mixture of workshops and interactive spaces. It's like a condensed version of the whole of Imperial, and it's already bursting at the seams with activity.

The Invention Rooms at White City has three key elements. There's the main Advanced Hackspace for College members, where they can collaborate with businesses and other partners. Next door is a

pandemic? Can malaria ever
meteorites in the Sahara tell
can we learn to sleep better?
sustainable transitions? Are
Could hot flushes ever become
geophysical fluid dynamics
How can we use smart
fight fires? What is the
neuropathic pain?

community 'maker space' that offers workshop and design studio facilities for young people from the local community. It's a way to foster and develop their curiosity, and I believe it's a game-changer to have the two spaces on the same site. Then there is the Interaction Zone – a vibrant public events space where local people and College partners can discuss science and connect with Imperial's research through a wide-ranging programme of activites.

Invention and innovation thrive on forums for discussion and development. One example is that of Hackathons that offer multi-disciplinary teams the opportunity to spend extended periods of time, from days to weeks, working on a challenge set by a member of staff, a partner company or a charity. This maelstrom of creative diversity always delivers unexpected results and it comes back to the principle of releasing ideas from sticky notes hanging on the wall. In a Hackathon, you don't just imagine it, you build it, and when the teams present their solutions at the end of the event, there may be five along the lines we'd imagined, but there will also be 15 that are so left-field. These catch the judges and sponsors totally by surprise, and outcomes like this demonstrate why the Hackspace has been described as a 'serendipity engine'.

True curiosity refuses to be contained within a silo. It encourages us to leave the comfort zone of our own specialism – and collaborate

Another example is that of entrepreneurial Dragons' Den-style competitions in College. During these, students come up with an idea for a start-up, and they are provided with training in development, marketing and business planning. Successful teams in these ventures are often invited to pitch to a 'dragon' for a chance to win some funding. Traditionally, when these students get to the final of the competition, it's on the basis of an idea they have never had a chance to test. So they could win the money with a great pitch, and then use it to come up with a working prototype and find out whether there was any development potential in the first place.

When you're awarding finance in this way, it's effectively a prize rather than development funding. This is something that the Enterprise Lab, a new entrepreneurship Hub at Imperial College, working in partnership with the Hackspace, is trying to change. If you can get the students to actually make a prototype during the competition and show that their idea works, you'll be awarding money that can immediately be used to push their business plan forward.

In the end, curiosity thrives when we are not afraid to fail. There are large numbers of people – both inside and outside Imperial – who are inherently curious and creative, but don't have the confidence to pursue their ideas. What initiatives like the Hackspace mean is that it doesn't matter if you fail ten times before you make your idea work.

We need these environments, and the time to use them, if we really are to go beyond the sticky note and pursue our creative goals. Even at a university, life has a habit of getting in the way. For students and staff alike, there will always be lectures to attend or research deadlines to meet. But we should be careful not to lose the instinct to learn for learning's sake, to build on our ideas and to find out just how far our curiosity can take us. ◆

To find out more about the Imperial College Advanced Hackspace, the Invention Rooms, the Enterprise Lab and the White City Campus, visit www.imperial.ac.uk/advanced-hackspace, www.imperial.ac.uk/enterprise/enterprise-lab and www.imperial.ac.uk/whitecitycampus.

The shape of things to come

The Imperial community is reinventing the world by imagining new uses for everyday materials.

Words: **Lucy Jolin**

Mind-bending. World-beating. And available from a shop near you. Material scientists at Imperial are changing the look and feel of the world we will live in – on earth, in the skies and in space – with research that is designed to have an immediate impact. How are they doing it? By focusing their inventiveness on materials that are already available.

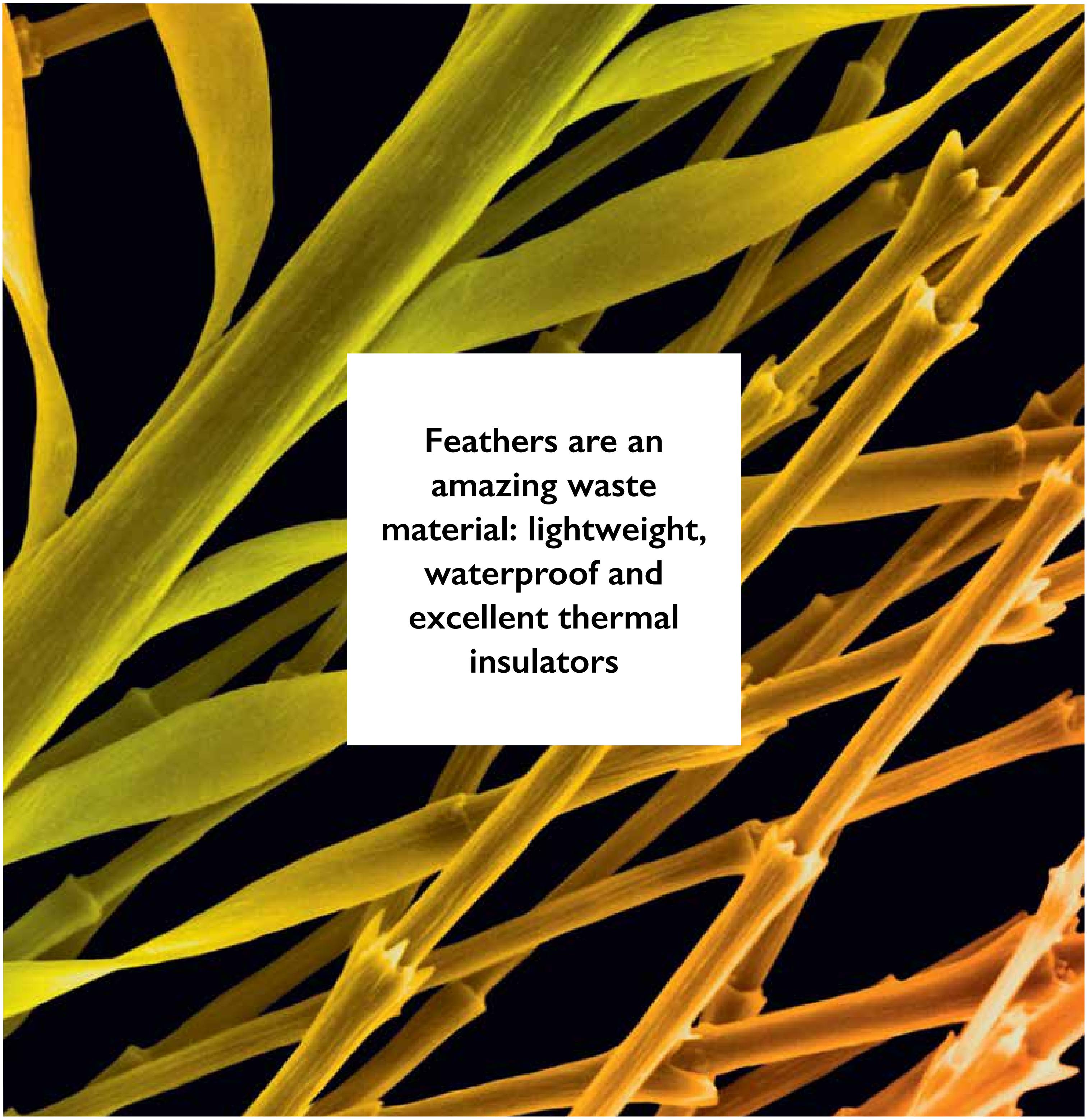
Take Elena Dieckmann (MSc Innovation Design Engineering 2016) and Ryan Robinson (PhD National Heart and Lung Institute 2016), founders of start-up Aeropowder, whose ingenious work could revolutionise the building industry using the ultimate waste product: chicken feathers.

Worldwide, we consume 134 million chickens daily: that's 10,000 tonnes of waste feathers every day, many of which are rendered down via a high-energy process into low-grade animal feed. And yet, as Dieckmann explains, feathers are material with incredible potential. "They are made of keratin, a chemically resistant and physically strong protein. Thanks to their microscopic structure, they are one of the lightest natural fibres in nature, they are waterproof and are also excellent thermal insulators," she says. "We realised there had to be a better use for them."

The multi-award winning pair have developed a low-cost, low-carbon conversion process to take feathers direct from the abattoir and turn them into a range of useful products, from a water-repellent powder coating that can be applied to a range of materials to thermal insulation blocks which are not only lightweight but are biodegradable, too.

Dieckmann is currently taking her research forward in a PhD project at the Department of Civil & Environmental Engineering at Imperial, funded by the ▶

Below: Coloured scanning electron micrograph (SEM) of Canadian goose down feather, shaft, barb, barbules and barbule tips.



Feathers are an amazing waste material: lightweight, waterproof and excellent thermal insulators

James Dyson Foundation and supervised by Professor Chris Cheeseman, Leila Sheldrick and Dr Koon-Yang Lee. Her co-founder Ryan Robinson is working full-time exploring the company's commercial potential.

But while the applications are immediately obvious, Dieckmann says the process of actually getting an idea to market has been eye-opening. "What happens in industrial testing and what happens in the lab can be two very different things!"

Dr Koon-Yang Lee, Senior Lecturer in the Faculty of Engineering, says that the Aeropowder approach has huge implications for material sciences. "What we're doing is taking whatever is available right now. We try to perform basic modifications or create simpler solutions which lead to the same outcome – better performing materials," he says.

And that has real, immediate benefits for researchers. First, it's easier to modify something that already exists rather than create something entirely new. Second, it's a quicker way to commercialise a product.

Lee points out that the compound polytetrafluoroethylene, which forms the basis of Teflon, was discovered by chemical company DuPont employee Roy Plunkett in 1938, but the first Teflon-coated 'Happy Pan' didn't go on sale until 1961.

"If you take existing materials, this allows you to solve problems in the immediate future, rather than waiting for the years of basic R&D needed when developing new solutions," he says.

Dr Ben Britton, Senior Lecturer in the Department of Materials, studies materials at the atomic level – how they bond together and how their structure performs. But his focus is on what the atomic scale means for life at the human one. "Changes at the smallest scale can have a huge impact on structures where failure could be catastrophic: aerospace jet engines, oil and gas pipelines and nuclear reactors," he says.

One of the most important aspects of running a nuclear reactor, for example, is making sure all the bits and pieces stay in one piece, especially with the UK's ageing reactor fleet, he explains. The reactors need to run for as long as possible, to maximise their life. "We need to predict when the materials will fail, so that we can rotate the parts out of service and put fresh parts in. In a jet engine, we look at the integrity of the disc and fan blades at the very front of an engine. And we look at pipelines and cutting materials in oil and gas – when you are drilling you want to make sure you can maximise the amount of time spent drilling. My colleague Dr Finn Giuliani and I are trying to understand the failure mechanisms in tools that sit on the front of the drill and bore into the rock."

Much of this work involves studying samples of materials that have failed or are likely to fail, and examining exactly what happens to them under the microscope when they're subjected to stress. "If you've ever been bored and bent a spoon back over and over again, you'll know that the spoon will eventually break," says Britton. "But in fact, that's not because you applied so much deformation. It's that you've effectively exhausted the plasticity within that material. Each time you fly a plane – taking off, going into cruise and then landing – you're bending the spoon."

Indeed, materials that go into orbit have to be able to cope with hugely demanding environments, both while they're out in space and when they're sent through the Earth's atmosphere. Understanding exactly how well they cope – and when they stop coping – is essential. Which is why Britton and Giuliani have recently developed a novel project to test exactly how well silicon carbide – a light, stable ceramic used in space telescope mirrors – performs under stress.

"We cut a square cross-section pillar-shaped object of silicon carbide, two micrometres by two micrometres by six micrometres," Britton explains. "Then we introduce a tiny crack in the top of that pillar, and push a diamond wedge into that crack. We watch in real time using the electron microscope. We measure the energy that dissipates as that crack progresses. This means we can understand the toughness: how high we can drop something before it cracks and how much weight we can put on an object before it breaks – essential knowledge when you are flying a satellite into space."

Feathers and silicon carbide both occur in nature – but synthetic materials are also ripe for improvement and reinvention. Foams, for example, are used widely where weight saving is critical, such as in aeroplanes. Currently, high-performance foams are produced in a block and shaved down into the required shape, while low-performance foams, such as those used in everyday packaging, are injection moulded into the desired shape. Lee's team have created a foam that combines the properties of both high and low – a foam that is strong enough to withstand the stress of an aerospace application but can be moulded to any exact shape, thus reducing cost and waste shavings.

If you've ever made a meringue, you'll be familiar with the process: it begins life as a liquid. Air is beaten into it so that it becomes thicker and easier to shape. "You can shape it into anything, from a gingerbread man shape to an aerofoil shape," Lee explains. "That automatically leads to cost saving, as you are not going to make a block and then shave it into the shape of a gingerbread man. You can just pull it directly into the gingerbread man mould. And in most processes, you have to modify your starting liquid to create a foam by adding, for example, five per cent of a blowing agent – a chemical that makes bubbles in a polymer foam. With ours, all we have to do is beat it, shape it and let it set. You don't need anything else other than a whisk and a mould."

Much of this work is done in close collaboration with industry, seeking real-world solutions for real-world problems. But that's not the only partnership needed: this kind of innovation also reaches across many other disciplines: chemistry, physics, engineering and materials sciences.

"It's really nice to sit on that cusp between science and engineering, where we can take engineering problems, apply scientific approaches and try to deliver something where we have a new understanding that companies and collaborators can gain from," says Britton. "We all like flying. We all like electricity. We all want our materials to perform better." ◆

PHOTOGRAPHS: SCIENCE PHOTO LIBRARY

Below: Styrodur insulating material, coloured scanning electron micrograph (SEM). Styrodur is an extruded polystyrene foam, whose cells are filled with air.

The team have created a foam that is strong enough to withstand the stress of aerospace but that can be moulded to any shape

scottfraser


Andrew Greenwood
Group MD


David Blythman
Managing Director

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Mr OM, Japan

DISRUPTOR / DR GERARD GORMAN

Writing research software can be like trying to build the Suez Canal with a spoon.

Take just one mathematician (or biologist, or geophysicist, or engineer) with a large dataset. Feed the data into the computer. Press a button and – bingo. Output award winning research.

If only it were so simple. In practice, one of the biggest challenges those of us working in mathematics, science and engineering face is the number of hours we spend keying in thousands of lines of complex, often monotonous and repetitive, source code.

The difficulty of developing fast and reliable mathematical software for science and engineering applications cannot be overestimated. Data applications require complex, high performance computing that can only be created by technology specialists – while simultaneously requiring the expertise of the application specialists for whom the software is developed. Practitioners in this area have to balance specialisation with the need to be highly multidisciplinary – and those who can do so effectively are so rare that they are often referred to as 'unicorns'.

On the surface, the obvious solution would appear to be to train more domain specialists as software developers. However, estimates of how many lines of source code can be written per day by a professional are as low as 10 lines per day, while even moderate application codes in science and engineering can have hundreds of thousands, and even millions, of lines of source code. Indeed, I have spent nearly 20 years writing and re-engineering hundreds of thousands of lines of parallel mathematical software – an experience I can only describe as trying to build the Suez Canal with a spoon.

Which is why the work we are doing in Computational Science is so exciting. We are creating software to write software – thousands of lines of highly bespoke, optimised and verified software are written in fractions of a second. Rather than trying to create an army of unicorns and giving them spoons, we design 'domain-specific' computer languages that allow subject matter experts to develop specialist software using high-level abstractions native to the subject matter.

Working with Professor Paul Kelly's team in the Department of Computing and funded by Intel, we have developed an open source domain-specific language called Devito. Successful, domain-specific languages allow complex algorithms to be expressed at a high level in very few lines of source code; bespoke compilers transform this into low-level (verbose), and highly optimised, software. This completely revolutionises not only productivity in software development, but also our relationship with computers and specialists from different disciplines.

By creating domain-specific languages that enable subject experts to express their methodology in a fashion that is native to the domain, they can essentially say: "This is my method, this is the data – create my bespoke software and compute my solution, fast." Our mission is to enable scientists to take ideas and be able to create production-ready software within hours rather than months, and Imperial is the perfect place for this to happen.

The collaboration between computer scientists and the domain specialist is making us completely rethink how we program computers. The ability to translate high-level algorithms or methodologies into low-level code is becoming so advanced that we are getting closer to the day when application specialists can write their equations and algorithms into research papers – and the paper itself would be directly compiled into software that can be executed. That would revolutionise the reproducibility of computational-based research and the adoption of cutting-edge innovation throughout the academic community, and technology transfer into industry.

Our mission is to enable scientists to create production-ready software in hours not months

I passionately believe that it is time to stop digging trenches with spoons and forks when there are diggers standing by ready to do the drudgery. Taking a historical perspective, automation has never been about replacing humans – it is about enhancing human capabilities so we can focus our energies on problems that require more creativity. And that collaboration between the creative human, software that writes software and machine learning will change the world. ◆

***Dr Gerard Gorman** is Reader in Computational Science in the Faculty of Engineering.*

OUR IMPERIAL

My Imperial experience has been instrumental

IMPERIAL ALUMNI ARE MAKING A DIFFERENCE AROUND THE GLOBE.

ALEX BOND

(MRes Chemistry 2014) is CEO of food safety pioneers Fresh Check Ltd, and is currently completing his PhD in Chemical Biology at Imperial.

When we first had the idea for our start-up, Fresh Check, we did have that "How has no-one run with this before?" moment. Inspired by the Centre for Doctoral Training's Dragons' Den-style event, my coursemates Robert Peach, John Simpson and I brainstormed a few ideas and landed on food wastage, and specifically the question of whether you really did need to throw out products that were past their sell-by date. So we developed food markers – a dye that changes from blue to orange to indicate that the level of harmful bacteria is such that food has gone off – and our company grew from there. We are now focused on food auditing, and provide our partners with a spray based on the same colour change principle to give restaurants and food producers a warning about cleanliness.

We were selected by Imperial Innovations and then took part in the Venture Catalyst Challenge, benefiting from expertise about working with patents and commercial trialling. We've been so grateful to have had the opportunity to really grow and trial the concept.

And all the while I'm still doing my PhD, so I can access the lab space here. Fresh Check is now trialling larger components with international auditing companies and we hope to launch our first products properly in February.

I'm enjoying working with students in the Enterprise Lab, and I mentored some of this year's entrants in the Venture Catalyst Challenge. I've taken so much from Imperial in terms of knowledge, resources and contacts, and it's great to help ensure that fantastic innovative environment continues.

CHRIS CIESLAK

(MSc Aeronautics 2010) is a director of BladeBug Ltd and Hacker in Residence at The Invention Rooms at Imperial's White City Campus.

I think Imperial is unique in how it invests in innovation – not just developing ideas, but getting them out into the real world. I haven't seen any other university with such a cutting-edge approach, and when I was given the opportunity to get involved, I leapt at it.

After 10 years in the turbine blade industry, and following the completion of my Master's, I began developing a small robot to maintain and repair blades, particularly offshore, in a more cost-effective way. Then, with perfect timing, I got an Imperial alumni email offering a new course and free lab space for tech start-ups. I signed up and it was excellent, covering aspects of starting your own business, such as raising the cash, PR, marketing, law – all in a tech space.

It got better: I met the Hacker in Residence at Imperial's campus in South Kensington and she suggested I could do the same at the College's new Invention Rooms at White City – so I got in touch and here I am! I support and mentor students, and help set up rooms and labs, all of which is tremendously exciting. But I also have the bonus of the lab resources, the networks and the expertise at Imperial to develop my own prototypes and work on my own products.

It's great to be able to give something back to the next generation of students but, in turn, I learn from them – and of course I can use these fantastic resources and the tech to take my own ideas further. My company, BladeBug, is doing bigger trials over the next year. Obviously I want to get our robotic device out to market as soon as possible but I truly believe I'm in the best possible place to expedite that.

MICHELLE WONG

(MEng Civil and Environmental Engineering 2004) is Director of Corporate Finance at Gaw Capital Advisors Limited in Hong Kong.

Imperial has always stood out for me as being different, interesting and innovative. When you've got lecturers at the cutting-edge of science – people like Professor John Burland, who had helped save the Leaning Tower of Pisa – it's clear that there is a uniqueness to much of what goes on here.

But as well as a brilliant course, it's the fantastic alumni network that has opened doors into my career in corporate finance in the private equity industry. Through the alumni association in Hong Kong I met older graduates, one of whom had qualified five years earlier and helped get me into the finance industry, at a time when Hong Kong's economy had been severely affected by the SARS virus and it was difficult to find a job. But he alerted me to an opening at Citigroup and helped me prepare for the interview – and I got the job. There were also a few other senior mentors who gave me advice for my career and we've became life-long friends. That support was invaluable to me and so, through the alumni association, I have mentored other new Imperial graduates and helped them in the same way.

The Imperial experience has been instrumental in my career – it is an advantage when working in a real estate private equity firm to have a really solid technical knowledge of how those buildings have been put together. The teamworking skills learnt from numerous projects working to tight deadlines with people from all over the world has made it easy for me to cope with the workload in banking and finance. I will always be grateful to Imperial and it has been fantastic to give back to the College.

WORDS: PETER TAYLOR WHIFFEN. PHOTOGRAPHS: ALAMY

WHAT'S ON AT IMPERIAL

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

2017
NOVEMBER

21 / PUBLIC LECTURE: ANGELA SAINI
How bias and prejudice have tainted research and given us an inaccurate portrait of women throughout history. *Sir Alexander Fleming Building, South Kensington Campus, London*

22 / MEET THE ARTISTS involved in Control to Collapse, a painting exhibition on show 22 Nov – 4 Jan in *the Blyth Gallery, Sherfield Building, South Kensington Campus, London*

22 / INAUGURAL LECTURE: PROFESSOR HENRIQUE ARAUJO
The story of the search for evidence of dark matter. *Blackett Building, South Kensington Campus, London*

24 / ROYAL SCHOOL OF MINES ASSOCIATION ANNUAL DINNER
Rembrandt Hotel, South Kensington, London

DECEMBER

01 / IMPERIAL COLLEGE SYMPHONY ORCHESTRA CONCERT
South Kensington Campus, London

05 / IMPERIAL FRINGE: WALKING IN THE AIR
Celebrate research into the invisible gases that fill our lungs and set the future of our climate. *South Kensington Campus, London*

06 / INAUGURAL LECTURE: PROFESSOR MANOS DRAKAKIS
Microelectronics for (and from) biology, *Lecture Theatre 164, Skempton Building, South Kensington Campus, London*

11 / COLLEGE CAROL SERVICE by candlelight, *Holy Trinity Church, Prince Consort Road, SW7 2BA*

13 / INAUGURAL LECTURE: PROFESSOR STEPHEN NEETHLING
Pulling metal from the rocks. *Lecture Theatre 1.31, Royal School of Mines, South Kensington Campus, London*

14 / ALUMNI AND FRIENDS RECEPTION IN DUBAI WITH PRESIDENT GAST
The Oberoi, Al A'amal Street, Business Bay, Dubai, United Arab Emirates

2018
JANUARY

29 / ANNUAL SCHRÖDINGER LECTURE
South Kensington Campus, London

FEBRUARY

05 / ALUMNI AND FRIENDS RECEPTION IN SHANGHAI WITH PRESIDENT GAST

21 / ANNUAL SIR ERNST CHAIN LECTURE
South Kensington Campus, London

23 / CITY & GUILDS COLLEGE ASSOCIATION ANNUAL DINNER 2018
Shaftesbury Place, Barbican, London

26 / ALUMNI AND FRIENDS RECEPTION IN CAMBRIDGE WITH PRESIDENT GAST
Downing College, Cambridge

27 / ROYAL COLLEGE OF SCIENCE ASSOCIATION 111TH ANNIVERSARY AT HOUSE OF LORDS
House of Lords, London

MARCH

05 / WOMEN @IMPERIAL WEEK
South Kensington Campus, London

14 / PRESIDENT'S ADDRESS
South Kensington Campus, London

APRIL

28-29 / IMPERIAL FESTIVAL AND ALUMNI WEEKEND
South Kensington Campus, London

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DATASET

The value of early detection

Name of study: The UK Flexible Sigmoidoscopy Screening Trial (long term effects of once-only flexible sigmoidoscopy screening after 17 years of follow-up)
Published: *The Lancet*, February 2017
Lead researcher: Professor Wendy Atkin
Department: Surgery and Cancer
Background: The trial aimed to examine colorectal cancer incidence and mortality after a single flexible sigmoidoscopy screening and 17 years of follow-up
Key findings: A single flexible sigmoidoscopy continues to provide substantial protection from colorectal cancer diagnosis and death, with protection lasting at least 17 years

"An ounce of prevention is worth a pound of cure." It's a proverb that dates back to the 13th century at least, yet its fundamental principle has driven medical researchers for centuries. And it's a principle that encourages people like Professor Wendy Atkin and her team in the Department of Surgery and Cancer to trawl through hundreds of thousands of patient histories to find the needle in the haystack.

But find it they did. Atkin has dedicated much of her career to the prevention and early detection of colorectal cancer – or bowel cancer – and her latest research could not only save lives, but could also save the NHS millions of pounds.

Around 40,000 people in the UK every year are diagnosed with bowel cancer, yet an even more sobering statistic is that more than half of these cases are preventable. One of the most common types of cancer diagnosed in the UK, bowel cancer mostly affects people over 55 and the current testing regime principally involves testing this age group every other year via a stool sample.

But Atkin's study of 170,000 patients aged between 55 and 64 discovered that a single sigmoidoscopy screening – a camera on a flexible tube which examines the lowest half of the large bowel – significantly reduced colorectal cancer incidence and mortality rates over a period of 17 years. That means one test is effective, rather than a series of them over a period of years.

Atkin says the findings have huge implications for the prevention of bowel cancer. "After lung cancer, colorectal cancer is the most preventable form of the disease," she says. "We can focus on prevention because we know that most cancers in the large bowel develop from a type of polyp called an adenoma.

"Adenomas tend to be small and most can be removed during the screening test. About one in 20 people will already have a larger adenoma that can be easily removed at colonoscopy, which examines the whole large bowel. Finding a cancer is extremely rare and the test is very quick and safe," says Atkin. "We were previously aware that the duration of protection from such a screening was 11 years, but the discovery that it is still effective after a median of 17 years makes such prevention extremely cost-effective."

The UK Flexible Sigmoidoscopy Screening Trial (UKFSST) – the largest and longest ever clinical trial into the prevention of bowel cancer – began in 1996 and invited one third of the participants to have the screening test. And despite examining only the lower part of the colon, the screening was found to prevent 35 per cent of cancers anywhere in the bowel and 40 per cent of all bowel cancer deaths. The sigmoidoscopy screen is now being rolled out across England at the age of 55 as part of the NHS Bowel Cancer Screening Programme.

35%
Prevention of cancer anywhere in the bowel

40%
Prevention of all bowel cancer deaths

Atkin's work is of benefit to the NHS as well as to individuals. "Our work focuses on providing protection from bowel cancer for people at risk in the most cost effective way," says Atkin. A second research paper published by her team earlier this year aimed to determine if the repeated colonoscopies, currently recommended after removing large or multiple adenomas from the large bowel, are necessary to prevent the future development of cancer.

After a median of eight years' follow-up of these patients (who are deemed to be at intermediate risk of cancer), around a third had a risk of cancer that was lower than the general population and really did not need further colonoscopies after removing their adenomas. The other two thirds were at higher risk but they found that just one colonoscopy reduced their risk by half.

The researchers suggest that their finding that a proportion of patients don't need surveillance (and that the rest need much less surveillance than currently thought) will affect future national and international guidelines on management of these patients. With colonoscopy costs around £400 a time, any review of the necessity of such regular surveillance in some patients could save the NHS millions of pounds.

Following her latest research, which was funded jointly by Cancer Research UK, the National Institute for Health Research and the Medical Research Council, Atkin is determined more work can be done. "Future studies should examine whether alternative, less costly strategies to surveillance colonoscopy might suffice for some patients," she says.

"The fact remains, many people who develop bowel cancer, many of those who die from it, do not need to. Bowel cancer can be prevented. The more effective, and the more efficient our screening programmes, the more people can be saved." ◆

WORDS: PETER TAYLOR WHIFFEN

ADVENTURES IN…

Life sciences

Professor Robert Ewers is on a mission to save the planet and change human behaviour – one rainforest at a time.

Words: **Lucy Jolin** / Photography: **Chi'en C. Lee**

Deep in the rainforest state of Sabah, Malaysian Borneo, an area of forest is being cleared to make way for a palm oil plantation. But what makes this deforestation different is that scientists are on site, recording exactly how the clearance affects the plants and animals that make the forest their home – everything from the stress that habitat change causes bats to the discovery of a rare pheasant.

This is the Stability of Altered Forest Ecosystems (SAFE) project, one of the world's largest ecological experiments. It's managed by the South East Asia Rainforest Research Partnership (SEARRP) in close collaboration with Imperial College London, and is the brainchild of Professor Robert Ewers of the Department of Life Sciences.

The only way to understand how we can correctly manage forest clearance, he says, is to study its processes. "We need to know what the forest was like before the impact, so you can compare directly," he explains. "Before the project started, I had to find a place where a change was about to happen, so that we could get there and monitor that forest before, during and after the change."

Tropical forests make up a relatively small area of the Earth: about 10 per cent of the world's terrestrial surface. But their impact is huge: they support roughly 1.5 billion livelihoods; they are one of the biggest terrestrial carbon sinks, in that they pull carbon out of the atmosphere and store around 50 per cent of the world's above-ground carbon; and around 50 per cent of all terrestrial species – vertebrates, invertebrates and plants – is supported by forests.

Humans impact forests in two main ways, says Ewers. "One is clearing the forests, typically to make space for agriculture. That's about as extreme an impact as you can get. The other mostly falls under the broad category of resource extraction – logging, bushmeat hunting for food, fishing and harvesting all those non-timber products – usually for food, but sometimes for medicine as well."

Above: Laying out plastic sheets to intercept rainfall as part of a drought experiment.
Above left: Attaching a tree tag to uniquely number a sapling.
Below left: Using calipers to record the diameter of regenerating trees.

And what happens to those forests in Borneo or Brazil will resonate across the globe. “Climate is a big global equaliser,” says Ewers. “In a nutshell: if you don’t want climate change on your doorstep, don’t stuff up the tropics and the forests. Tropical deforestation accounts for around 15 per cent of global carbon emissions. If you can stop that, you can have a noticeable effect on the rate of climate change.”

It’s hoped that the SAFE project in Borneo will play a part in that process. It’s now been going for seven years and the forest is almost cleared. The next stage of the research will be taking the empirical observations and using that data to try and predict how the entire ecosystem might be affected.

“The world already has tree models, biodiversity models and carbon models, but stitching all those things together at a single site hasn’t been taken on yet,” says Ewers. “The aim is to find better ways of doing agricultural expansion and designing the land that’s left behind. For example, perhaps we can find ways where we can sacrifice, say, 10 per cent of the agricultural value but in return gain 30 per cent extra biodiversity value, just by leaving one or two pieces of forest behind.”

But, he emphasises, the project isn’t about banning humans from forests. Rather, it’s aiming to find ways in which agricultural expansion can take place while minimising environmental cost. People need money, he points out, and agriculture is a perfectly valid way of doing that. “Palm oil plantations, for example, employ around half a million low-skilled people in Malaysia alone. It’s hard to imagine what they would be doing for a living without large-scale agriculture. We have to recognise that reality and learn how we can have agricultural expansion, but do it while minimising the environmental cost.” ◆

If you don’t want climate change on your doorstep, don’t stuff up the tropics and the forests

MY IMPERIAL

Serpentine surprise

Kunal Bhatia (MSci Physics) says a coffee by the Serpentine is the best way to cope with pressure.

Words: **Lucy Jolin** / Photograph: **Joe McGorty**

During the winter of my first term I discovered the Serpentine Bar & Kitchen in Hyde Park. I'd just been wandering around, exploring. It was cold, so I went in and had a latte, and I've been a regular ever since.

The café is another side of my Imperial experience: the side where we have to develop our own ways of coping with those high-pressure moments. As a theoretical physicist, I don't spend a great deal of time in the lab, but there's a lot more mathematical work, so I tend to be in the library an awful lot. This year I'm doing my Master's on modelling tropical cyclones, so I'll be in front of a computer. You need somewhere to go to get away from the books and screens.

Flying is also my thing: I'm currently captain of the Imperial Pilot Society and I hope to be a commercial pilot one day. It fits with my degree very well in terms of the technical side, but also in terms of learning to stay calm in stressful situations – landing a plane, for example!

So, going to the Serpentine is all about being somewhere completely different, where I'm not thinking about science. It's a way to get a little bit closer to nature, sitting in front of the lake, watching the ducks go by. When I'm there, I think about nothing – and that's so valuable.

I also have a happy association with the place. In my second year, I interviewed for the Royal Air Force University Squadron, a reservist squadron of the RAF. After my interview, I went straight to the Serpentine café, and it was there that I got my email offer to join.

I love the café all year round. In the cold of winter, when there are fewer tourists, it's always nice for a hot coffee. But it's probably at its most beautiful in the autumn, when the academic year starts again and when the leaves start to colour and fall. I know that in 10 years or so it will be a wonderful place to go back to: to remember both the hard and the good times I had at Imperial.

Kunal Bhatia is in the fourth year of his MSci Physics with Theoretical Physics course.

When I'm there, I think about nothing – and that's so valuable

“It’s incredible to know that there are people generous enough to donate to support students. This has definitely served as an inspiration during my course, as well as providing a financial support so that I can pursue opportunities during my time at Imperial.”

– Mohammad Fallaha, Medicine 2017, President’s Scholar

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