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imperial/74

THE MAGAZINE FOR THE IMPERIAL COMMUNITY

SPRING 2018

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Nicola Pogson, Director of Alumni Relations

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To join the Imperial Plexus community, please make sure your email address is up to date and watch out for your unique activation link in your inbox.

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Imperial/44

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Cover shows P. aeruginosa PAO 1 bacterium in a lung representation.

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YBM

Letters

WRITE TO US
Email: imperialmagazine@imperial.ac.uk
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Please mark your letter 'for publication'. Letters may be edited for length.

Access all areas

Your readers' recollections (*Imperial 40*) remind me of exciting aspects of my undergraduate years at Imperial.

In 1964, the Old Imperial Institute Building stood empty before work commenced on underpinning the foundations of the Queen's Tower. In those days it was possible to enter the heating tunnels under Southside, then, in almost total darkness, find your way to the base of the tower and very carefully climb to the top. It was considered very dangerous, but the views from the top were breathtaking.

When the Queen's Tower refurbishment was completed (around the late 1960s) we were still able to gain access from underneath. On one occasion, we climbed down a vertical shaft above the main Queen's Tower door, removed (from inside) the external security lock, took it to the workshops under Mech Eng, dismantled it and fabricated a new key – enabling us access to the Queen's Tower whenever we wanted. I think we started at midnight and had the lock back in place by 4am, and I don't believe anyone ever found out about our expeditions.

On leaving Imperial, we took our professor down to the Ennismore Arms (a pub in the mews behind Southside; long since gone) and described our exploits. He was stunned, particularly when we gave him the Queen's Tower key (we never knew if he ever passed it on … or used it himself!).

I still enjoy my visits back to the university whenever I'm over from Australia. Congratulations on the new Alumni Visitor Centre by the way; very impressive and a great coffee machine!

Dr Ian Merker
(Electrical Engineering 1967, PhD 1971)

Fascinating read

As an Imperial alumnus in New York, I want to say that *Imperial* does a great job engaging and connecting alumni to what is currently happening at College. The stories, particularly on research and student innovation, are very informative – even inspiring.

Virtually every article in Issue 43 was a fascinating read, especially those on photosynthesis and Ebola. The photographs in photosynthesis were near gallery-worthy, which is commendable for a science article.

Ian D'Costa Correia
(Electrical Engineering 1989)

Better representation

Reading the letter entitled 'Chemistry memories' (*Imperial 43*) , when John Ault recalls just three ladies in a total of 3,000 undergraduates, it brought to mind the experiences of my sister, Mary Hesse (Mathematics 1945, PhD Chemistry 1948), who was studying at the Royal College of Science towards the end of the war. Out of 120, there were seven women, so they are slightly better represented than a decade later.

Being a woman in the overwhelmingly male world of academia, Mary was affected well on into her career as a Philosophy of Science Professor at Cambridge. In the 1960s, as one of the few female lecturers, her first five years there were made difficult by the male-dominated establishment.

This all changed when Mary became a Fellow of the new Wolfson College, where she held the position of Vice-President for some time and travelled the globe as a world-renowned lecturer in her field. It is nice to think that it all began at Imperial.

Richard Hesse

More from the mailbag

We are delighted so many of you took the time to give feedback on your Imperial connection through the recent alumni survey (and you can find more details on the results of the survey on page 8 of this issue).

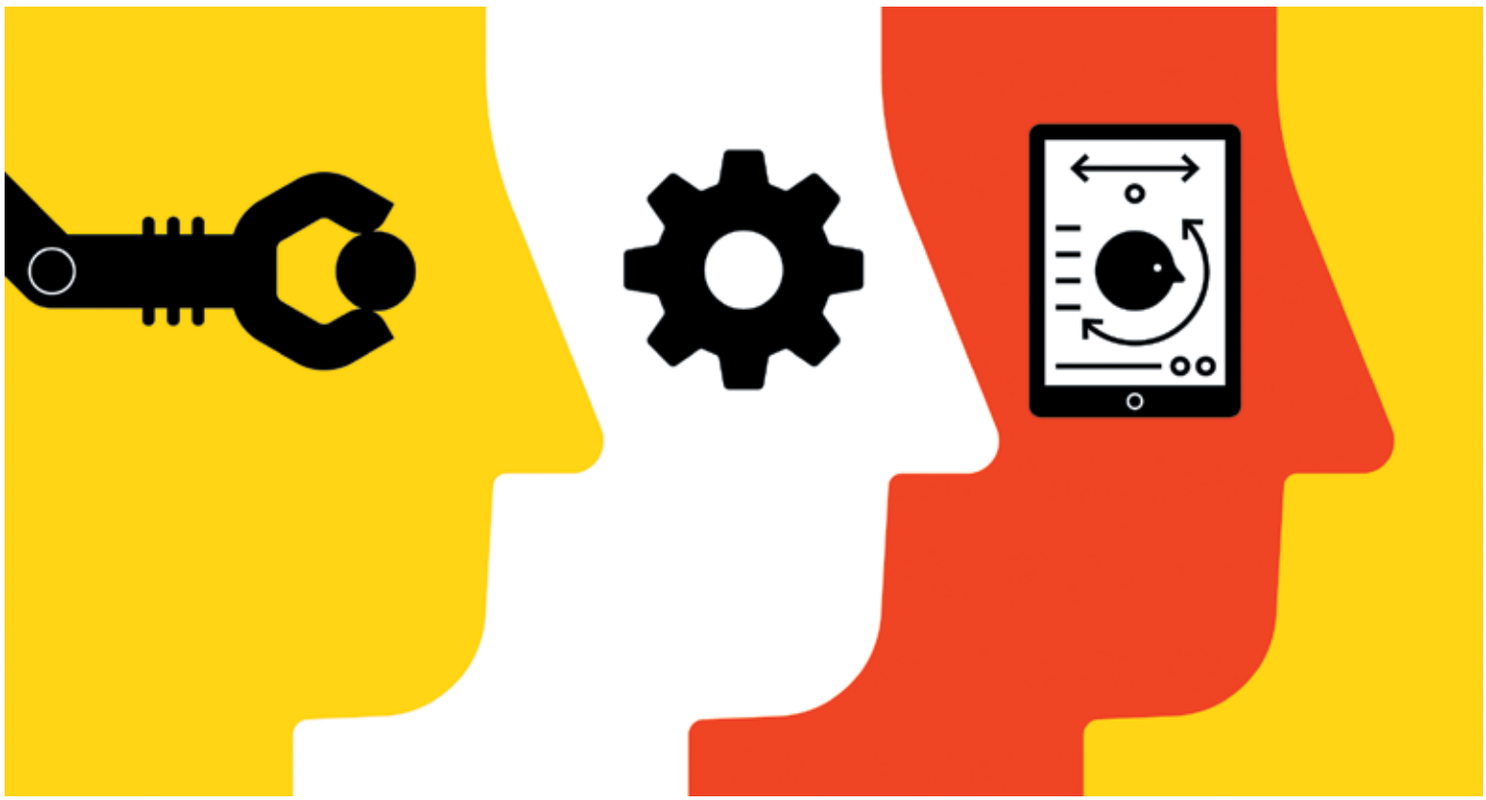
Jane Pairman (Biochemistry 1983) says: "Just the way [*Imperial*] arrives makes you feel like you are important – they are sending a magazine to the other side of the Earth for goodness sake! I'm grateful the alumni office keep sending me the magazines and emails; they don't let me forget, and if I make a connection, they reciprocate. "The alumni bulletins are nice because it's a digest and it's not so frequent that you don't read it," says Laura Elizabeth Simmons (Life Sciences 2013, MRes Medicine 2016).

Judicaelle Hammond (MBA 2014) writes to say: "The newsletters keep me abreast of what is going on. As I still live in London, I make a point of going to the Imperial Festival every year with my family, so it all takes me back to campus quite literally."

And according to Adam Tan Mohd Amin (MEng Bioengineering 2008): "I didn't know the effect of graduating from Imperial when I was there. I didn't realise the impact it would have on my life, so when I tell people in Malaysia now that I studied at Imperial they are impressed. It's a good feeling to have that connection and to stay in touch."

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

DIGEST



ILLUSTRATIONS: THIS PAGE: THE PROJECT TWINS. OPPOSITE PAGE: MIKE LEMANSKI

DESIGN ENGINEERING

New Dyson building leads culture of innovation

Some of the most innovative and experimental minds in the world will soon be under one roof, once the new Dyson School of Design Engineering building completes its transformation later this year.

The former Edwardian post office, later owned by the Science Museum, is expected to become one of the most exciting spaces at Imperial.

"The great thing about the School is that everybody is involved in highly innovative and transformative projects," says Professor Peter Childs, Head of the School. "Whether student originated or knowledge developing from research, the scope is immense and highly diverse. It's a pleasure to be a little part of future history."

A key facet of the School is design through prototyping – whether it's a physical or non-physical project, it prototypes and tests with users and stakeholders in order to explore a project's viability and work towards its improvement.

And it's with that focus in mind that the heart of the building has been designed. Housed over five floors, it has a 90-seat lecture theatre, boardroom and library, of course, but with much of the focus being on hands-on, practical coursework, there's also an emphasis on creative spaces, such as the Robo-Studio and open teaching spaces on the upper floors.

According to Childs: "The provision of workshops, studios and laboratories embedded in the heart of the School will all serve to drive an innovation culture, to provide the products, services and systems of tomorrow."

The Dyson School of Design Engneering's research focus is on three main strands: human factors (e.g. ergonomics and the development of audio-visual innovation); advanced manufacturing and robotics (including machine learning and 3D printing); and engineering design.

FROM THE PRESIDENT / PROFESSOR ALICE GAST

"Our focus on prevention, early intervention and mental and physical health is as important locally as it is around the world"

On a recent family walk in Nunhead Cemetery, I was struck by the stark history of longevity in the tombstones. Recorded there are so many touching memories of babies and children dying in their early months or years in the late 19th century. Of course, this is a reminder that we can be grateful for important improvements during the industrial revolution that have greatly reduced childhood mortality.

Now we are entering another era of discoveries and advances that will improve health and wellbeing. As you will read in this issue, our understanding of not only our genetic makeup, but also the genome of the thousands of bacteria that make up our 'microbiome', is giving us unprecedented insight into the causes of diseases, their course and our susceptibility to them. For instance, our colleagues have made an exciting breakthrough by looking at lung diseases in a new way, from the understanding of the lung microbiome. Combining easier and more rapid sequencing with a curiosity questioning the standard thinking, we have the possibility to treat, and perhaps one day prevent, many lung diseases.

Opportunities such as this come from the great research occurring throughout Imperial and from collaborations around the world. The impact of such discoveries come together in our world class School of Public Health. Diseases are not contained by borders and world health has been a sustained focus of Imperial's forefront research and education. Sustained global efforts have reduced the burden of disease faced by populations worldwide. Major contributions from Imperial have led to new understandings and developing interventions that have dramatically reduced major infectious killers such as HIV, malaria and TB. We work where needed and we are needed where we work. Now we are needed right here in London.

We are engaged in a significant campaign to raise £100m to bring our outstanding Public Health academics, students and practitioners to a new state-of-the-art facility on our White City Campus. On this campus, a ten-minute walk from our Clinical Trials unit and excellent researchers at Hammersmith Hospital, the School will also have molecular sciences and bioengineering collaborators, housed in the Michael Uren Biomedical Engineering Research Hub (to open in 2019). Never before have we had so much opportunity to improve health and wellbeing. Technological innovations are breaking down barriers, bringing insights from abundant data, and providing advances in areas such as medicine, nutrition, mental health and children's health. With one of the world's leading Schools of Public Health embedded in a top-flight medical school and with strong collaborations across disciplines, Imperial's research is improving health and wellbeing through medical interventions and opportunities for prevention.

> We work where we are needed, and right now we are needed here in London

We need to bring this talent to White City, where lifespans are 8.5 years shorter than the London average, and where children suffer from asthma, tooth decay and extractions, obesity and other chronic and preventable diseases. Imperial is already making a difference in the community through The Invention Rooms, and by collaborating with the local residents, listening to their ideas and needs and supporting their local efforts alongside our own. We are building relationships, developing opportunities and helping improve future prospects of our new neighbours.

As we move our School of Public Health to White City, we have an important opportunity not only to coalesce our great academic talent, but also to bring research discoveries and educational programmes to address the serious health challenges in this community on our doorstep. Our focus on prevention, early intervention and mental and physical health is as important locally as it is regionally and globally. Public health based upon modern evaluation of population and community needs, combined with a focus on prevention, will make all the difference to this community and to the rest of the world. I hope that you will visit us soon and join us on this important mission.

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

ENTERPRISE WEEK

Innovation overload

Game-changing inventions and transformative new technologies were just two of the highlights of Imperial's Enterprise Week 2018, organised by the College's Enterprise Lab.

Bringing together Imperial's community of innovators, the series of events, exhibits and Dragons' Den-style competitions demonstrated just why the College is ranked the UK's most innovative university by Reuters.

In fact, Imperial now boasts more than 136 active startups founded by members of the Imperial community, which together support more than 1,300 jobs and generate close to £900m of investment since 2012.

One current student, Saujanya Vruddhula (below) from the Department of Life Sciences, won £15,000 through WE Innovate, a personal and professional development programme aimed at women studying at Imperial. Her startup, Oggic, aims to stop counterfeit drugs entering the market using blockchain technology. "With the support of the Enterprise Lab," says Vruddhula, "I've created a business which could save both lives and vast amounts of money for industry."

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

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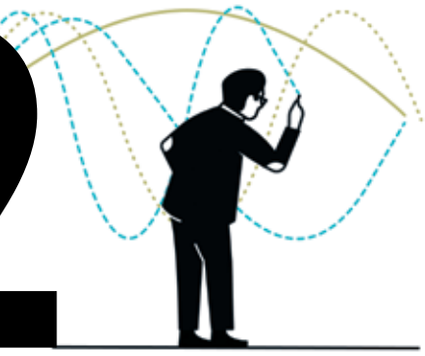

According to *The Hitchhiker's Guide to the Galaxy*, 42 is the answer. But what is the question? Professor Martin Hairer, Professor of Pure Mathematics, says it's all about understanding the truly random.

Martin Hairer, Professor of Pure Mathematics and Chair in Probability and Stochastic Analysis, says his big question centres on explaining what happens when properties behave randomly, such as when liquid is stirred or a sheet of paper burns unevenly. This could potentially have applied technological uses: in machine learning, for example, where a neural network's reasoning is not always evident, even when it produces the correct result. But that's not something he dwells on. "As a pure mathematician, I'm aiming to better understand the world," he says. "It's not about using that knowledge to build a gizmo or set up a company, it's more of an intellectual challenge."

In 2014, Professor Hairer was awarded the Fields Medal, the highest honour in mathematics, for his work on stochastic partial differential equations (SPDEs), which are often used in physics to describe the random outcomes that result from random inputs. Hairer says that while they may seem to account for the way a system behaves, they don't always stand up to mathematical scrutiny.

"When you look at these equations more closely, you realise the solutions are too irregular for the equation itself to actually have any meaning," says Hairer. "I've been working on a general theory that allows us to give intrinsic meaning to these equations."

His next task will be to not only ensure this theory works mathematically, but to test it against increasingly accurate representations of real-world situations. However, he points out that progress often doesn't happen overnight – one famous mathematical theorem was first discussed in the 1780s but not fully understood for another 150 years. So a fuller understanding of why random distributions of random variants behave as they do is still some way off. Even then, there will be more work to do. "This is relatively open-ended," Hairer says. "You never really end up with a theory of everything."

OVERHEARD ON CAMPUS

Radiation reaction
The dynamic reaction of light hitting electrons, demonstrated in a lab for the first time by Imperial researchers using an ultra-intense laser beam.

Molecular machines
Miniaturised machines, such as a tiny lift, artificial muscles and minuscule motors, with controllable movements at the molecular level when energy is added.

Organ-on-a-chip
Simulated human organ technology, uniquely used by Imperial scientists to test the impact of viral infections (specifically hepatitis B) on an artificial liver.

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IMPERATIVE / DR ANA COSTA-PEREIRA

"Knowledge is always changing but the skills required to apply it are timeless – and essential"

Why is everyone so obsessed with knowledge? I'm sure that sounds strange coming from the head of a biomedical sciences degree programme – but knowledge is temporary; it changes. Of course a solid knowledge base is fundamental in any field, but, often, advances are so quick that what we know at any given point is soon superseded and may even become obsolete as it is replaced by new discoveries.

Most factual knowledge doesn't even need a person – a lecturer – to impart it. We can provide it online and students know very well how to Google. And, accepting that, how can we give our students the best, most valuable learning experience during their time at Imperial and prepare them for the future?

That was our starting point when we designed the BSc Biomedical Sciences. We were fortunate to be given a blank sheet and the freedom to redefine what a 21st-century biomedical science undergraduate programme should be like. We went wild and looked far beyond the College, asking: "What will biomedical research need in ten years?"

The answer was to focus on current human health challenges and to interweave transferable skills along the curriculum. Rigorous scientific knowledge remains hugely important, but we need to teach our students to think like scientists, and to know what to do when they don't know what to do. And so we designed what we think is a ground-breaking course that does just that.

For a start, we focused on 'flipped learning'. We provide e-learning modules for students to complete before coming together with academics, turning what might once have been a one-hour lecture of passive note-taking into a three-hour discussion and practical session in which students apply what they've already learned to practical tasks academics give them. It enables them to engage on a much deeper level than just taking notes in a lecture theatre – and it builds teamwork, leadership and communication skills.

But our real revolutionary teaching comes with our 'Lab Pods'. Again, we started with a blank sheet of paper – what we came up with aren't student labs, but recreations of real-life research labs with high-spec, state-of-the-art equipment. You can't teach for the future using tools of the past.

But it's less about fancy equipment than how students learn. We don't say: 'Class, today we'll learn about this', and give them a protocol to follow. We don't even give them a project – we give them news cuttings from reputable and not-so-reputable journals, with interviews from a real patient, oncologist and research nurse, to get the full perspective, then ask them to discuss and come up with their hypotheses. Within an hour the board is covered in ideas and then we say: 'So how will you prove it? What do you need?'

Our first-year undergraduates are thrown in at the deep end, in a real lab, in real time – we encourage them to discuss and to formulate; independently, individually and in groups. They have much less traditional scaffolding around them: we just ask lots of questions, they find the answers. And then afterwards there's a lot of reflection time assessing how things went, in terms of process and teamwork, and noting any possible areas of improvement.

Why is this different and important? Because we are fulfilling our own brief – to develop analytical graduates who think like scientists. It makes them much more fully formed, ready to hit the ground running when they go into business or research. They leave here with a more resilient understanding of what to do, with a deeper level of learning than many other graduates, knowing how to use a real-life lab – but also understanding how and why they work as they do; able to assess, analyse, reflect and, if needed, adapt.

> Students are ready to hit the ground running, whether they go into business or research

It's not often you get the chance to re-invent something completely from scratch, and I'm not sure it could happen anywhere but Imperial. Knowledge will continue to come and go, but having the skills to apply it, to work with it for the good of society, is the most valuable asset we can give our students, and the wider world.

> ***Dr Ana Costa-Pereira*** *is Head of BSc Medical Biosciences (BMB) programmes in the Faculty of Medicine at Imperial College London.*

Test your brain power

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

1: HARD

I have a rectangular bar of chocolate consisting of four rows of three small chocolate squares each. Being of a generous disposition I want to divide the bar into the 12 small squares to give to my friends. I can break the bar in many different ways. For example I might start by breaking it into two 2x3 bars or perhaps three 1x4 bars and then subdivide the resulting pieces. At each stage a cut is made along a single straight line between some of the small squares until all 12 squares of chocolate are separated (no stacking of one piece on top of another is allowed as it makes too much of a mess!).
Is there a method for doing this that involves the least number of such cuts?
From: Dr Lynda White, Principal Teaching Fellow in Experimental Design in the Department of Mathematics

2: VERY HARD

A general decides to count the number of soldiers in his battalion. When he tries to line the soldiers up in threes, he finds that he has one soldier left over. He then tries to line them up in fives and there are three soldiers left over. Finally, he attempts to line them up in rows of seven and there are two soldiers left over.
How many soldiers are in the battalion? Is this the only answer?
From: Melissa Lee, Research Postgraduate, Department of Mathematics

ALUMNI SURVEY

Thank you for your feedback

Ninety-two per cent of our alumni say that they have had a positive experience studying at Imperial, and seventy-five per cent are satisfied or extremely satisfied with this magazine, according to the latest alumni survey.

Findings reveal strong feelings of warmth and pride towards the College, with a majority of alumni indicating that they would recommend Imperial to prospective students. Feedback on our communications with alumni, events, services and benefits will be critical to planning over the next few years.

As Nicola Pogson, Director of Alumni Relations, notes: "We have gained invaluable data-driven perspectives into our alumni community. While our current events and communications are valued by alumni, we have identified different needs and interests based on their career stage. Imperial Plexus, our new online alumni community platform, responds to a greater interest in engaging online, and we've also seen that alumni are motivated to connect both with each other and with the College's current students and staff."

> *For more insights from the survey, visit the website at: www.imperial.ac.uk/alumni/survey*

IN BRIEF

New partnership
A major new research partnership, led by Imperial and UCL and funded by £10m from the Wellcome Trust, will explore ways of reducing health inequalities in cities around the world.

Mary Wells is Lead Nurse
Professor Mary Wells, recently appointed Lead Nurse for Research at Imperial College Healthcare NHS Trust, will work with Imperial to grow the research capacity and capability of nurses, midwives and research practitioners.

AI learning online
Some of the world's top researchers in artificial intelligence (AI) will be leading a set of three online courses – Mathematics for Machine Learning – as the College launches its first Massive Open Online Courses (MOOCs) with Coursera.

Imperial podcasts
The latest in the Imperial podcast series, featuring lecturer and BBC World Service broadcaster Gareth Mitchell, is now available. Visit imperial.ac.uk/podcast

3: FIENDISH

A prime is a whole number only divisible by itself and 1, so the lowest primes are 2, 3, 5, 7, 11, etc. The number of primes thins out quite dramatically when you go higher – there are 25 primes between 0 and 100, 16 primes between 1,000 and 1,100 and just 11 between 10,000 and 10,100. But do they run out altogether or are there infinitely many? And how can you be sure?
From: Dr Daniel Mortlock, Lecturer in Astro-Statistics, Department of Physics

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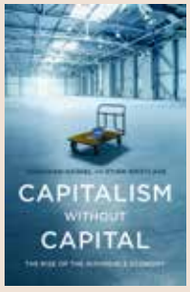
Senders of the first ten correct solutions for two or more of the puzzles will receive a signed copy of Professor Jonathan Haskel and Stian Westlake's new book, *Capital Without Capitalism: The Rise of the Intangible Economy* (see p22).



Please send completed answers by email to the website at: imperialmagazine@imperial.ac.uk. Entries close Friday 27 July 2018.

Solutions and winners will be printed in *Imperial 45* in November 2018 and online at www.imperial.ac.uk/be-inspired/magazine from August 2018.

WORLD ECONOMIC FORUM

Our President at Davos

Imperial's potential for invention and innovation was one theme of Professor Alice Gast's message at the World Economic Forum in Davos recently.

Speaking alongside the entrepreneur Tony Elumelu, Crescent Enterprises CEO Badr Jafar and Black Eyed Peas frontman will.i.am, Gast said: "We want our teams to have the opportunity to try some really outlandish things. It's important that we get the discoveries in research out into society as quickly as possible", whether that's through startups, corporations or Imperial academics working on low-cost "frugal innovations".

> We want our teams to have the opportunity to try some really outlandish things

ILLUSTRATIONS: MIKE LEMANSKI

Test tube

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

WHO Nikos Moraitakis (Computing 1999)

WHAT Our company, Workable, makes software to help organise and run the recruiting process, from advertising jobs and scheduling interviews to collecting feedback about prospective hires. We are growing at 70 per cent per year and 6,000 companies currently use our software in 80 countries.

HOW Most companies do a better job of hiring if the directors are also hiring managers. However, directors don't have the time to look at 200 résumés, so the HR department does it for them. That means the director/hiring manager cannot steer the hiring process to better outcomes. We give them an online applicant tracking system so that hiring teams can collaborate on the sourcing and evaluation of candidates.

INSPIRATION My co-founder Spyros Magiatis and I are both software engineers, so we wanted to build something that was product-centric. We'd encountered large enterprise recruitment software, and wanted a better tool for running our hiring process – so we made it. It turned out we weren't the only ones who wanted it.

MOTIVATION If you start your own company, you get to determine what type of workplace it's going to be, and we wanted to create jobs that we would enjoy. Our customers are the small and many, not the big and the few.

THE FUTURE Machine learning will mean that instead of just automating workflow, software will increasingly define the process, provide us with the appropriate information and do a lot of the clerical work. This will make recruiting cheaper and smarter because we're going to spend more time talking to people and figuring out who's right for us, and less time in the surrounding processes. We hope to be one of the agents that brings about that change.

> *Nikos Moraitakis is co-founder of Workable, a recruitment software company based in Boston, US and Athens, Greece.*

RESEARCH FOCUS / POLICY AGENDA
PROFESSOR GARY FROST
CHAIR, NUTRITION AND DIETETICS

“Malnutrition is one of the world’s greatest health challenges, but the humble legume could hold the key”

THE PROBLEM

When populations eat too much, and become obese, that’s a big problem. When they can’t eat enough, and suffer from malnutrition, that’s also a big problem. Yet these two issues don’t exist in isolation from each other: many low to middle-income countries are now carrying this double burden of both over- and under-nutrition. Professor Gary Frost, Chair in Nutrition and Dietetics and head of the Nutrition and Food Network, believes there could be a food-based solution.

A FOOD-FOCUSED SOLUTION

That solution is urgently needed. People who are overweight or obese are more likely to develop Type 2 diabetes: a recent study in the journal *Diabetes* pointed out that the condition has now “attained the status of a global pandemic”. A 2016 *Lancet* study estimated that the cost of treating all diabetes worldwide is $825bn annually. The costs of malnutrition, both human and financial, are just as staggering. The World Health Organisation says that around 45 per cent of child deaths globally are linked to undernutrition, while at the same time, rates of childhood overweight and obesity are rising. It calls the problem “one of the greatest global health challenges”.

PEAS AND BEANS

Frost believes the key could lie with the humble legume – peas and beans – as they have double benefits. At the recent World Economic Forum in Davos, Frost presented a pilot study in Kenya that showed, for the first time, that feeding legumes to malnourished children improved their gut microbiota, essential for good gut health. The legumes could also reduce the risk of sepsis in undernourished children. And they could help those who overeat, too. “Legumes potentially also have effects on appetite regulation,” explains Frost. “They suppress appetite when they are eaten in large amounts.”

A SYSTEM OF FOODS

The concept, says Frost, is to create one product to help solve these two very different but symbiotic problems. “Or it could be a system of foods that can be grown in local communities, which impact both over- and under-nutrition. We have a long way to go, but we hope that in a number of years’ time we will have some kind of methodology that can be put into local communities, and policy can be written around it. This would encourage local populations to grow and eat legumes, to reduce the impact of these very costly conditions.”

REAL-WORLD APPLICATION

Real-world application is key in Frost’s research: the science is one thing but translating that to vastly different cultures and conditions is quite another. “If you are dealing with food, you need to understand how that food can be grown in different communities and different settings,” says Frost. “We are working with experts at the John Innes Centre to help us understand what crops will deliver the functionality that we want. We are also working with Dr Lesley Drake at the School of Public Health. She is director of the Partnership for Child Development, whose aim is to set up policy and education systems with low- to middle-income countries, and she is helping us with the question of how you drive this into local environments, to make a difference.”

GROWTH POTENTIAL

The work, says Frost, is just beginning. “There are massive unknowns around this area. We don’t even have a methodology that gives us reliable data on what people eat in their home environment, for example, but we are working on that, too. We have a great opportunity here.” ◆

> ***Professor Gary Frost*** *presented his findings, “Food solution to the double burden of malnutrition”, to global leaders at the World Economic Forum at Davos in January 2018.*

MATHEMATICS RESEARCH

New joint maths laboratory launches

Two of the world's best and Fields Medal-winning mathematicians, Imperial's Professor Martin Hairer and Professor Cédric Villani, opened a new joint laboratory set up by Imperial and France's National Center for Scientific Research (CNRS).

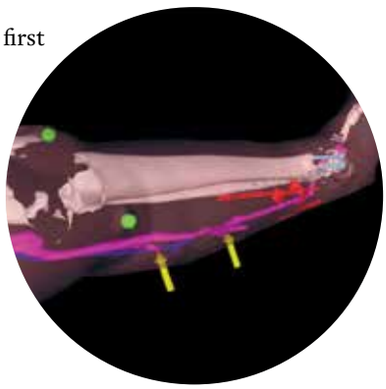
The new international research unit, named UMI Abraham de Moivre after the great French mathematician, will be based at the South Kensington Campus, and will integrate researchers and students from both institutions to advance understanding in areas such as number theory, biomathematics and financial mathematics.

HEALTH SCIENCE

Augmented reality breakthrough

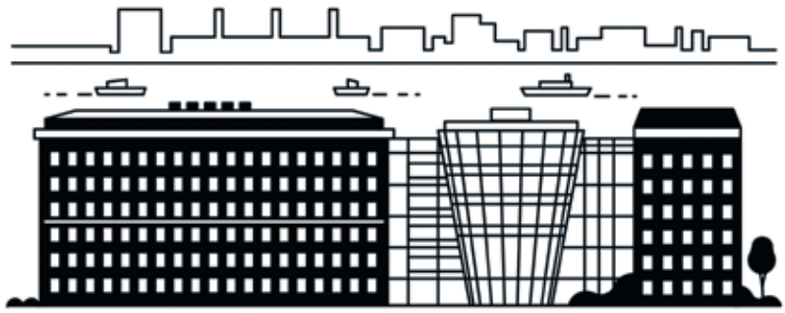
Augmented reality is coming out of the arcades and into operating theatres, thanks to the pioneering work of a team of Imperial researchers. And the techniques could help surgeons to fundamentally improve the outcome of reconstructive surgery for patients.

The Imperial team at St Mary's Hospital used Microsoft HoloLens headsets to overlay images of CT scans on to patients' legs, in effect enabling surgeons to 'see through' limbs during surgery.



"We are one of the first groups in the world to use the HoloLens successfully in the operating theatre," says Dr Philip Pratt, a Research Fellow in the Department of Surgery and Cancer. "We can identify where the blood vessels are in 3D space and use virtual 3D arrows to guide the surgeon. This is a great example of what can be achieved in an academic health science centre."

ILLUSTRATION: MIKE LEMANSKI



A working life

Structural engineer and Vice Chairman of Thornton Tomasetti Áine Brazil says her workday essentials are confidence, humility – and a sharp pencil.

My working life is a tricky balancing act between accuracy and adventure, so the thing I need most is confidence in my ability, paired with a healthy amount of humility. It's important to get it right because public safety relies on our judgments, but you also need to be able to push the envelope to create interesting structures and meet the visions of the client and architect.

The most challenging building I've worked on is also my favourite: a lab for Rockefeller University on the east side of Manhattan which will open soon. It spans the FDR highway, which had to stay operational during nearly all the construction. It is 30 metres wide, which increases the chances of vibration problems, but it is filled with lab equipment, so it mustn't vibrate. Plus, we needed to clear a certain height over the highway, and the top had to blend into an existing park.

It was assembled on the Raritan river 40 miles away, shipped by barges before several 700-ton sections were lifted into place using a barge crane on the river, which we could only move at ebb tide. But all the constraints made it exciting. I could design a building tomorrow in a vacuum but there would be no challenge in it.

My husband John and I both grew up in Ireland but he was born in the United States. He is also a structural engineer, and we thought we'd come to work here for a couple of years and then go back. That was 36 years ago. I love New York because the variety is amazing. I usually have several ongoing projects. I worked on a development at Hudson Yards at the same time as I was finishing a hospital on the Upper East Side, and then I started a university project and a new terminal at LaGuardia airport.

Without my pencil I'd be pretty lost. We have wonderful young people here who use technology with ease, but we teach them that it's not all about computer models. You need to be able to understand, predict and visualise how a building will move, and you do that by sketching it out by hand first.

The best thing about this job is that you're learning something new every day. You're also contributing something to the environment that people will enjoy, that you can touch and feel, and that will hopefully be longlasting. There's an essential satisfaction to having an impact on the skyline of a city.

***Áine Brazil** (MSc Civil Engineering 1980) is a chartered engineer, a fellow of Engineers Ireland and vice chair of New York engineering firm Thornton Tomasetti. She has also been named as one of New York's '100 Most Influential Women in Business', according to Crain's New York Business.*

The performing brain

Whether for an audience of one or thousands, performance does interesting

Words: **Megan Welford** / Photography: **Andrew Swannell** / Stylist: **Vicky Lees**

Months spent poring over the score; hours spent in the rehearsal room; days going through the parts with your fellow musicians. And then the moment comes when you walk to the podium and the performance begins – for real. And something happens: to the quality, the energy, the tone.

According to jazz trombonist and physics tutor Samuel Sankey (Physics and Music Performance 2012), performance is "where the magic happens" – or, as Professor Henrik Jeldtoft Jensen, a professor at Imperial's Centre for Complexity Science, puts it: "Music is communicating the brain's excitations to the audience."

"Performance is incredibly exciting. It's why I play, it's why I practice. It's the buzz," says flautist Lois Ashenden (first year MBBS Medicine and recipient of an Ash Scholarship). "It's noticing the little things that I love, like the first sound of a violinist's bow hitting the string. Then the big, lavish moments. The silence of the pause at the end – you keep your instrument up, you can't put it down, you have to let the resonance hang in the air. There's a hesitation that no-one wants to break. You think, 'We did it!', and then the applause comes."

During performance those musicians are communicating not only with the audience, but with each other. "I find it hard to stand still," says Ashenden. "I've been told I move too much, that I should channel my energy into the instrument, but playing fills you with so much emotion you have to let it out somehow."

Dr Tania Lisboa, Imperial Research Fellow in Performance Science, says you can often feel the moment a performance becomes ▶

things to our brains.

extraordinary. “At times we see chamber groups who have been performing together for decades and the musicians seem to ‘feel’ each other,” she says. “They don’t need to look at anyone, they have the ‘feeling of presence’ and a small gesture is enough for them to know how to react musically. For new groups there is much more verbal communication.”

Jensen has for several years worked together with pianist Professor David Dolan and music psychologist Professor John Sloboda, from the Guildhall School of Music and Drama, to try to get under the skin of performance and understand what happens to musicians and their audience during improvised classical music. Through a number of experiments involving top-level musicians from Guildhall, they used electrodes (EEG) attached to the heads of the performers and audience to measure what was going on during performance, with and without improvisation, to better understand the different reactions in our brains.

The musicians were asked to play first in a ‘structured’ or ‘strict’ way, and then to improvise the interpretation, which they call ‘let go’. “We found that the brain activations in musicians and audience were much more similar during ‘let go’ performances, particularly during special moments in the music, which we sometimes refer to as having the ‘tingle factor’,” Jensen says. “During these moments the brain activity of musicians and audience, measured by EEG, was very similar.

“Our analysis suggests that during ‘let go’ there is a decrease in inhibition and self-awareness of the audience, and a decrease in the flow of information between the musicians.” This is interesting, because it suggests the musicians are communicating less, or perhaps less consciously, during improvisation.

Kneebone is interested in embodied knowledge: how the body learns and how

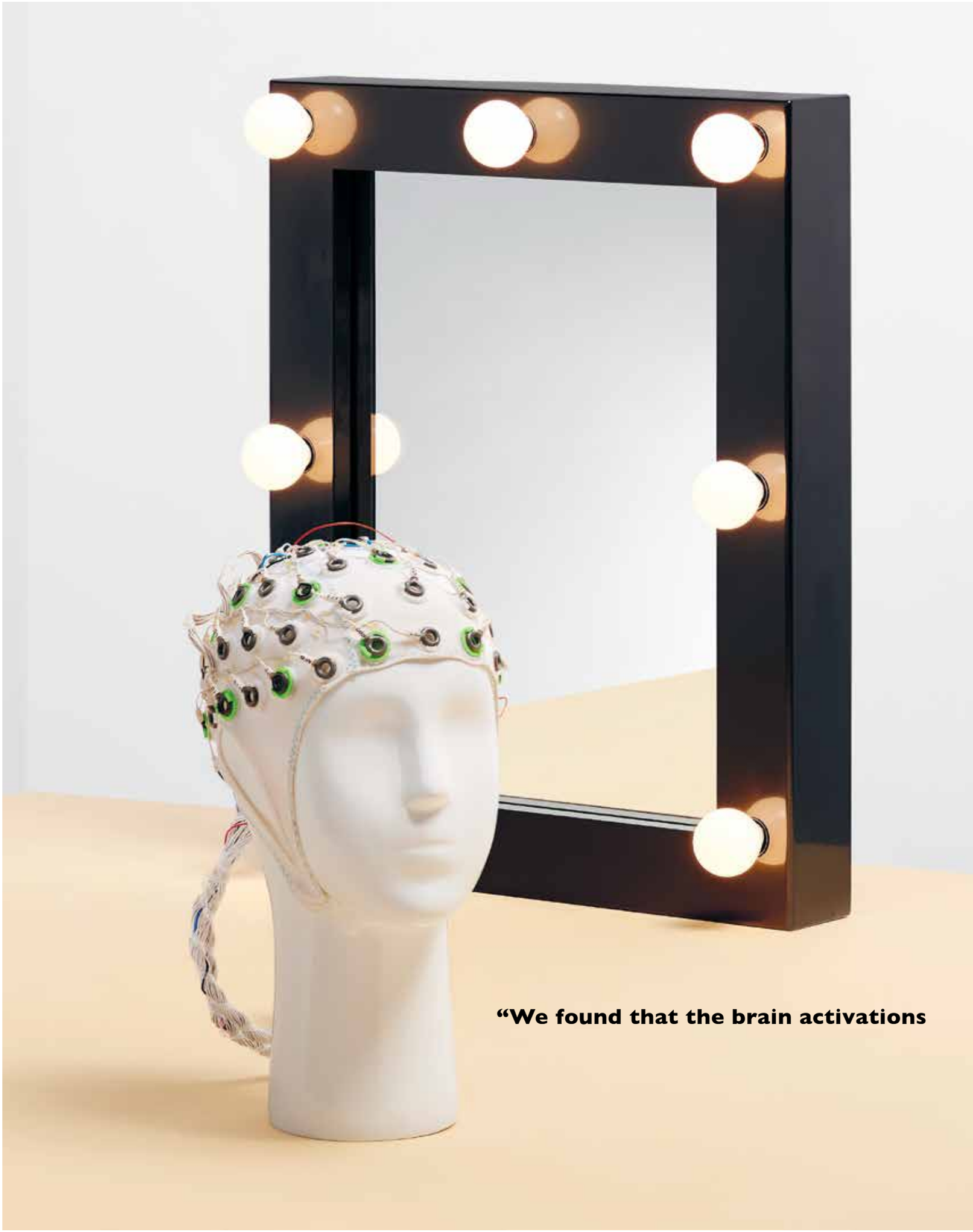
For complexity scientists, there are implications to studying how, for example, electrode number eight on the flautist relates to electrode number five on the harp, says Jensen. “We call this causal time series analysis. How different time series relate to each other helps us make sense of big data. For instance, how computer algorithms in finance influence each other.”

Sankey describes improvisation as “requiring computational power of the brain”. Jazz improvisation is something you do through hearing, he says, “but you have to work things out in your head. It’s instantaneous composition. There are rules – it’s easier if you know what the chord patterns are – but you have to keep them flowing through your brain.”

It’s all about connections, then, but not just the scientific ones. “The skill of performance is communication with the audience,” says Imperial’s Director of Music, conductor Richard Dickins (who will be retiring this year after 40 years of working with the UK’s finest musicians). “It would be possible to play the piano sitting motionless with no facial expression and your hands just whizzing around the keys, but that would be very dispiriting for the audience.

“It’s the same skill as a presenter, or an entrepreneur explaining their idea to stakeholders. If you’ve seen a good communicator, you will know. Actors are master communicators, so are chief executives. It is something we teach; we say performance is about what you see as well as what you hear: ‘Why is a live performance so much more vivid than a recording?’ But it’s also something you learn by seeing, recognising ▶

this impacts performance



“We found that the brain activations

and watching people who do it better than you. We say, with music, as with acting, the audience can see into your very soul through your eyes. You can't hide, so you might as well enjoy the feeling of letting go."

As we all know, performance is a nerve-racking business. "You have to love it," continues Dickins. "The lovely thing about being a conductor is you have your back to the audience, although someone once said to me, 'You have the most expressive back I've ever seen!' But as conductor I'm fully engaged with the musicians in front of me."

Professor of Surgical Education and Engagement Science, Roger Kneebone, believes science and performance are intricately linked, but in reverse: it's not the science of performance he's interested in, but the "performance of science". He believes that by noticing the ways that surgery, for example, is like performance, we can improve the way we do it. "Cutting out someone's stomach cancer, for example," he says, "what is the difference between a good and bad operation? It's to do with performance. People don't always do it well."

Kneebone is interested in 'embodied knowledge': the way your body learns to do things and how this can contribute to expert performance, in its broadest sense. He has set up 'serendipitous encounters' between craftspeople, musicians, artists and surgical teams.

"You could look at an operation as a group of people working together, doing dextrous things with their fingers," he says. As a result, lacemaker Fleur Oakes came to watch operations in the vascular surgery unit at Imperial's St Mary's Hospital, and is now developing a training programme for surgeons.

"The arteries of elderly patients with chronic diseases don't hold stitches well," explains Kneebone. "They break up. Lacemakers are used to handling fragile, delicate textiles, and develop deep sensitivity in their fingers. You can train surgeons to feel with their fingers when they can't see something. Repetitive knots, stopping threads snagging – these are also useful things for surgeons to learn. At first the medics found it a bit odd, but now they think it's useful."

He has brought together stone carvers and orthopaedic surgeons. "Stone carvers use chisels on hard materials, they listen to the sound the stone makes as the chisel strikes it," he says. "Orthopaedic surgeons making chisel-cuts in wrist bones do something similar. Stone carvers have a long apprenticeship where they start by learning to manipulate their tools; surgeons learn by taking part in operations. Other performers, such as puppeteers, warm up their fingers for 20 minutes before they perform, but surgeons don't. Why not? Musical quartets communicate without looking at each other, as a surgical team must do because they're looking at the patient. And each must think beyond their own part, to the bigger picture. Learning how physical dexterity relates to neurodiversity, and particular ways of learning, can allow us to perform better."

in musicians and audience were much more similar during improvisation"

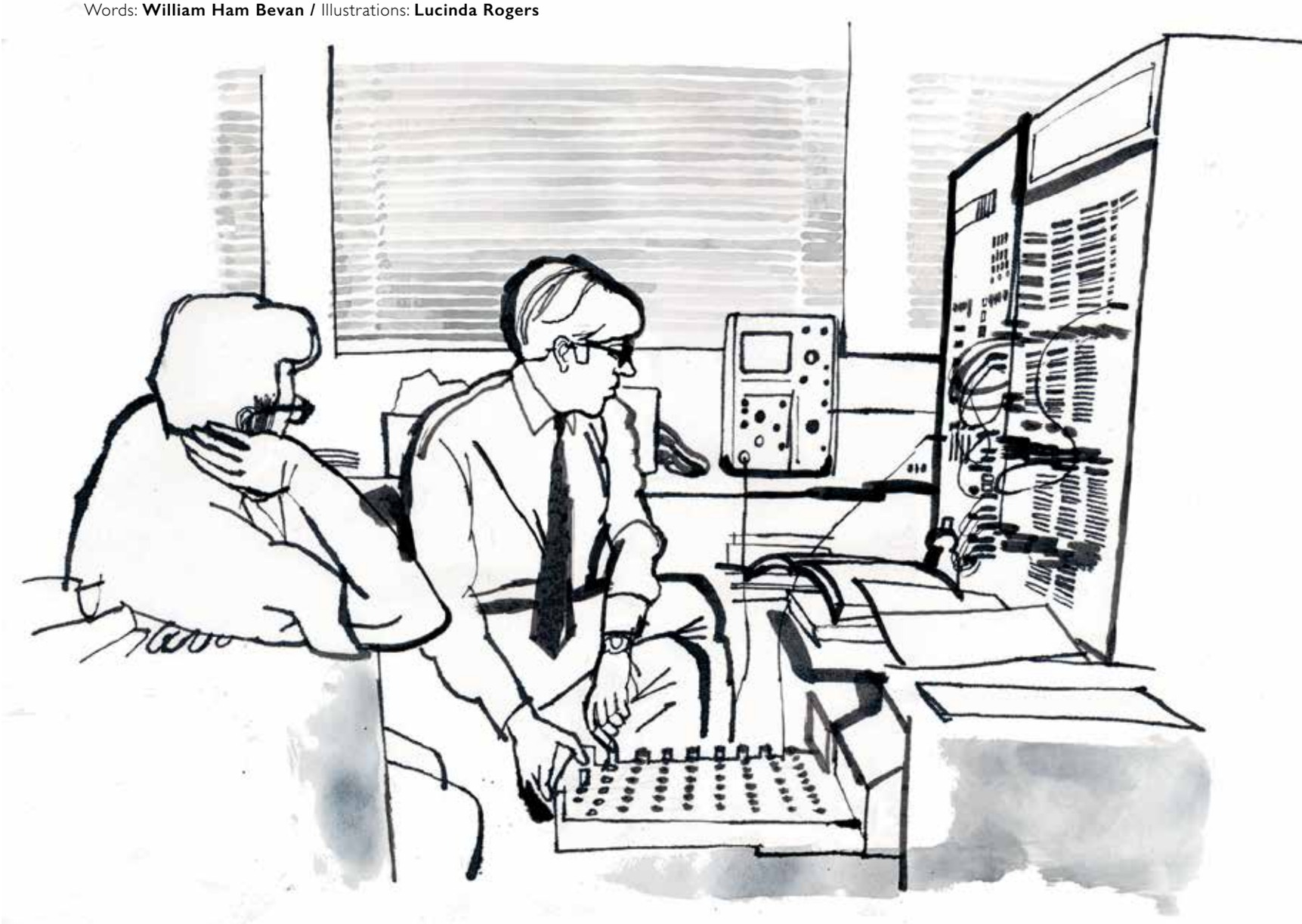
Science and performance are closely related, then, and in ways we might not expect. But, as a conductor, what does Dickins think about the idea that music performance is 'communicating the brain's excitations to the audience'? "Music is not science," says Dickins. "It's about passion, it's about love. Of course these are driven by neural impulses, but in music it's the heart that is communicating." ◆

***Richard Dickins** will retire this year as Imperial's Director of Music. Much admired for his sympathetic rapport with concerto soloists, Richard has been fortunate to work with some of the UK's finest musicians, and is also well known for his work with young musicians. He became conductor of the Symphony Orchestra at Imperial while still a student and was later appointed the College's first Director of Music. A graduate of the Royal College of Music, he was, until recently, principal conductor at the RCM Junior Department. He has also been artistic director of the Minehead and Exmoor Festival for more than two decades.*

I said I'd waterski on the Thames. Everyone laughed. I had no idea how funny it was until I got to London and saw the river...

HOW THE ATHLONE FELLOWSHIP TRANSFORMED THE LIVES OF A GENERATION OF CANADIAN ENGINEERS.

Words: **William Ham Bevan** / Illustrations: **Lucinda Rogers**



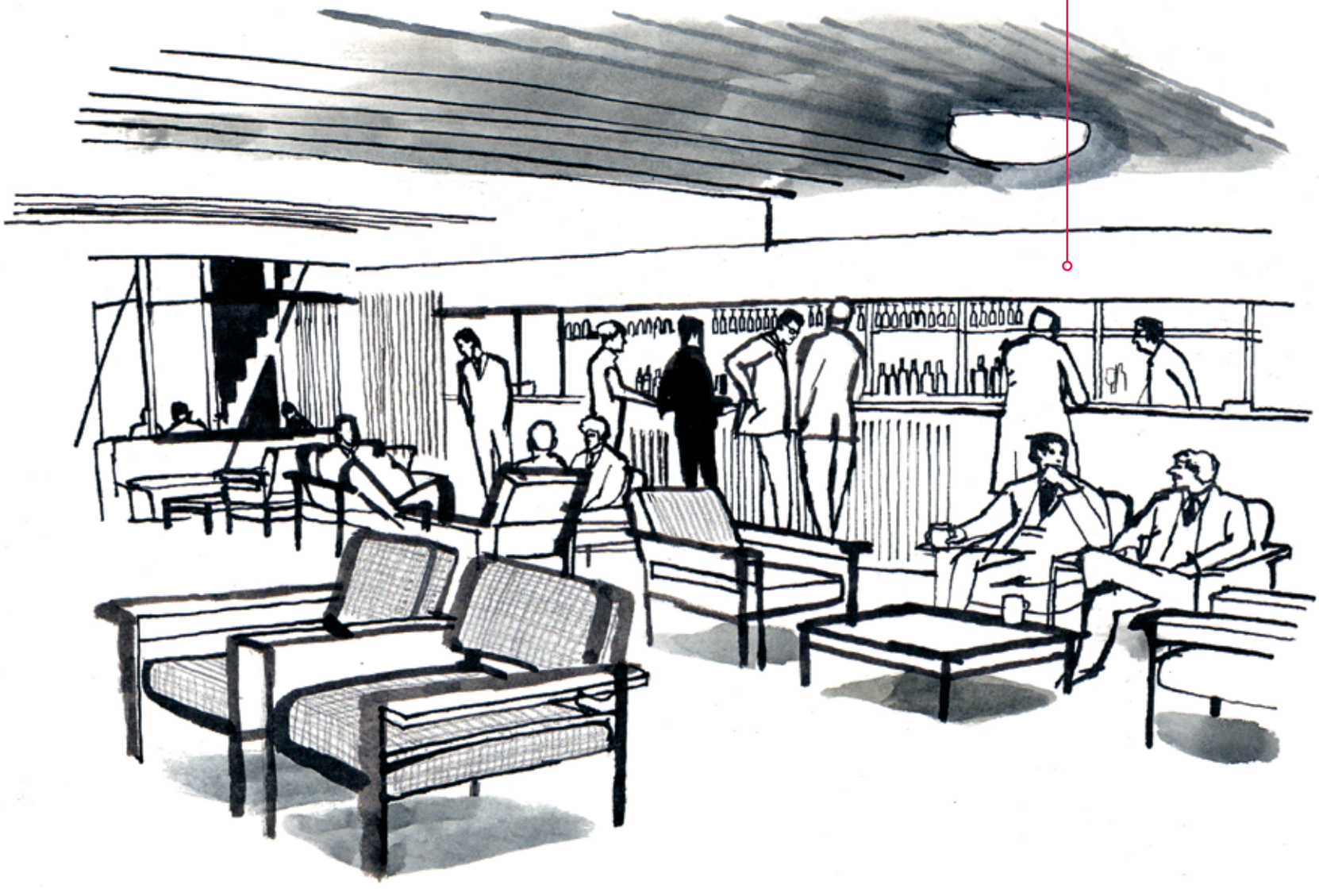
When recalling the interview for the Athlone Fellowship that brought him to Imperial College London from Winnipeg in Canada, Neil MacKenzie (MSc Mechanical Engineering 1967) credits an unintended joke with sealing the deal. He says: "I was asked, 'What would you do if you went to London?' I said, 'I'm going to waterski on the Thames.' Everyone started to laugh. I had no idea how funny it was until I got to London and saw what the river was like."

MacKenzie was one of 810 Canadian graduates to take part in the programme, aimed at bringing the country's most talented young engineers to the UK for further training. Named in honour of the Earl of Athlone, Canada's Governor General from 1940 to 1946, it was first mooted by Harold Wilson in 1949 to encourage trade and exchange expertise between the two nations.

The first cohort of Athlone Fellows was selected in 1951. Successful applicants had their passage to England funded, plus their tuition fees, and received a yearly travel grant within the UK, a textbook allowance and a modest weekly stipend (initially £6 10s – the equivalent of around £190 in 2018). They could choose to spend two years – or a single year in some cases – on a university research programme, an industrial secondment or a mixture of the two. The academic route proved most popular. By 1970, when the scheme was wound up, 754 fellows had spent all or part of their time at a British university. Imperial was by far the most sought-after destination, taking a total of 304.

The successful candidates were warned that they would experience culture shock when they arrived in Britain – "especially those, like me, who were living on the western side of the Rocky Mountains and had hardly been anywhere else," says Gary Elfstrom (PhD Aeronautics 1971). He adds: "They didn't just pick the highest-marked students as Athlone Fellows, because they might not cope with cultural differences. They were looking for more rounded applicants."

Opposite: Students at the Electrical Engineering Building get to grips with the new hybrid (analog/digital) computer in 1969. **Below:** The early evening scene from the early 60s looks sedate enough, but Southside Bar saw its fair share of lively encounters.



GOOD FELLOWS

A total of 810 Canadians took part in the Athlone Fellowship scheme between 1951 and 1970, the majority (304) at Imperial, including:

Robert Leslie ('Bob') Hemmings read Chemical Engineering at the University of Alberta before coming to Imperial as an Athlone Fellow in 1962. He graduated with a PhD in the same field in 1965.

Neil MacKenzie, a Mechanical Engineering graduate of the University of Manitoba, won his fellowship in 1966. He chose to spend a year at Imperial, reading for a MSc in Operations Research and Management Science, and then taking up an industrial placement at the Birds Eye frozen-food division of Unilever.

J. Spruce Riordon came to Imperial in 1963 after completing a Master's at McGill University, Montreal, and spending six years working on radar development at the National Research Council in Canada. He was awarded his PhD in Electrical Engineering in 1967.

Ian Rowe, a University of Toronto alumnus, was working for the guided missiles division of De Havilland of Canada when he accepted an Athlone 'B' Fellowship in 1964. He studied for a PhD in Automatic Control Systems at Imperial, successfully completing his studies in 1967.

Monique Frize (née Aubry) received a BASc in Electrical Engineering from the University of Ottawa in 1966. In 1967, she became only the second woman to win an Athlone Fellowship, electing to spend two years at Imperial on an MPhil programme in Electrical Engineering (Engineering in Medicine).

Gary Elfstrom, a graduate of the University of British Columbia in Vancouver, won his fellowship in 1968 and arrived at Imperial the same year. In 1971, he graduated with a PhD in Aerospace, Aeronautical and Astronautical Engineering.

Murray Clamen followed his undergraduate studies in Civil Engineering at McGill University with a PhD in Hydraulics at Imperial. He was part of the last cohort of Athlone Fellows to be selected.

For Bob Hemmings (PhD Chemical Engineering & Chemical Technology 1965), one of the first new experiences was the unfamiliar (and unwelcome) smell of kippers at Nutford House, where new fellows were temporarily billeted. A greater surprise was the extent of war damage still in evidence in 1962. He says: "Many areas of London had bomb-damaged ruins – blocks and blocks of devastation. It became more personal to me when I attended Remembrance Day at the Cenotaph. The war was still an open wound."

Ian Rowe (PhD Electrical Engineering 1967) says: "Being married with young children, the culture shock was felt by my whole family. We had to find out that you used markets, not supermarkets, for groceries if you wanted value. We had to work out the health system and the language: if someone said, 'I'll knock you up at 7am tomorrow', it didn't mean they were going to bang me in the belly."

Dealing with pre-decimal currency presented another challenge. Spruce Riordon (PhD Electrical Engineering 1967), who was six years into his career as a radar engineer when he applied in 1963, says: "They still had pounds, shillings and pence. If I had a substantial calculation to do, I'd switch back to Canadian dollars, work it out and convert back. The cars were very small – much smaller than ours – and rationing had ended not long before, so the quality of food was very uneven. But it was exciting to see London."

Becoming part of an international community at Imperial was an education in itself. MacKenzie says: "One way the Athlone changed my life was by showing me I was living in a bigger world than Canada. One day I went to College and around seven of my colleagues weren't there – they were Israeli, and they'd gone back to fight in the six-day war."

When Murray Clamen (PhD Civil Engineering 1973) arrived at Imperial in 1970, there was political volatility in Canada, making for bittersweet memories of his first year. He says: "I went back to get married that winter and there was a serious crisis going on in Quebec. The FLQ [Quebec Liberation Front] had kidnapped the minister, Pierre Laporte, and the British Trade Commissioner, James Cross. We later met him at an event, and he spoke about how difficult the situation had been for his family."

The Athlone Fellows also had to adjust to big differences in academic culture, with British research degrees far less regimented than their North American counterparts. Riordon says: "In Canada and the States, you went through a series of examinations and presentations to work towards the point where you could proceed with the thesis. In Britain, you were just thrown in and had to sink or swim. It prepared you for independent research."

Monique Frize (MPhil Electrical Engineering 1969), the second female Athlone, had little trouble in negotiating the male culture of Imperial. She says: "There hadn't been many women at Imperial, but I never felt treated any differently from the men. Everyone was supportive, though Bill the technician would always find one of us Canadians frying the College power supplies – which we did because the wiring in Canada is different."

Imperial's engineering facilities were locked up outside office hours, leaving plenty of time for extracurricular activities. Bob Hemmings was introduced by another Athlone Fellow to the Victoria League for Commonwealth Friendship, a charitable organisation made up "mostly of ladies; they were very interested in people from the Colonies, and I'd be invited to speak to them about the history of Canada." Through the League, he was able to get seats in the royal boxes of London theatres, including the Royal Albert Hall.

Frize also took advantage of inexpensive opera, ballet and concert tickets. "I'd been a bit of a Quebec separatist in Canada," she says. "That ended very soon after I moved to London and attended the Last Night of the Proms. I was singing Rule, Britannia! as loudly as anyone in the hall. In the summer of 1968, I married an Englishman in Chelsea Registry Office. The years I spent in London and at Imperial remain unforgettable!"

But if there is one attribute that links all the Athlone Fellows, it's a belief that their time at Imperial was pivotal. Elfstrom says: "Employers would see the fellowship and the Imperial PhD on my résumé, and doors would open. It was a tremendous start to my career. Though I didn't end up as the rocket scientist I once dreamt of being, I still ended up in the high-tech aerospace field that grabbed me and never let go."

Rowe says: "Athlone Fellows were expected to become leaders, and many of us did exert great influence in Canada. I wouldn't call myself a captain of industry, but I think I met the criteria for leadership: learning to cultivate the skills and motivations of the people around me and bring the most out of them. And there was a camaraderie that has stayed with us. That's a lifelong thing."

In a measure of that comradeship, reunions took place last year in Toronto and Ottawa. More activities are planned, both as a means of renewing links and of exploring whether a similar programme could be brought back.

It's a plan that appeals to Clamen, a member of the youngest group to benefit from the fellowship. He says: "The Athlone had a very significant impact on me, my wife, my family and my career – and it forged friendships that have gone on to this day. It was a special time in my life, and I'm very grateful that the scheme was created." ◆

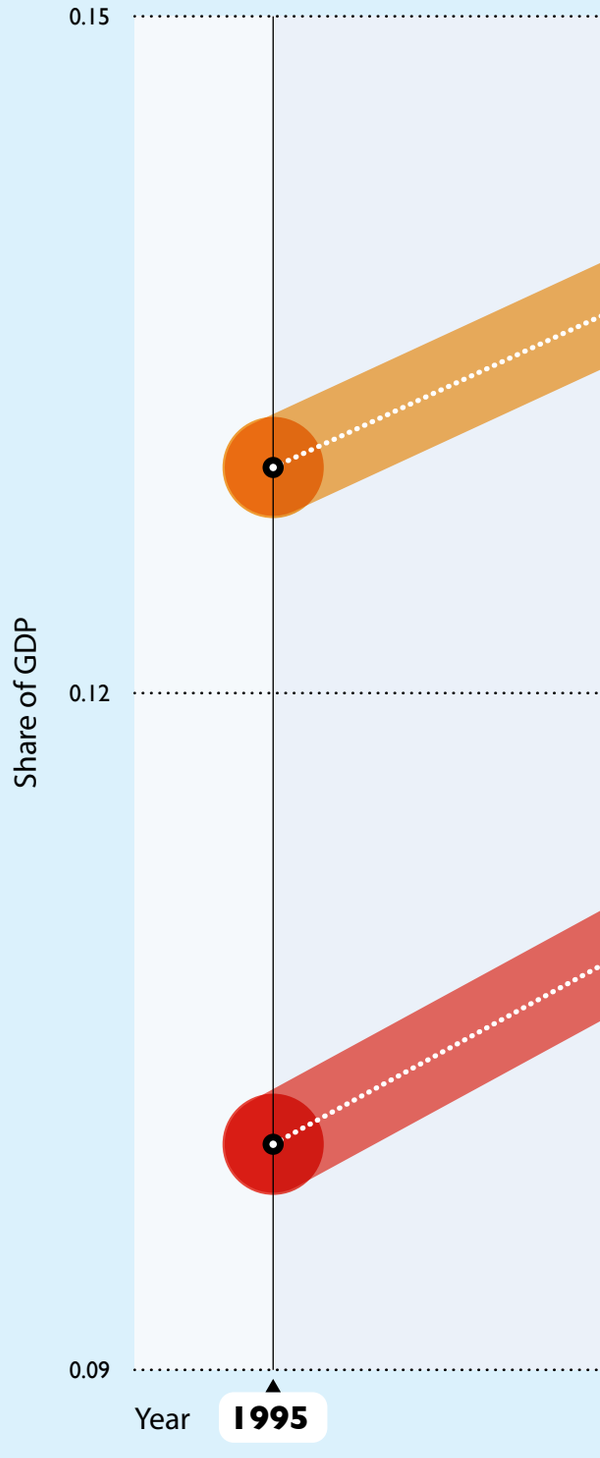
Below: The Thurloe Street of 1970 was a long way from the largely pedestrianised version today's students encounter; then as now, however, food outlets of some sort predominate.

TANGIBLES AND INTANGIBLES

Not all investments are things you can touch. As well as machinery, vehicles and buildings (tangibles), companies also invest in R&D, design, creative work, market research and training (intangibles).

EUROPE AND THE US INVESTMENT:

Intangible investment is no longer a sideshow. In many economies, it has steadily increased, even while tangible investment as a proportion of the economy has slowed or even decreased. In some, it now outstrips tangible investment, as the graph shows. The authors of *Capitalism Without Capital* based their calculations on figures from the INTAN-Invest database for the US, UK and ten other European countries (Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain and Sweden).

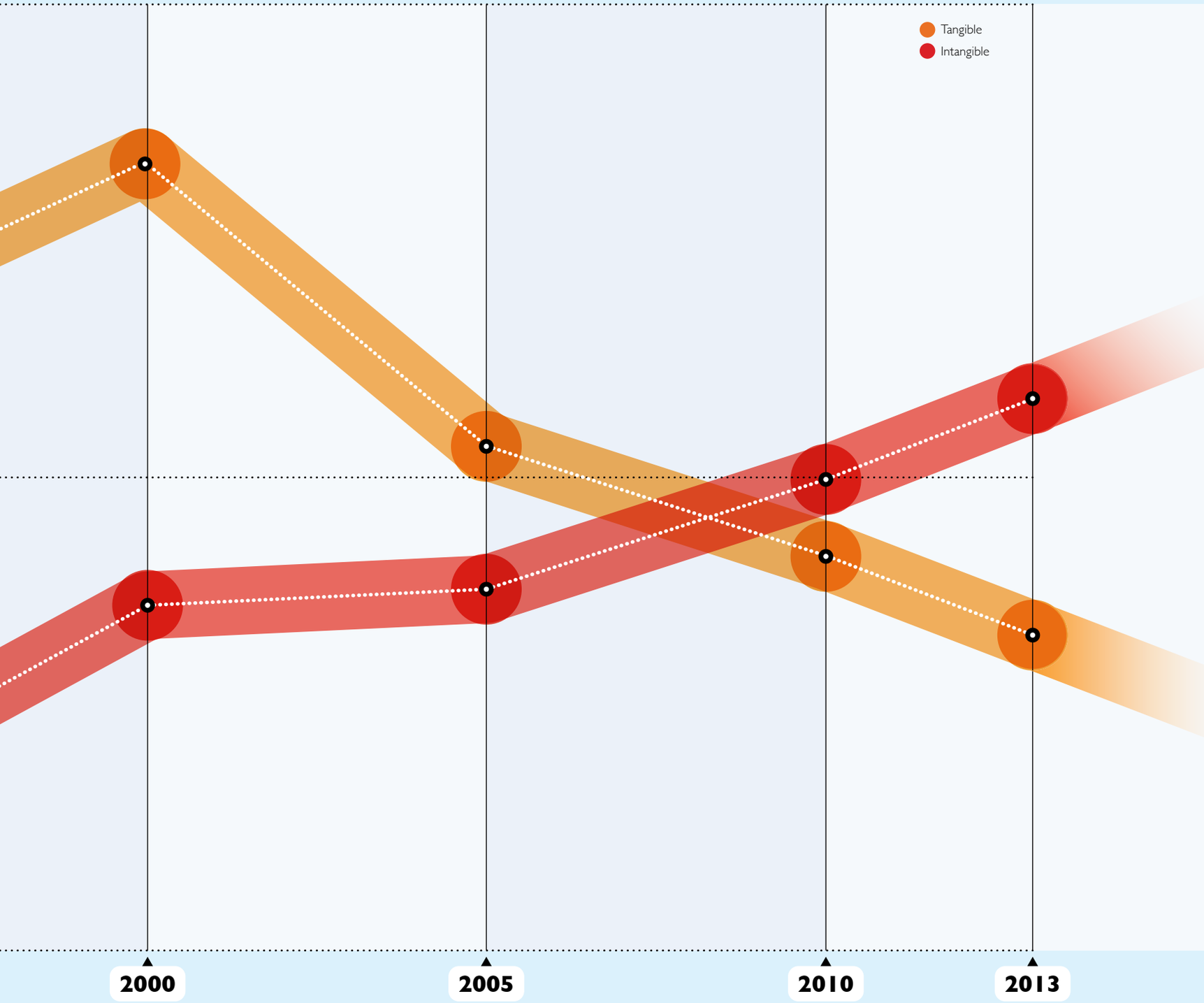


Forget goods you can see or products you can touch – 2018 is all about the intangible asset. Professor Jonathan Haskel explains why the rise and rise of the intangibles are having an impact on all aspects of economic life, from growth to inequality.

Words: **Jessica Twentyman** / Illustrations: **Valerio Pellegrini**

CAPITALISM

INTANGIBLES VERSUS TANGIBLES



WITHOUT CAPITAL

THE FOUR IMPACTS OF INTANGIBLES

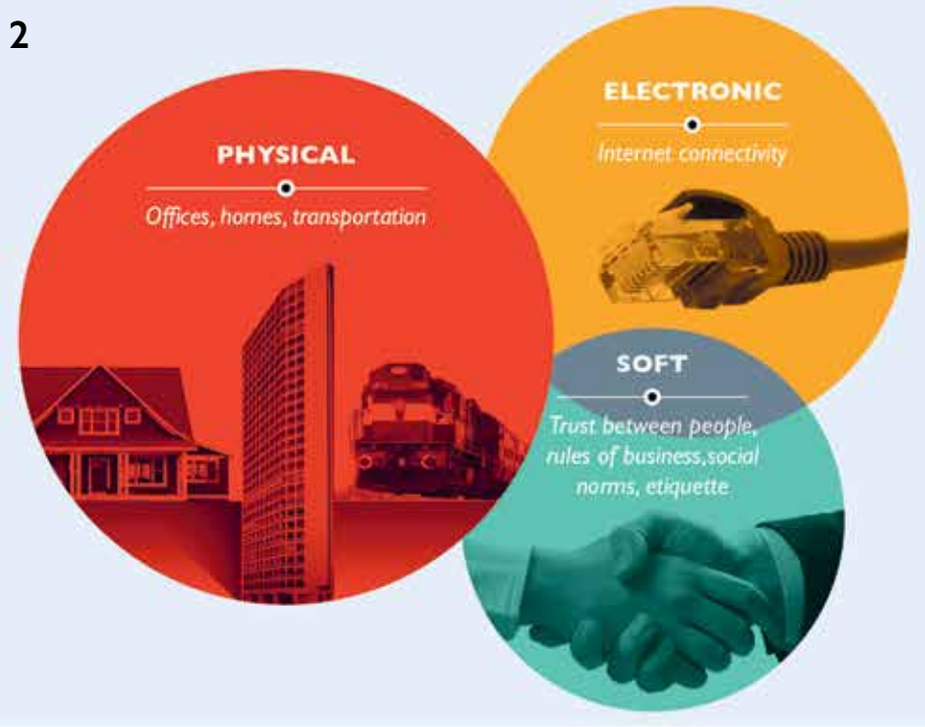
In addition to secular stagnation and financial inequality, other major impacts of intangible investment involve the financial services sector and the national infrastructure of developed countries. In the financial services sector, we can expect to see a shift away from debt financing as a means of business borrowing because intangible-intensive businesses have little to offer in the way of collateral. In other words, a bank is unlikely to lend money against the value of your idea for a piece of software, your movie script or the contents of your marketing database. That suggests a shift is needed towards the use of equity as a means of financing. In terms of infrastructure, the importance of spillovers and synergies in the intangible economy means that people must come together to share ideas, with huge implications for transportation and housing in the cities in which they work. And where they can't get together physically, they need the technology infrastructure in place to work remotely. At the same time, intangibles place greater demands on 'soft infrastructure' – the norms, standards and rules that foster trust and social capital, enabling people, companies and governments to work together effectively.

1

THE NEED TO RESTRUCTURE FINANCE

An intangible economy can't be financed by traditional debt financing from banks, as many companies don't have the tangible assets (a building, for example) to offer as collateral against what they borrow. Therefore, financing must move to venture capital funding based on equity shares – far more risky.

2



NEW INFRASTRUCTURE NEEDS

An intangible economy needs physical infrastructure – affordable office space and places to live in cities – so that people can exchange ideas. It needs electronic infrastructure, so people can work remotely. It needs 'soft infrastructure', ie trust and social capital, so that people can work together despite language, cultural and other barriers.

Early in the twenty-first century, a quiet revolution occurred. For the first time, the major developed economies began to invest more in intangible assets – such as design, branding, R&D and software – than in tangible assets, such as machinery, buildings and computers.

Businesses such as Uber don't own cars; they own software and data. Coffee bars and gyms rely on branding to help them stand out from the crowd. Pharmaceutical companies have vast budgets for marketing as well as research and development. This is capitalism – without capital.

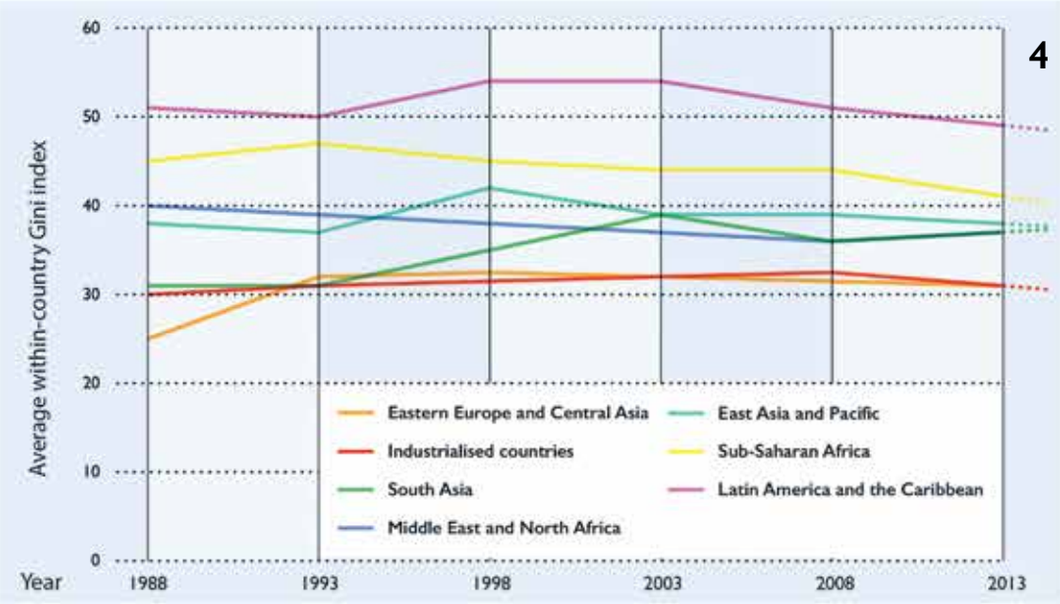
As an economist and co-author of *Capitalism Without Capital: The Rise of the Intangible Economy*, I watched the February 2018 meltdown of Carillion with dismay. How could such an established company, the second largest construction company in the UK, listed on the stock exchange and with more than 40,000 employees worldwide, fail so spectacularly?

Many observers looked at the asset sheet and assumed that was where the problem lay. It was apparent that the company had little in the way of tangible assets – such as buildings, vehicles and machinery – and that, when push came to shove, there was nowhere for it to go. It was, some said,

3

SECULAR STAGNATION

Secular stagnation' refers to the ongoing period of stubbornly low economic growth in developed countries. Following the 2008 global crisis, there has been no 'bounce back' to pre-crisis rates of economic growth. In other words, business investment is low even though interest rates are low, too.



4

INEQUALITY

Very simple, this one: the rich are getting richer, and the poor are getting poorer. Inequality is also observable between generations, between cities and rural areas etc. (The Gini coefficient is a statistical measure of distribution, most frequently used to gauge economic inequality, where 0% represents perfect equality and 100% perfect inequality.)

a salutary lesson in the perils of companies built on intangible assets. But, while it's true that intangibles represented 77 per cent of Carillion's non-cash assets, the real problems lay in the mix and type of intangibles on its balance sheet – and the foolish ways in which these assets were valued.

It certainly doesn't follow that intangible assets are a bad thing per se. After all, many businesses based on intangibles are wildly successful and eminently well run. Take Apple, for example, with its instantly recognisable brand, its elegant designs, its software, and its supply chain that enables it to bring new products to market quickly and in sufficient numbers to meet customer demand. Apple owns almost no tangible assets at all – but its intangible assets are clear sources of huge growth and long-term value.

In fact, for businesses of all kinds, investment in intangible assets has become increasingly important in recent decades – in R&D, branding, training, software, artistic creations, market research and business process reengineering, for example. At the same time, tangible investments have been declining. In some developed countries, including the UK, US and Sweden, they were outstripped by intangible investments some years ago.

This is significant, because as my co-author Stian Westlake and I explain in *Capitalism Without* ▶

THE FOUR ATTRIBUTES OF AN INTANGIBLE ASSET [THE FOUR Ss]

To understand how economies perform and businesses innovate, you need to understand their different attributes. In the book, we refer to these attributes as 'the four Ss': scalability, sunkenness, spillovers and synergies. Why does this matter? Well, if intangible investments behave differently from tangible ones, then it follows that an economy dominated by intangibles is likely to behave differently from those we've seen in the past. In other words, its impacts on all of us are likely to be different too.

SCALABILITY

SCALABILITY
This refers to the way in which, once an intangible asset exists, it can be used over and over again, in multiple places at the same time – a mobile app, a training manual or a design for a jet engine, for example.

SUNKENNESS

SUNKENNESS
This, meanwhile, is what we've seen at Carillion: once an intangible investment has been made, the resulting asset has little resale value.

SPILLOVERS

SPILLOVERS
We also see how an intangible asset sometimes benefits companies beyond the one that originally invested in it. When Apple launched the iPhone, for example, it also launched the smartphone sector, with its rival handsets and operating systems.

SYNERGIES
Finally, intangible assets can be combined with others to create marketable products. Ideas can go well together, after all, as was seen when US defence contractor Raytheon and white-good manufacturer Amana combined their thinking on microwave technology and kitchen appliances, respectively, in order to invent the microwave oven.

Capital, intangible investments behave very differently from tangible investments. So what does the intangible future hold for us?

The rise of the intangible economy holds clues to one of the most troubling and widely discussed puzzles in economics today: secular stagnation. In short, why has business investment and productivity growth remained stubbornly low in recent decades, even during the 'recovery' years since the 2008 financial crisis, despite low interest rates making it extremely cheap to borrow money?

Here, the intangible economy could be causing, or at least contributing to, the problem in several ways. The first is simply an issue of mismeasurement: since intangible investments are harder to measure than buying a building or a fleet of vehicles, for example, these investments have not been accurately factored into estimates of business investment and GDP growth. Once rectified, however, we can see that this mismeasurement effect is pretty small.

More significantly, the scalability of intangibles has allowed very large and very profitable firms to emerge, ones that leave their competitors lagging behind. Laggards consequently have less incentive to invest; a larger, more successful company is better placed to appropriate the spillovers of a laggard's intangible investments than vice versa. Finally, since intangible investment, just like tangible investment, has remained subdued since the financial crisis, spillover effects have been muted, too. In short, there have been fewer good ideas flying around to imitate.

Another key impact of the intangible economy – and one with particular public resonance – is inequality. In a city like London, we can see with our own eyes the construction work under way on luxury apartment blocks located just a stone's throw from some of the UK's most deprived communities. This pattern can been observed in most developed countries. The rich are getting richer and the poor are getting poorer – and there's a clear case for arguing that this is down to the growth of intangible investment.

Just as the scalability of intangible investment favours large companies that come to dominate their market sector – by pouring money into new ideas, new technologies, new ways of doing things, new forms of creativity – so the employees who work for these companies do well in terms of pay. Their counterparts at smaller companies do less well, leading to income inequality.

Then there's the effect of spillovers and synergies: these tend to flourish in cities, driving up property prices to the benefit of the rich. San Francisco is a case in point. Finally, intangible investments are mobile, in the sense that they can be easily shifted across corporate and geographic boundaries, making them harder to tax. In turn, that makes it harder to redistribute taxation in order to reduce wealth inequality.

In the business world of the future, a 'good' organisation will be one with managers in place to carefully coordinate sunk costs and spillovers, and exploit the opportunities that arise from scale and synergies. Managing large firms is hard, but managing large, intangible-intensive firms is even harder. When a company is building information and ideas, rather than physical objects, it becomes even more important to share information so that everyone understands the big picture of how their activities fit together. That is an important role for the modern manager. At the same time, the manager must also keep valuable knowledge workers on side. This is because if they leave the company, their tacit knowledge leaves with them. Unlike tangible assets, this asset cannot be secured by lock and key.

For financial investors, success in the intangible economy will be about understanding the complexity of intangible-rich firms. After all, their intangible assets are less certain sources of value and their accounts less useful, because finance departments tend to count intangible spending not as investments, but as day-to-day expenses. That means that the investor must rely on information beyond the usual financial statements. They must develop new insights into how firms are managed by leaders who motivate and inspire – and the results they are able to deliver.

Policy-makers, meanwhile, will need to focus on facilitating knowledge infrastructure, such as education, internet and communications technology, urban planning and public science spending. They will need to clarify intellectual property regulation – but not necessarily strengthen it, as this could damage productivity gains from synergies. Above all, they must tackle the inequality that arises from an economy reliant on intangibles.

This, in particular, is a very difficult challenge. To help the intangible economy thrive, policy-makers will want to encourage trust and strong institutions, to encourage opportunity and mitigate divisive social conflict. But right now, an effective intangible economy seems to exacerbate all of those problems.

I'd like to say I have the answers but, along with most politicians in the developed world, I don't. What is clear is that this tension looks set to dominate the political and economic landscape for years to come. The country that is able to resolve it, however, will be on course for great prosperity. ◆

> *About the authors of* Capitalism Without Capital*:* ***Jonathan Haskel*** *is Professor of Economics at Imperial and a member of the Financial Conduct Authority Competition Decisions Committee. In 2017 he won the Indigo Prize, celebrating radical and creative thinking measuring the modern economy.* ***Stian Westlake*** *is a policy adviser to the UK's innovation Minister and a Senior Fellow at NESTA. He was previously at McKinsey.*

A crucial curve

Professor Colin Caro explains why helical stents can change lives – and why, at 92, he still has much to do.

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

Emeritus Professor Colin Caro keeps the fruits of a very long life's work in the top drawer of his desk: two feather-light, finger-length tubes. Both are made of thin, wire mesh, zigzagging around to create hundreds of tiny triangles. But there is a vital, and deceptively simple, difference between them: one tube is straight, like a drainpipe; the other is gracefully curved, like a snake.

The tubes are both stents: scaffolds to keep a blocked or narrow artery open, allowing blood to flow through it. The straight one will be familiar to heart surgeons. First used in 1986 in Toulouse, France, by doctors Jacques Puel and Ulrich Sigwart, it is widely employed in modern heart surgery, both in its basic form and with various enhancements, such as a coating of drugs to discourage further blockages.

The curved one, however, could also become a common sight in the operating theatre one day. It is Caro's own invention, the BioMimics 3D® helical-centreline arterial stent, created as a result of a basic realisation: blood flows in three dimensions, not two. "For 500 years people have known that arteries branch and bend," he points out. "But what has really been underappreciated is that they don't do this in a planar fashion: it's more of a curve, a helix."

Working on the single challenge of how to stop so many people dying of heart disease, Caro theorised that the helix had something to do with atherosclerosis, the narrowing of the arteries, which was affecting half the world's population back in the 60s and 70s. This turned the accepted theory on its head. "For a hundred years or more, people believed that the cause of atherosclerosis was blood flowing too quickly through the arteries," he says. "I showed, using several simple experiments – postmortem studies and modelling – that the opposite is the case. The slower flow is dangerous, and the faster flow actually protects against disease."

This is due to the three-dimensional nature of blood flow. Atherosclerosis is not a uniform disease, explains Caro: not every inch of the arteries is affected, because the helical flow is not uniform, either. Within the branches and bends of our arteries, there are areas of low wall shear, where the blood flows more slowly, and areas of high wall shear, where it flows quickly. Areas of low shear are more likely to develop atherosclerosis. That is why the BioMimics 3D stent is designed to mimic how the blood flows and, by doing so, harnesses its ability to protect artery walls.

"The helical stent causes the flow to rotate, to swirl, and it causes mixing," he says. "In a straight stent, blood and the oxygen it carries gets from the middle of the artery to the wall by diffusion – Brownian motion, which is a slow process. In the helical case, the blood in the middle of the artery gets to the walls faster by being stirred, rotated. And that's what you need."

Yet this insight, Caro emphasises, did not come in a sudden flash of inspiration. Rather, it was the culmination of many years' work. And being an outlier at the beginning wasn't easy. "It's hard trying to persuade people that a long-held theory is wrong, though it never got unpleasant," he emphasises. "It can take time to turn the Queen Mary around."

For a hundred years or more, people believed that the cause of atherosclerosis was blood flowing too quickly – in fact, the opposite is the case

Above: Cast of a human aorta showing its non-planar geometry (*DH Tompsett*).
Right: Professor Caro's Certificate of Award of Fellowship of the Royal College of Physicians.
Opposite: Straight control stent (left) and stent with 3D helical technology (*Veryan Medical Ltd*).

The results from the first randomised controlled trials in humans have been promising. Use of the BioMimics 3D helical stent resulted in arteries being more open at two years when compared with a straight stent. Ongoing research is being carried out by Veryan Medical Ltd, a company formed in 2003 with initial funding from Imperial Innovations, when the commercial possibilities of Caro's idea were recognised.

Originally from South Africa, Caro gained degrees in both medicine and physiology at the University of the Witwatersrand, Johannesburg, after volunteering for the South African navy from 1944 to 1946. In the 1950s, he taught medicine in the US and at St Thomas's Hospital Medical School in London, before founding Imperial's Physiological Flow Studies Unit in 1966. In 1989, the unit became the Centre for Biological and Medical Systems and then the Department of Bioengineering, of which he was director. Next year the department will be moving to a new state-of-the-art facility, the Michael Uren Biomedical Engineering Research Hub, at the White City Campus.

His many honours and achievements include serving on academic scientific advisory boards in the US, France and Japan; receiving the 2003 Arthur Guyton Award from the International Society of Cardiovascular Medicine and Science, and being named Outstanding Engineer at the 2007 Engineer Technology and Innovation awards. He is author of *The Mechanics of the Circulation* (1978), and was awarded honorary doctorates from Imperial in 2003, the University of Paris in 2005 and the University of the Witwatersrand in 2010.

"When I was a young doctor, we had engineers in the department who were regarded as technicians; they weren't quite respected. Nowadays there is full and open recognition that many of the scientists are just as bright, if not brighter, than the doctors," Caro says.

Despite being ahead of its time, the idea of collaboration between medicine and engineering seemed entirely logical to Caro. "I have always been interested in physics, mathematics, biology and medicine," he says, "so I was an engineer and a doctor, which was helpful. And I was a doctor in a hospital, and therefore in a better place to recognise disease. But I was working alongside mathematicians from Cambridge and King's. I took a few extra courses in maths, and it struck me it might be interesting to see what could be done in terms of collaboration. I talked to a few people, and Imperial said they would give me one room – it was at Princes Gate, across Exhibition Road – and we would see how it went, and how long it would be before I failed!" With typical understatement, he adds: "We were lucky. It went well."

And it continues to go well. He has never retired or left Imperial, he says, because he still finds the work exciting – and important. "It is a serious business, the potential to prolong life. I have always been aware that this could be important. And it's exciting to see it possibly change things. We are starting to understand the why, and that's even more important to me."

And at the age of 92, Caro is still not finished. What concerns him now, he says, is exactly why low shear and slow flow cause atherosclerosis. "You're never satisfied: you always want to know the mechanism. If you go to a GP, they will say you have high blood pressure and that it is a danger to your arteries. Both those statements are correct. But why? Years later, we are still uncovering what that is all about." He is currently working on how oxygen is transferred from the bloodstream into the artery wall: if this isn't done efficiently, the artery will become diseased.

"We have these tiny, fine vessels, called *vasa vasorum*, which supply the artery walls," he explains. "But if mixing is inadequate – which it would be in a planar bend – they can get squashed. And they can get squashed when you are stressed, or if you smoke, or if you don't exercise enough, as these all cause the walls of the artery to constrict and get stiff. The key to progression of disease rests on the tension of the artery wall, and the flow of blood. And it is therefore imperative to keep the flow stable and three-dimensional, and well mixed."

Caro continues to research and publish, and his office door is still always open to colleagues and students. There aren't too many places, after all, where you can draw on the experience gained over a 70-year-long career. His advice to those following behind is simple. "This area is wide open. Encourage younger people. Work as hard as you can. And carry on as long as you can." ◆

PHOTO: VERYAN MEDICAL LTD

Left: Gram stain of healthy human broncho-alveolar lavage fluid, showing human cells and cell debris in red, and Gram positive bacteria in pairs of *diplococci* in dark purple.

UNDER YOUR BREATH

When Imperial researchers turned decades of research into the way our lungs function on its head, the medical world refused to believe. This is what happened next. ▶

Words: **Becky Allen** / Illustrations: **Sarah Wickings**

Left: *Micrococcus luteus* growing on a blood agar plate supplemented with mucin. The organism was isolated from a lung brush taken from a person with asthma.

In 2010, a pair of Imperial professors rewrote the medical textbooks. Their paper, analysing the characteristics of asthma patients, overturned everything we know – or thought we knew – about how our lungs function.

Indeed, what Miriam Moffatt, Professor of Respiratory Genetics, and William Cookson, Professor of Genomic Medicine, discovered was so unexpected that a string of scientific journals rejected their paper.

"It took us two years to get our paper published because lots of journals said the lungs are sterile – and that our results were nonsense," Cookson remembers. We've grown accustomed to the idea that we need to care for the hundreds of other species that share our guts, but when it came to the airways and lungs, there was an assumption that it was a sterile environment – in other words, devoid of all microbes. "But we found lots of bugs down there. In healthy people's lungs we found a characteristic community of microbes, and in asthma we found a very different microbiota."

Researchers have long recognised that a rich microbial environment protects against asthma, but Moffatt and Cookson wondered whether it might be down to the microbes in the lungs modifying our immune system. So, together with colleagues from Imperial and Dublin's Connolly Hospital, they set out to sample the lung microbiome in people with and without asthma.

With hindsight, the idea of sterile lungs seems pretty far-fetched. Even at rest, we inhale 10,000 litres of air a day, and air is far from sterile. In cities, every litre of it contains up to 100,000 bacteria. Yet, in 2008, when the Human Microbiome Project began mapping the microbial communities of hundreds of healthy humans, it omitted every part of the respiratory tract – from the nose to the nether reaches of the lung.

There are good reasons the textbooks were so wrong, for so long. First, lungs are inaccessible places. Whereas gut researchers have a ready supply of raw material to work on, collecting samples from the airway involves a hospital visit for a bronchoscopy. Second, until the relatively recent advent of affordable DNA-sequencing technology, researchers relied on 19th-century culture methods, tools that detect only a small subsection of the microbes in lung samples. Despite the amount of air we breathe, there are parts of the lung that get little oxygen and, here, anaerobic organisms thrive unseen.

According to Moffatt: "They are not oxygen lovers, so they need very special anaerobic culture that's not typically done in the microbiology lab. That explains why they'd not been seen before – because only five per cent can be cultured using standard techniques."

Discovering that we share our lungs with all these other organisms poses a whole new set of questions – and opportunities – for lung researchers: what are all these microbes doing down there? How do their communities differ between health and disease? And how might this knowledge lead to new ways of diagnosing and treating lung disease?

Making progress matters because lung disease is a huge global problem. Asthma affects 300 million people worldwide and chronic obstructive pulmonary disease (COPD), 64 million. Respiratory infections are the leading cause of death in developing countries, killing more than four million people a year. Added to this, antibiotics used to treat lung infections are fuelling the global crisis of antibiotic resistance. ▶

Similar microbiome changes have already been found in a range of lung diseases. Jane Davies, Professor in Paediatric Respirology and Experimental Medicine at Imperial's National Heart and Lung Institute (NHLI), has found it in cystic fibrosis (CF). The nature of the disease means Davies is familiar with seeing microbes in her patients' lungs. In CF, a genetic mutation causes the production of large amounts of mucus, trapping bacteria and viruses in the lungs and resulting in inflammation and irreversible lung damage.

Using new molecular tools to study the lung microbiome has changed her view of CF. "Patients start with a mixed, diverse community of microorganisms and, over 20 years, this healthy diversity decreases in line with their evolving lung disease. The more severe the disease, the lower the diversity," she says. "What's new for us – but not to gut researchers – is that in any ecological niche, diversity is good because it helps keep things in balance. Once it becomes disrupted, certain organisms can become dominant and cause trouble."

For Davies, the challenge now is to understand these changes so that they can be used to improve treatment in CF: "What's most important for me as a clinician is what these findings mean. We still don't know. So far it's not changed how we treat patients and isn't helping us with prognosis – these are the burning issues."

The challenge for respiratory professor Toby Maher, British Lung Foundation Chair in Respiratory Research at Imperial, focuses on a disease of older age: idiopathic pulmonary fibrosis (IPF). Partly hereditary – about 50 per cent is genetic – it is also caused by a lifetime of physical damage to the lung, such as working in dusty conditions. The lungs become progressively scarred, and, as they shrink and stiffen, patients becoming more and more breathless.

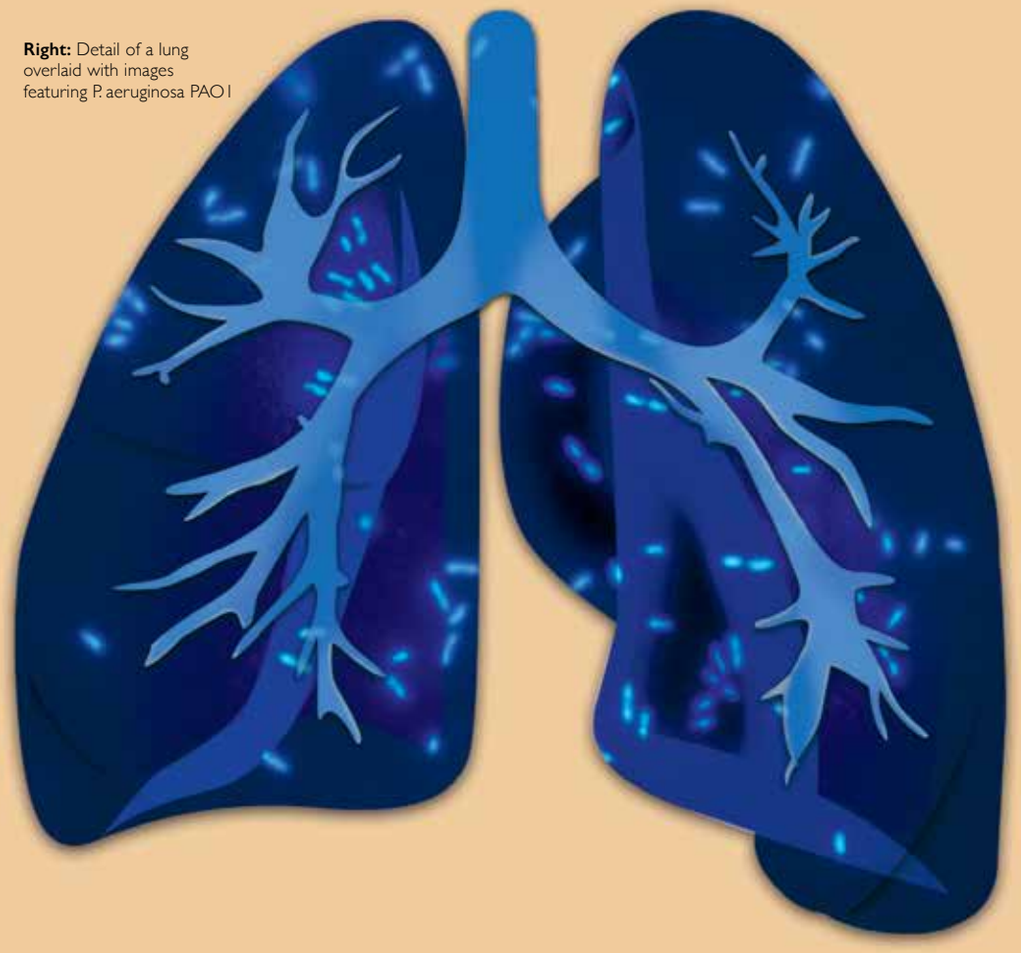
The puzzle for Maher is IPF's hugely variable progression. Some patients deteriorate rapidly, while in others the disease is more stable. "I want to understand the factors that contribute to IPF's development and progress, so that ultimately we can intervene and treat patients," he explains. "Studying the microbiome has allowed us to explore environmental factors that may be responsible for some of the differences we see between patients."

Maher is also studying how the immune system contributes to fibrosis. "There's clearly an important overlap between the microbiome and the host immune system. Research in the gut tells us it's a two-way process," he says, "so we're trying to understand how the relationship between the immune system and colonising bacteria affects disease progression."

COPD is another lottery of a lung disease, progressing very rapidly in some patients and more slowly in others. COPD kills around 30,000 people a year in the UK, and is the third-highest cause of death worldwide.

Largely smoking-related, it is one of the commonest causes of medical hospital admission, and is associated with many other conditions, from heart disease and diabetes to osteoporosis and cognitive decline. "COPD is a complex disease in which the microbiome seems to play a crucial role," says Wisia Wedzicha, Professor of Respiratory Medicine at Imperial's NHLI. "And it is a very important condition because it often affects people who are still working. Patients become breathless – which is a horrible symptom – and our interventions are very limited at the moment. We really have nothing that affects disease progression."

For the past 20 years, Wedzicha has been studying sudden flare-ups in COPD, because these exacerbations cause the disease to progress more rapidly. "Exacerbations are caused by infections such as cold and flu," she says, "and we're only now discovering these exacerbations are also associated with changes in the microbiome, which could help lead to earlier diagnosis and better treatment."



Right: Detail of a lung overlaid with images featuring P. aeruginosa PAO1

We still have more to discover about what the lung microbiome does, but, from what we know about the gut, these bugs probably work in tandem with human cells to form a healthy immune system. If that turns out to be correct, Moffatt and Cookson believe that it will change how we diagnose and treat lung disease, and help us tackle antibiotic resistance.

"In two to three years we're going to have a range of diagnostic tools that can quickly diagnose lung infections, not just in asthma but in children with CF who have a complicated mix of pathogens," says Moffatt. "Treatment regimes have been based on the idea that lungs are sterile and you get a single pathogen, but actually they have a soup of pathogens, so DNA sequencing will change clinical management of acute and chronic infections."

Quick and accurate diagnosis should also cut unnecessary antibiotic use, as prescribing will become more precisely tailored to the pathogens that are actually present. Moffatt and Cookson also plan to develop inhaled antibiotics that do not damage the gut microflora and will, therefore, help prevent antimicrobial resistance.

In the longer term, their rewriting of the textbooks could herald revolutionary new ways of treating lung disease, including phages (viruses that attack bacteria) and – most speculative of all – transplanting healthy microbial communities into diseased airways. "I don't know when," Cookson concludes, "but I'm sure it will happen, and sooner rather than later." ◆

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DISRUPTOR / PROFESSOR JAMES STIRLING

"Imperial is an innovation powerhouse – I have learned as much in my time here as any student"

Imperial has more than 100 years of history of leading from the front, with ideas that shape the wider world, and in my five years here I've learned as much as any student.

Together, we have taken some ground-breaking strides that, in true Imperial tradition, disrupt to keep us at the forefront of research and education.

Every day we see examples of our research benefiting the wider world. For example, the Grantham Institute's research on climate change provides hard scientific evidence that is having a huge impact on the global environmental debate. The Data Science Institute is forging collaborations with research partners in healthcare, financial services and city infrastructure. And our new Michael Uren Biomedical Engineering Research Hub will soon bring together engineers, scientists and medics in an unprecedented collaboration to carry out life-changing research into new and affordable medical technologies. Combining expertise from different disciplines inevitably sparks truly innovative solutions to some of our most complex global issues, and this is where Imperial excels.

Imperial is changing education, too. Our Vice-Provost (Education), Professor Simone Buitendijk, is overseeing the implementation of a new College-wide Learning and Teaching Strategy that uses the latest pedagogical innovations to put students at the heart of their education; for example, flipping the classroom experience with digital resources they can study ahead of lectures. This means they get much more out of face-to-face time with their academic teachers, which becomes more discussion than lecture – a two-way conversation that, again, has huge potential to produce new ideas.

Our innovation in research and education means that we are a natural port of call for global leaders visiting the UK. During my time here we have been honoured by visits from the Presidents of China, South Korea and Singapore, which raises our profile even further in these parts of the world. This is one of the many elements that make my job so varied and interesting – one minute I'm meeting one of the most powerful people on the planet, the next I'm dealing with a complaint about blocked toilets!

My academic background is theoretical physics, so unexpectedly finding myself in charge of the welfare of the animals we use in research in 2014 was a steep but fascinating learning curve! It has been a pleasure to work with our dedicated animal facilities technical support staff and our world-leading life sciences researchers to create a culture that is now regarded as an exemplar in the sector.

But, aside from all this, for me the most significant, vital change at Imperial has been how the College treats its staff, and how they treat each other. Our history as a male-dominated, hierarchical institute had led to instances of unacceptable behaviour. Two years ago we commissioned a rigorous independent review that, while commending much of what we were doing to address our shortcomings, shone a light on some dark corners – for example, revealing that some staff felt unable to speak out against unacceptable behaviour they had experienced. We have worked closely with our staff and students to eradicate such practices and make Imperial a better place to work and study for everyone.

This is not an overnight fix but a process that will take time. However, the openness, transparency and planning that has gone into setting us on the journey to where we want to be are all legacies of which I am proud. Building an environment in which every single person can feel relaxed, comfortable and fulfilled can only be good, not just for the wellbeing of our staff and students but also as a foundation for the excellent education and research work we continue to do.

> I am proud of the work done with staff and students to make Imperial truly open and transparent

All of our recent achievements tie in with the five-year College strategy we announced in 2015, to attain enduring excellence in science, medicine, engineering and business.

Imperial is without doubt one of the world's best universities, with an illustrious past and an exciting future. I am proud to have been part of it for the past five years. ◆

> ***Professor James Stirling,*** *Imperial's first Provost, will retire in September. He will be succeeded by Professor Ian Walmsley, currently Oxford's Pro-Vice-Chancellor (Research and Innovation).*

INTERVIEW: PETER TAYLOR WHIFFEN / PHOTO: THOMAS ANGUS

INDIAN SOCIETY

Bollywood dreams

Imperial's Indian Society is preparing for the longest-running student show in the country.

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

Producing a theatrical spectacular starring 130 amateur performers every spring term is no small feat, but the Indian Society has a tradition to uphold. Its signature show East Meets West is in its 26th year, making it the longest-running student show in the country. A multicultural celebration of music, dance and drama, it is held together by an original narrative each year – most recently, an Indian twist on the BBC's Sherlock.

"My flatmate forced me to audition in our first year because she didn't want to go by herself," says Harshil Sumaria (Electrical and Electronic Engineering, third year), one of the society's two presidents. "None of the people we met there had ever danced before, it was just about trying something new and having fun."

Fellow president Arohan Subramonia (Mechanical Engineering, third year) also tagged along to support a friend and soon found himself in rehearsals – and performing at the Mermaid Theatre in the West End. "I probably should have been nervous, but I was oblivious to the fact that anything could go wrong because I was having such a good time."

Not all the society's social events involve putting on a show: the 22-person committee has also organised a bowling trip, club nights and

Members of the Indian Society in rehearsal for the East Meets West show.

It is a huge undertaking: more than 130 performers, and lines, music and dance to master

a family scheme that matches older members with new students to help them settle in. But the lure of the stage is never far away.

In the autumn term, while East Meets West is in the early planning stages, the society shifts its focus to its other annual show, Just Bollywood. An inter-university dance competition, this takes place on campus every December and is another huge endeavour: ten student teams from around the UK compete by performing to a mix of Bollywood and chart music, and a panel of professional dancers and choreographers picks a winner.

Sumaria says the end of the last Just Bollywood was particularly special. "Arohan and I walked on to the stage to give the closing remarks and that was the first time we properly saw the crowd, which filled Logan Hall. Seeing all those people and knowing all the hard work had paid off is my favourite memory from my time in the society."

However, organising two shows a year can be stressful, and Subramonia says it's challenging to balance the demands of being president with prioritising university work. "The upside is it teaches you good time management, but the downside is you're worried about hitting deadlines."

Both presidents say the hard work is worth it, however. "We had so much fun through the society in our first two years and this is the best way to ensure that carries on," says Sumaria. Their complementary personalities make their partnership work, Subramonia says. "I tend to be quite overambitious and Harshil will say, 'That's a good idea but why don't we do something more realistic', so we often bounce ideas off each other."

Earlier this year, they were awarded Best Indian Society and Best Presidents at the inaugural UK-India Youth Awards, but they say they couldn't have succeeded alone. "We both felt that the award overlooks the work of the entire committee," says Sumaria, "but they have been exceptional and an integral part of this year's success."

Subramonia says it's a misconception that you have to be Indian to join the society, and that students with no desire to perform are also welcome: there are backstage positions available, or you could just be an enthusiastic audience member. Equally, though, no-one should let nerves hold them back. "It's not really about performing, it's more about meeting new people. And if you enjoy spending time with them, that overcomes any shyness or trepidation you might feel." ◆

SARAH WILKINSON
(Mathematics 1991) is CEO of NHS Digital and previously Chief Digital, Data and Technology Officer at the UK Home Office

Q: What did Imperial do for you?
I fell into working at *Felix*, the student newspaper, early on in my time at Imperial, and found that I loved writing as well as mathematics. We ran the whole production process, so it was great training. I also rowed and enjoyed the real sense of camaraderie being part of a team gave me.

Studying mathematics led me to apply a degree of rigour to my work that has never left me – along with an intolerance of slack thinking! In many ways I have never really left Imperial – from the start of my career I often returned to campus to run recruitment sessions, and still do so today.

Q: Why is your work important?
Imperial taught me to apply logic – today, I look to recruit people who have the ability to construct a set of hypotheses and then test them against the data. Technology is wonderful, but it can also be really complicated. The NHS has a totally unparalleled database; nowhere else in the world do healthcare professionals have access to the records of 70 million people over a 70-year time span. Hidden in that data lies the answer to many of today's diseases and it is incumbent upon us to find them.

We are at a unique stage in the digitalisation of the NHS, as we create algorithms that, for the first time, make the treatment decisions explicit. Society has to become more comfortable with the way medical decisions will be reached in the future, and communicating that is vital to my job.

Q: What's the secret to a career in technology?
When I talk to students today, what I impress upon them is that working in technology is intellectually challenging and highly creative. There is no monotony or repetition – and the financial rewards are high. But you must be able to think in a straight line, and Imperial showed me how to do that.

OUR IMPERIAL

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AN EXPERIMENTAL MINDSET IS JUST ONE OF THE BENEFITS OF THE IMPERIAL EXPERIENCE, AS THREE ALUMNI LEADING THE CHARGE IN DIGITAL TECHNOLOGY PROVE.

ANETTE LIPPERT

(Biology 1993, MSc Environmental Technology 1994) is a digital transformation consultant for startups and other companies

Q: Why did Imperial stand out?
The lecturers were truly inspirational and not afraid to talk about mistakes they have made – German professors are often treated like gods, they can do no wrong and students aren't expected to build up a relationship with them. I was taught to keep asking questions until you get to the bottom of the issue, to learn to be open and see different perspectives.

Q: How did it set you up for a future career?
It's my job to bridge the gap between the language scientific and engineering people use and the way marketing people talk – and it all started at Imperial. Reading Biology and Management allowed me to acquire two mindsets in one course. That option would not have been available back home in Germany, where you only ever study one subject.

Q: What does the technology market look like today?
I left Imperial just as digital was taking off, and the first startup I joined was too early for the German market – people didn't get it. I joined BMW and the job was all about being ready for change and helping others to embrace it. We forget how far we have come in a short space of time. With digital applications today, we can analyse huge amounts of data. For marketing, that is both a dream and a curse. We are still teaching people that their data is an asset that both sides must protect.

Q: What's the biggest lesson you've learned?
Imperial taught me never to give up – now I have come full circle supporting a tech startup working on smart cities. My Dad used to joke that biologists make the best secretaries and, in the past, there was some truth in that – there weren't many jobs unless you worked in a laboratory. I am delighted to have proved him wrong!

SELEN FOBIAN

(MSc Management 2008) is currently Digital Marketing Manager for the publishers Condé Nast in New York City

Q: What's the biggest lesson you learned at Imperial?
At a time when the digital world was still emerging, Imperial taught me not to jump at the first opportunity. I remember our group developed an Oyster-type product that we were very proud of. Our lecturer's first question was how much it would cost to produce. There was an awkward silence – we didn't know the answer. It is easy to get carried away with technological flights of fantasy without considering the impact on a company's finance and strategy.

Q: How did your time here shape your career?
My first degree was in Electronic Engineering, where I worked on a 4D animation project. It made me realise I wanted to go into marketing, so I took my Master's at Imperial to get a broader business sense. We worked on a lot of diverse group case studies and I left knowing I wanted to work in different industries, focusing on digital.

My first job after Imperial was in Barclaycard's graduate scheme and it was great to be at the cutting edge of digital. Today at Condé Nast in the US, one of my tasks is to convince our readers to pay for quality online – paywalls provide a way of unlocking revenue. It was a very successful initiative for *The New Yorker* back in 2014 and I've been lucky enough to work on the *WIRED* launch this year. In previous companies, focus on content generation required senior buy-in and investment, but here high-quality content is bread and butter, with *WIRED* producing ten new articles a day online.

Q: And the future?
We have to measure performance and to do that we need people with analytical minds to work in marketing. Imperial gave me a different way of thinking that has stayed with me throughout my working career. We need more people, and especially women, with that kind of mindset.

WORDS: SARAH WOODWARD

WHAT'S ON AT IMPERIAL

May – October 2018

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

17/MAY

Organic chemistry: the proof is in the making

In his inaugural lecture Professor Chris Braddock will discuss the benefits of total synthesis in organic chemistry.
Lecture theatre 200, City and Guilds Building, South Kensington Campus

22/MAY

Imperial in the City

Make new connections at this networking event for Imperial alumni working in finance.
City of London

30/MAY

Precision airway sampling to enable personalised medicine for lung diseases

Professor Trevor Hansel presents research into personalised medicines and his belief in the right therapy for the right patient in his inaugural lecture.
Lecture theatre 200, City and Guilds Building, South Kensington Campus

30/MAY

The Athena Lecture

Dame Mary Archer will give the annual Athena Lecture which celebrates the achievements of women in science.
Lecture theatre 200, City and Guilds Building, South Kensington Campus

4/JUNE

The Annual Peter Lindsay Memorial Lecture: Neil Turok

Neil Turok presents the 11th Annual Peter Lindsay Memorial Lecture on the Quantum Universe.
Lecture theatre 200, City and Guilds Building, South Kensington Campus

6/JUNE

Rainforest resilience

Discover the impacts of logging and agricultural expansion on tropical ecosystems in Professor Rob Ewers' inaugural lecture.
Lecture theatre 164, Skempton Building, South Kensington Campus

18/JUNE

A decade of difference in climate change and environment

Marking the end of their tenth anniversary celebrations, the Grantham Institute looks back at the last decade in climate change and the environment, and asks a panel of distinguished guests what the next ten years will hold.
Great Hall, Sherfield Building, South Kensington Campus

18/JUNE

The Bioengineering Lecture

Distinguished biological engineer Professor Natalia Trayanova presents the 2018 Department of Bioengineering annual lecture.
Lecture theatre G16, Sir Alexander Fleming Building, South Kensington Campus

7/SEPT

Sir Derek Barton Centenary Celebration

A symposium commemorating the centenary birth of Sir Derek Barton with a number of outstanding organic chemists invited to deliver lectures and discussion.
Lecture theatre G16, Sir Alexander Fleming Building, South Kensington Campus

5/OCT

Inaugural lecture: Professor Prapa Kanagaratnam

Professor of Cardiology, Prapa Kanagaratnam, discusses his research at the National Heart and Lung Institute.
Lecture theatre G34, Sir Alexander Fleming Building, South Kensington Campus

10/OCT

Inaugural lecture: Professor Sonia Saxena

Reducing the burden of long-term childhood illness including asthma, diabetes and those at early cardiovascular risk.
Brian Drewe Lecture Theatre, Reynolds Building, Charing Cross Campus

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

RESEARCH FOCUS / DATASET
DR NIAMH NOWLAN
SENIOR LECTURER IN THE
DEPARTMENT OF BIOENGINEERING

> “The movements of the developing human skeleton in utero have never previously been characterised – it gives us a new baseline”

CONTEXT

A baby’s kick from inside its expectant mother is arguably one of the most awe-inspiring aspects of pregnancy. But, far from simply being an emotional high point, one Imperial researcher has set out to demonstrate that the kick could have a fundamental story to tell about the baby’s development.

BACKGROUND

Dr Niamh Nowlan, Senior Lecturer in the Department of Bioengineering, has begun a ground-breaking study into the impact of fetal movements – the baby kicking in the womb – by analysing what actually happens during that kicking process. These fetal movements are essential for the health of the baby, and, in particular, for the normal development of the bones, joints and spine. Yet little is known about how much movement is necessary for normal skeletal development, when movement is most important, and whether the effects of reduced movement on the skeleton can be mitigated.

METHODOLOGY

Nowlan and research colleagues from Imperial, Great Ormond Street Hospital and King’s College London set out, for the first time, to explore how fetal movements affect the formation and development of the bones and joints, and may be indicative of the health and development of the unborn baby. They used scans from a range of pregnant women at 20, 25, 30 and 35 weeks to produce a computer model that calculated the stresses fetal movement puts on the uterine wall. From this they created a musculoskeletal model that could then compute the level of stress and strain experienced by the fetus.

FINDINGS

“The movements of the developing human skeleton *in utero* have never previously been characterised,” says Nowlan. “We discovered that the stress stimulation – the kicking – actually plays a role in the development of the skeleton, with the amount of stimulation increasing as the baby grows, and as the bones, such as the limbs and pelvis, are created.

“Quantifying those biomechanical movements over the second half of gestations gives us a new baseline of what is normal development. It advances our understanding of the biomechanical environment of the uterus, and ultimately allows for better screening. Our research also increases our understanding of other developmental problems, such as hip dysplasia, where ball and joint sockets fail to form properly.

OUTCOMES

“These achievements form part of the aims of a three-year grant from Arthritis Research UK,” says Nowlan. “We are not just pushing back those boundaries now, but creating an environment that enables us to answer the questions of the future.” They also reflect Imperial’s five-year strategy to attain enduring excellence in science, medicine, engineering and business.

“Our results will, for the first time, help identify environments that increase the risk of joint malformations, helping clinicians to consider interventions prenatally, to perform more intensive screening on at-risk infants after birth and to prescribe suitable postnatal physiotherapy.

“They may also inform future preventative measures for neonatal joint conditions, thereby potentially reducing the risk of osteoarthritis in later life. With this understanding of what is normal, we can create better-quality monitoring, which is of huge benefit to our advancement of knowledge, medical staff and, most importantly of course, the health of mothers-to-be and their babies.” ◆

> Stresses and strains on the human fetal skeleton during development*: Verbruggen, Kainz, Shelmerdine, Hajnal, Rutherford, Arthurs, Phillips, Nowlan. Journal of the Royal Society Interface, January 2018.*

WORDS: PETER TAYLOR WHIFFEN

ADVENTURES IN...

Fire science

For a laboratory-based expert, **Professor Guillermo Rein** has experienced his fair share of blazes.

Words: **Helena Pozniak** / Photography: **Joe McGorty**

Every year, fires kill more than 150,000 people in the world. But scientists still don't know enough about the science of fire. "As an engineer I try to make sure our knowledge can be used for the benefit of society," says Guillermo Rein, Professor of Fire Science. "I'm happy if our research leads to new technologies that might truly help save lives and protect the environment."

Fires have fascinated Rein since the beginning of his career, when he was sponsored by NASA to investigate how flames behaved in space, free of gravity. A mechanical engineer by training, he arrived in the US from Spain shortly after 9/11, and was profoundly moved. "Today we are still studying the details of how fire caused those towers to collapse," he says. "It was a defining moment in fire science."

Similarly, London's Grenfell Tower fire of June 2017, which killed at least 71 people, was a tragedy his team could not ignore. One of his researchers was already investigating the flammability of façades containing polymers, but now his team are working urgently to help understand whether high-rise blocks in other parts of the world are vulnerable. "Right now there are tens of thousands of buildings with façades that have different levels of flammability. We need to know immediately whether we need to act. We want to convert this tragedy into something positive so those lives were not lost in vain."

Fire research is carried out at the Hazelab in the Department of Mechanical Engineering, where engineers, physicists and chemists conduct laboratory-based fire experiments to help inform larger-scale computer simulations. The team carries out a range of large-scale studies, such as deliberately igniting an isolated farm building in Poland, then monitoring the fire with infrared cameras and precise thermometers – the biggest-ever fire experiment to date.

As an expert on smouldering fires, his knowledge has helped with the analysis of historical events, notably the sinking of the Titanic. According to Rein's research, a fire burning in the ship's coal bunker, possibly for weeks before her final voyage in 1912, would have severely weakened a crucial part of the hull. This would have caused the steel bulkhead to collapse and flood sooner than it might have.

"Crew at the time said the bulkhead had previously been red-hot and warped," says Rein, who has been presenting his findings at international conferences and will publish them shortly in the academic press. "We showed it would have lost ten times its strength. Had the bulkhead held longer, it's possible the Titanic could have stayed afloat in time for rescue to arrive."

Currently, he is engrossed in understanding the dynamics of naturally occurring peatland fires, the largest fires on Earth, in the likes of Indonesia, Malaysia and Russia. "Our team was the first to consider how current climate change affects smouldering peat fires, which will then affect our future climate," says Rein. "Geoscientists are now taking it into account in their calculations, partly thanks to our research." ◆

1. Globe-trotter laptop
2. Polymers for experiments
3. Missoula wildfire cap
4. Smoke machine
5. Building cladding for experiments
6. Infrared and portable imagining
7. Computer simulation of fire
8. Fourier law of heat transfer
9. Li-ion batteries for experiments
10. Replica of the Titanic
11. Smoke detector
12. Dummy replica of landmine
13. Cotton detector of embers
14. Safety glasses
15. Hi-vis jacket
16. Fireproof gloves
17. Scientific photography
18. 1874 edition of *The Chemical History of a Candle*
19. Datalogger and thermo couples
20. Residues from burnt samples
21. Essential fire books
22. Replica of the Atomium
23. Filters with smoke particle
24. Reactor for peat fires
25. High precision balance

MY IMPERIAL

Down to business

Elisabeth Mahase (MSc Science Communication) can't resist the lure of the big 'baked bean tin'.

Words: **Diane Shipley** / Photograph: **Joe McGorty**

I used to come to Imperial all the time when I was little because my dad was a cleaner here. That was when they were building the Business School, and I loved the huge cylinder in the café, which I always called the 'baked bean tin'. There are lectures in there now, but, at the time, I just thought it was big, shiny and impressive.

I thought I'd study at Imperial at some point in my life and the Master's in Science Communication sounded perfect. I've always wanted to be a science journalist, or someone who communicates about science, and it teaches everything from writing to documentary and radio production.

In the future I'd like to do a mixture of writing and documentary, but for the moment I'm focusing on the written side. I'm also freelancing as a journalist for *Pulse*, a magazine for GPs; I've just done an investigation into cervical cancer tests that were incorrectly labelled 'all clear', which was picked up by the national papers. I'm very keen on investigations: going out and finding stories rather than just re-reporting. Apart from it being important, it also gives you a bit of a rush.

Imperial is internationally known as being one of the best, but more diversity in its students would make it even better. I think it's important that the university encourages people from different backgrounds to come here, especially women, people of colour and people from poorer backgrounds.

Although I don't study at the Business School, I often go to the café because it reminds me of going there with my dad. It's a nice place, and a good spot to people-watch because a lot of people walk through it to get in and out of campus. I've seen many stressed students walking around talking to themselves, especially at exam time.

Sometimes I'll study there if I have an afternoon class. I usually just meet up with friends from my course, bring a packed lunch and have some tea; I'm a massive tea-drinker. It was so nice to be able to tell my dad that I was coming to Imperial, like things had come full circle. ◆

> *Elisabeth is studying for a Master's in Science Communication and is a reporter for* Pulse *magazine.*

I often go to the café at the Business School – it reminds me of going there with my dad

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