UNIVERSITY OF CAMBRIDGE

Chemistry at Cambridge Magazine
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Chemistry opens its doors

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Sparks fly at Open Day

A Wider Approach to Alzheimer's

Alumni Celebrate Women in Chemistry

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Contents

WOMEN IN CHEMISTRY

BOOKS

PEOPLE

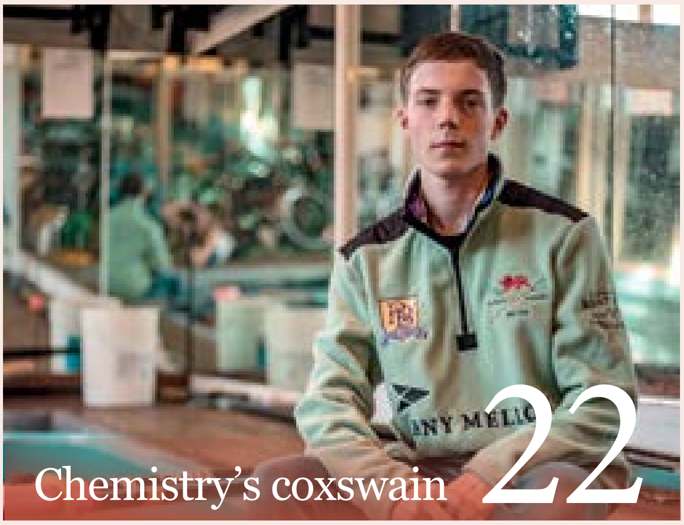

Image: courtesy of AllMarkOne

RESEARCH

Welcome

I have had several opportunities in the last few months to welcome groups of Chemistry alumni back to the department. It has been wonderful to meet old friends, to hear their memories of life in the lab and to find out about what they are doing now.

Our annual alumni reunion in March was centred around the celebrations of the 150th anniversary of the Periodic Table. (*See the feature on pages 6-7*). My colleague Peter Wothers gave a splendid talk shedding light on how the Periodic Table evolved into its current form and the chemists who played a key role in developing it. As we heard, it is not really the case that Mendeleev 'invented' the Periodic Table, but rather that he has ended up with much of the credit.

Alumni were also treated to a tour around a special exhibition that Peter had put together to illustrate the development of the Periodic Table. The exhibition included a selection of Peter's amazing collection of historical chemical items, including 'bromide' toilet paper and a medal struck in tellurium. At the drinks reception afterwards, knots of alumni enjoyed scrutinising the posters of old group photos, trying to find themselves and their friends. (*See one of the photos, and test your knowledge of departmental faces, on page 31.*)

We also piloted a new alumni event in February celebrating 'Women in Chemistry.' A panel of female alumni gave candid accounts of their lives in science and what has helped and hindered them. In the afternoon we followed on with a session in which students and postdocs were able to join in the discussion about what more we can do to encourage equality and diversity in science. (*See the feature on pages 14-15.*) Many alumni who came along told us they were pleased to see how much both the University, and we as a department, are doing to promote women in science. We clearly have more to do, but they told us they are keen to support our efforts. We were delighted with the reaction the event received and are planning how best to follow it up.

Of course we wouldn't have alumni if we didn't have students: you can read about some of our current students in this edition, from the Natural Sciences undergraduate who helped make this year's Boat Race so exciting (*page 16*) to the PhD students who are measuring air pollution (*page 18*) and looking for ways to turn plastic waste into renewable fuels (*page 24*).

I hope you enjoy this edition of Chem@Cam. Do keep in touch: we are always interested to hear your news and views. If you would like to revisit the department, why not come along to our next alumni event this September? See the back page for details.

James Keeler
Head of Department

Cover photograph taken at Chemistry Open Day by Gaby Bocchetti.

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Sparks fly at Open Day

They came to make 'Elephant Toothpaste', enjoy the Liquid Nitrogen Magic Show and zinc plate their own coins. But along the way, visitors to our annual Open Day — including alumni and their families — learned how to extract DNA from strawberries and discovered the structure of molecules by making models of them.

The Department of Chemistry runs an Open Day every year as part of the Cambridge Science Festival. Hundreds of people come through our doors and enjoy exploring aspects of chemistry from the explosive to the illuminating. And they thoroughly enjoy it.

The volunteers have a good time too. Undergraduate student Navyaa Mathur, who was helping out at the event for the first time, said: "I really enjoyed it. It was a challenge explaining the science to children of a wide range of ages and temperaments, but a very satisfying one. My favourite thing was when a child really understood a concept that they'd encountered for the first time, or when they asked further questions about the science."

"The lecture was inspiring: we played 'find the element' all the way home!"

Navyaa added: "I also like that the experiment was not reduced to just doing the steps with minimal explanation of the science: as demonstrators, we were encouraged to explain each step and encourage critical thinking."

Open Day always includes a demonstration lecture by our Teaching Fellow Dr Peter Wothers. This year, he devoted his lecture – 'Table Talk' – to the Periodic Table and audiences loved watching him demonstrate how atomic structure gives rise to a diverse range of chemical properties from metals that explode in water to elements that enable things to burn.

One parent, Jane Herbert, tweeted: "Awesome time: plenty of big bangs at the @peterwothers talk, and ice cream! Kids and I loved it." Another parent, Julie Aspin, also took to Twitter to praise the event. "Kids inspired by this superb lecture on the Periodic Table," she posted. "We played 'find the element' all the way home on the bus!"

- **We gratefully acknowledge The Walters Kundert Charitable Trust whose support makes it possible for us to put on this annual event.**

Table Talk

Dr Peter Wothers took us time-travelling through the history of the Periodic Table at our annual alumni reunion at the end of March.

Some extraordinary exhibits – from a first edition of Mendeleev's *Principles of Chemistry* to contemporary versions of the Periodic Table in macramé, silver and etched glass – were on display when our alumni came along to the annual reunion.

Over 100 alumni turned up at the event in March, held at St Catharine's College. This year the reunion coincided with the 150th anniversary of the publication of Mendeleev's Periodic Table. To celebrate this, our Teaching Fellow Dr Peter Wothers, a chemistry history enthusiast, gave a special lecture in which he took us time-travelling. His talk shed light on all the chemists in addition to Mendeleev who had played a key role in developing the table, and discussing how it evolved into its current form.

Spilling out of the lecture theatre into the foyer, alumni were able to pick up a glass of something thirst-quenching. They were then escorted round an exhibition Peter had curated on the subject.

It showcased samples of elements and their applications to our lives, with items ranging from selenium light-meters and silicon chips to fluoride toothpaste and bromo toilet paper. Some alumni enjoyed it so much that they returned the following day to have another look. In particular, a beautiful silver artwork commissioned especially to mark the anniversary caught many eyes. (*See photograph, far right*). Lots of our guests snapped photos of the striking band of silver, wound around a rod, bearing 118 individual tiles representing each element.

They also took the opportunity to mingle with fellow alumni and former lecturers, rekindling memories and sharing stories. We had created banners showing departmental photos taken in the 1970s and these attracted a lot of interest. Alumni enjoyed looking at them and trying to identify their teachers and contemporaries.

Following the lecture, exhibition and drinks, around 40 alumni who had been in the department up to 1979 joined us for dinner. They had all been asked to contribute a photo, a favourite memory of their time in Cambridge (*see side panel, right*) and a paragraph about what they had done since then. These made for entertaining reading in the commemorative programmes we gave them.

We're glad our alumni enjoyed the occasion and look forward very much to the next one.

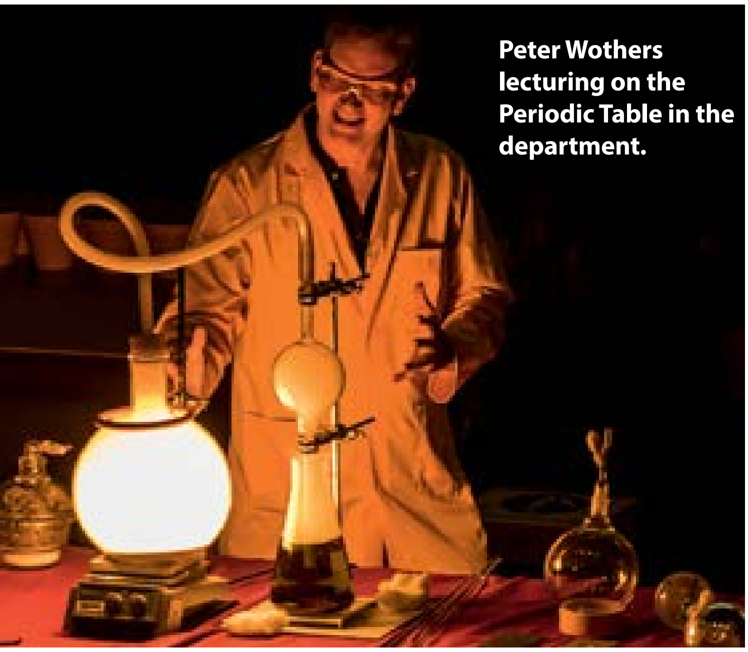
- ***Our next alumni event is our Wine Tasting in September (see back page for details). Our next annual alumni reunion will be in March 2020. See booking information in the next Chem@Cam.***

Periodic Table developments

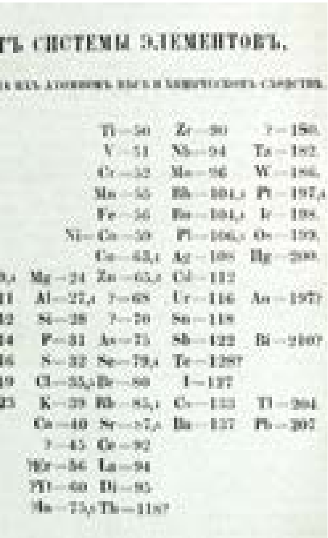
1862: In his '*Telluric Screw*' system Alexandre-Émile Béguyer de Chancourtois arranges elements in order of increasing atomic weight and plots them around a cylinder of such a circumference that elements with similar properties align down it in vertical groups.

1864: John Newlands devises his *'Law of Octaves',* arranging the elements in order of increasing atomic weight and noting the similarity between an element and the one eight places after it (like the notes in a musical scale).

1864: a remarkably similar version to Mendeleev's later table is published by William Odling, Secretary of the Chemical Society of London.



Peter Wothers lecturing on the Periodic Table in the department.



Above: Mendeleev's first table from 1869 and the new silver artwork based on a design from 1920.

1869: Dmitri Mendeleev publishes his now iconic Periodic Table in his *Principles of Chemistry*. In 1882, he and Meyer receive the Davy Medal from the Royal Society for their work on the Periodic Law.

1864: Julius Lothar Meyer publishes a version of the periodic table in *Die modernen Theorien der Chemie*. It contains 28 elements, classified into six families by their valence.

Alumni memories

Howard Colquhoun, St Catharine's 1969-72

"Favourite memory? Final year lectures from Max Perutz on his newly-completed structure of haemoglobin (and his kind invitation for all his undergraduate students to tea and cake in Peterhouse)."

Mike Gibson, St John's 1974-77

"I have memories of friendships made and the splendour of the backs in summer. And I do wonder what it would have led to had I accepted a prompt from my organic chemistry supervisor to apply to stay on for a PhD."

Alison M Griffin (née Ryder), Girton 1969-75

"One memory is of Professor Emeleus soon after he had retired, taking over an area in the lab and blowing his own vacuum line for practical research work he was planning. I smelled some singeing and turned round to see he had set fire to his hair and I had to work out how to tell this eminent and distinguished gentleman that he had a problem..."

David A Griffin, Jesus 1969-75

"I particularly enjoyed lectures by Stuart Warren and Ian Fleming. They inspired me to pursue a career in organic chemistry."

Timothy Horne, Peterhouse 1970-73

"My memories from Cambridge range from walking to Grantchester for Sunday lunch to learning computing on the Titan in the Maths Lab."

News

Arise, Sir David

Professor David Klenerman received a knighthood in the New Year Honours List 'for services to Science and the Development of High Speed DNA Sequencing Technology'.

A professor of biophysical chemistry here, and a Fellow of Christ's College, he co-founded – with his Department colleague, Professor Sir Shankar Balasubramanian – Solexa, a high-speed DNA sequencing company. Their invention of the leading next-generation sequencing methodology has made routine, accurate, low-cost sequencing of human genomes a reality, revolutionising biology and genomic medicine. David said: "The development of Solexa sequencing was the result of a massive team effort. I want to sincerely thank the highly talented people who have worked with me over the years "

Lectureship for Daan

Professor Daan Frenkel has been awarded the 2019 Lars Onsager Professorship, awarded to an internationally leading scholar. He will receive the silver Onsager medal, and will be invited to stay at the Norwegian University of Science and Technology for up to six months, where he will have the opportunity to collaborate with scientists there. www.ntnu.edu/onsager

ERC Advanced Grant for new battery research

For her work in developing longer lasting, higher energy density and cheaper rechargeable batteries, Professor Clare Grey has won an Advanced Grant from the European Research Council (ERC), Europe's premier research funding body.

ERC Advanced Grants are designed to support excellent scientists in any field with a recognised track record of research achievements in the last ten years. Clare, a Royal Society Research Professor here, leads a project focused on the development of longer lasting, higher energy density and cheaper rechargeable batteries, a major technological challenge. Batteries are currently the limiting components in the shift from gasoline-powered to electric vehicles.

Using a variety of experimental techniques, including dynamic nuclear polarisation NMR spectroscopy, Clare and her team will explore a variety of different battery chemistries, including more traditional lithium-ion and newer solid state and redox-flow batteries, with a particular focus on understanding the interfaces and interphases that form in these systems. The interdisciplinary project combines analytical and physical chemistry, materials characterisation, electrochemistry and electronic structures of materials, interfaces and nanoparticles. The final result will be a significantly improved understanding of the structures of new types of batteries and how they evolve during the charge-discharge cycle, coupled with strategies for designing improved battery structures.

Alumnus elected to the Royal Society

Congratulations to Alumnus Dr Yusuf K Hamied, who has been elected an Honorary Fellow of the Royal Society. Honorary Fellowship is awarded, very exceptionally, to those who have given distinguished service to the cause of science.

Dr Hamied came to Cambridge to study Natural Sciences in 1954, and stayed to complete his PhD here with Lord Todd. Later, as CEO and Chair of the Indian pharmaceutical firm Cipla, Dr Hamied campaigned to provide low-cost generic antiretrovirals to people primarily in sub-Saharan Africa with HIV and Aids, reducing the cost from $15,000 to $350 per year. These actions saved millions of lives.

Head of Department Dr James Keeler said: "The election of Dr Hamied as an Honorary Fellow of the Royal Society is a fitting tribute to his outstanding contributions across many fields. We are so proud to be able to count him as an alumnus – and a friend of the Department." As an alumnus, Dr Hamied has donated generously to the Department in many areas, including the

News

creation of the Todd-Hamied Meeting Room, named in honour of Lord Todd, and the Yusuf Hamied Laboratory for Chemical Synthesis & Catalysis, which opened in September 2015. Most recently Dr Hamied has supported the 1702 Chair of Chemistry at Cambridge – one of the longest-established Chemistry Chairs in the UK – which has been renamed the Yusuf Hamied 1702 Chair of Chemistry in his honour.

The Royal Society is a Fellowship of many of the world's most eminent scientists and is the oldest scientific academy in continuous existence. Dr Hamied will be formally admitted to the Royal Society at the Admissions Day ceremony in July.

Honoured by her adopted country

Alumna Professor Mary Garson has been made a Member of the Order of Australia for services to education and as a champion for women in science.

Image: courtesy the University of Queensland

Mary studied Natural Sciences here before completing a PhD with Professor Jim Staunton. She migrated to Australia in 1983 as a Queen Elizabeth II Research Fellow and subsequently spent her career researching the chemistry and chemical ecology of bioactive metabolites from marine sponges and molluscs. She also became the first female academic, and first female professor, in the University of Queensland's chemistry department where she taught organic chemistry to thousands of students.

She said she was delighted to be recognised for her work in championing women in science as "I've always fought for other women to have access to the same opportunities that I've been fortunate enough to experience." Her own studies here in Cambridge were in classes where women were heavily outnumbered by men, but that certainly did not hold her back.

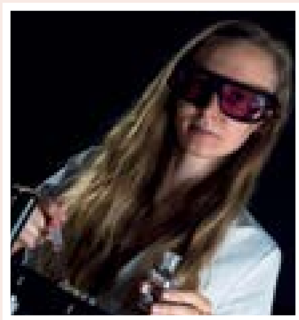
"When I was sitting in third year lectures in Lensfield Road, I would never have guessed that this would eventually lead me to completing over 400 scuba dives and to having a marine flatworm (*Maritigrella marygarsonae*) named after me," she says. "My advice to others is that the opportunities are always there, but you have to be willing to spot them."

Today she still helps support women in science. She mentors both men and women and was also involved in organising the global networking breakfast in February to celebrate the centenary of International Union of Pure and Applied Chemistry. "The response was amazing," she says happily. "Women chemists from over 50 countries joined in."

Recognition for two young researchers

A postdoctoral researcher in the Klenerman group has received a prestigious award from Alzheimer's Research UK for his study into dementia.

Dr Jason Sang was awarded the Alzheimer's Research UK Jean Corsan Prize for best paper by an early career researcher. In the article, published in the Journal of the American Chemical Society, Dr Sang describes how he and other departmental researchers found that a protein that builds up in Parkinson's disease spreads through the brain in a way similar to the prion protein responsible for Creutzfeldt Jakob disease (CJD). He says: "Winning the Jean Corsan prize is the highlight of my career so far. It's an honour to receive this award and to be given an opportunity to present my work to world experts at the Alzheimer's Research UK Conference."



Meanwhile Dr Kadi Liis Saar, a postdoc working on devising new methods for probing protein folding and aggregation in the context of neurodegeneration, was elected as a Schmidt Science Fellow 2019 by the Eric and Wendy Schmidt Foundation.

This innovative postdoctoral program aims to develop the next generation of interdisciplinary science leaders. It deliberately exposes them to new ideas from a different scientific discipline. In Kadi's case, she will be making use of new techniques, similar to those used by the computer chip and microprocessor industry, to develop a platform for high-throughput characterisation of proteomic fingerprints of individual cells, opening up the possibility of identifying previously unknown targets and disease biomarkers.

News

RSC recognition for department researchers

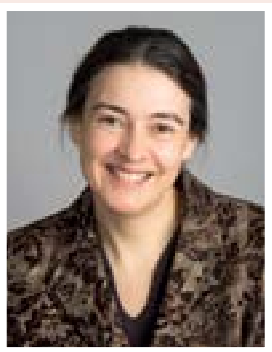
Six researchers from this department have received prestigious Royal Society of Chemistry prizes, it was announced in May. Their work spans the molecular origins of neurodegenerative diseases, synthetic organic chemistry and electrochemical devices.

Dr James Keeler, Head of Department, said: "Congratulations to our colleagues. It is wonderful to see so many prestigious awards coming to the Department."

Professors Sir Christopher Dobson, Tuomas Knowles and Michele Vendruscolo won the **Rita & John Cornforth Award** for their groundbreaking collaborative interdisciplinary research on the molecular origins and treatment of neurodegenerative disorders. As Co-Directors of the **Centre for Misfolding Diseases**, the team have developed and applied a range of advanced spectroscopic techniques to begin to define the mechanisms of protein aggregation and amyloid formation and to probe their consequences.

"We are absolutely delighted to have received this award from the Royal Society of Chemistry," said Sir Christopher. "This award is particularly important for us, as it recognises our long-term endeavour to establish a highly collaborative interdisciplinary programme to understand the molecular origins of protein misfolding disorders, and to develop methods to combat them."

Professor Clare Grey was awarded the **John B Goodenough Award** for her pioneering and innovative uses of magnetic resonance methods to study structure and dynamics in electrochemical devices.



Professor Grey said: "I was a student at Oxford at the time when John was head of the Inorganic Chemistry Laboratory, so I am particularly delighted to win the John Goodenough Award. His ground-breaking work, be it in battery electrode materials, in solid oxide fuel cell materials or in the development of the rules that describe magnetic couplings has inspired so much of my work."

Professor Matthew Gaunt won the **Synthetic Organic Chemistry Award** for his development of catalytic C-H activation strategies in aliphatic amines. Methods that enable the selective functionalization of unreactive aliphatic C–H bonds have applications in fields that range from drug discovery to functional materials.

Professor Gaunt said: "Our team questioned whether C–H activation could be controlled in molecules called alkylamines, a feature of molecules that are present in many pharmaceutical agents and other biologically important molecules.

"We identified a number of mechanistic factors that underpin the successful realization of our ideas, which led to the development of a series of new synthetic processes that enabled C–H activation in a wide range of alkylamines and streamlining the synthesis of complex variants of these molecules with previously unexplored properties.

"We expect that these methods will expedite the synthesis of new biologically active alkylamines which could aid the discovery of new medicines and agrochemicals."

Dr Robert Phipps has received the **Harrison-Meldola Memorial Prize** for inventive research on the application of non-covalent catalysis to selectivity in synthetic organic chemistry. He is developing new ways to construct small organic molecules which can be used for a variety of purposes – from pharmaceuticals to biomolecules. His team's approach aims to develop catalysts that allow challenging reactions to occur while also allowing them to select which one of several possible products is ultimately obtained – a challenge referred to as selectivity.

Dr Phipps said: "It's very gratifying to have this recognition for our group's research. My students and co-workers have been instrumental to the group's achievements over the last four years, and I am eternally grateful to them for their efforts, trust and enthusiasm."

Write to us

We are always delighted to receive your emails and letters.

Email your comments to: news@ch.cam.ac.uk
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Correspondence

The mystery of the underground cycle park

From Emeritus Professor Brian Thrush
In your article about the Lensfield Road building's 60-year history in *Chem@Cam 58*, you asked if any readers knew about the proposed 'underground bicycle park' mentioned by the architect John Murray Easton.

I can shed some light on this. There were indeed plans to include an underground bicycle park at 'the University Chemical Laboratories' *[as Lensfield Road was originally known]*. It would be beneath the large lecture theatre and the idea was to have a ramp leading down to it. But it was then decided that this would be impractical – and also quite dangerous if lots of cyclists arriving for a lecture were all trying to cycle down the ramp at the same time! So the idea was abandoned. The area subsequently became an X-ray diffraction facility, a storage area and some rather generous loos.

The Lensfield Road building was the first chemical laboratory designed by the architects Easton & Robertson. (This partnership between the Scottish architect John Murray Easton and the American Howard Morley Robertson was also behind the design of the Shell Centre on London's South Bank.) Their thoughtful design for Lensfield Road produced a durable, solid building which subsequent work using AFM and electron microscopy found to be remarkably free of vibration, despite its proximity to the busy Lensfield Road.

I was also interested to see the letters from users of the building who mentioned problems in fume cupboards and their make-up air. This was solved by the provision of 32 additional fume cupboards and extra make-up air for the arrival of [Professor] Steve Ley in 1992.

Lensfield Road under construction in 1954.

A wider approach to Alzheimer's

New work by researchers here suggests way forward after recent high-profile trials failures

Work by researchers here that was published in the wake of two high-profile Alzheimer's drug trial failures offers evidence for taking a wider approach to treating the disease.

Trials of drugs by Roche and Biogen, halted respectively in January and March this year, were both targeted at removing the insoluble clumps of the protein beta-amyloid (Aβ42) that build up as plaques in the brains of patients with Alzheimer's disease. But in a study – *Different soluble aggregates of Aβ42 can give rise to cellular toxicity through different mechanisms* – published in April in *Nature Communications*, researchers here suggest we need a much greater range of therapeutic tools than a drug that purely targets Aβ42 amyloid plaques.

A range of toxic effects on nerve cells

It has been argued, in the 'amyloid hypothesis', that the accumulation of amyloid plaques in the brain is the primary cause of the memory-destroying disease. Yet we know that the picture is more complex, as other (smaller, soluble) species of aggregates are also built up during the clumping process. And from studying them, our researchers found that their size and structure, and how they change during the aggregation process, can have a range of toxic effects on patients' nerve cells.

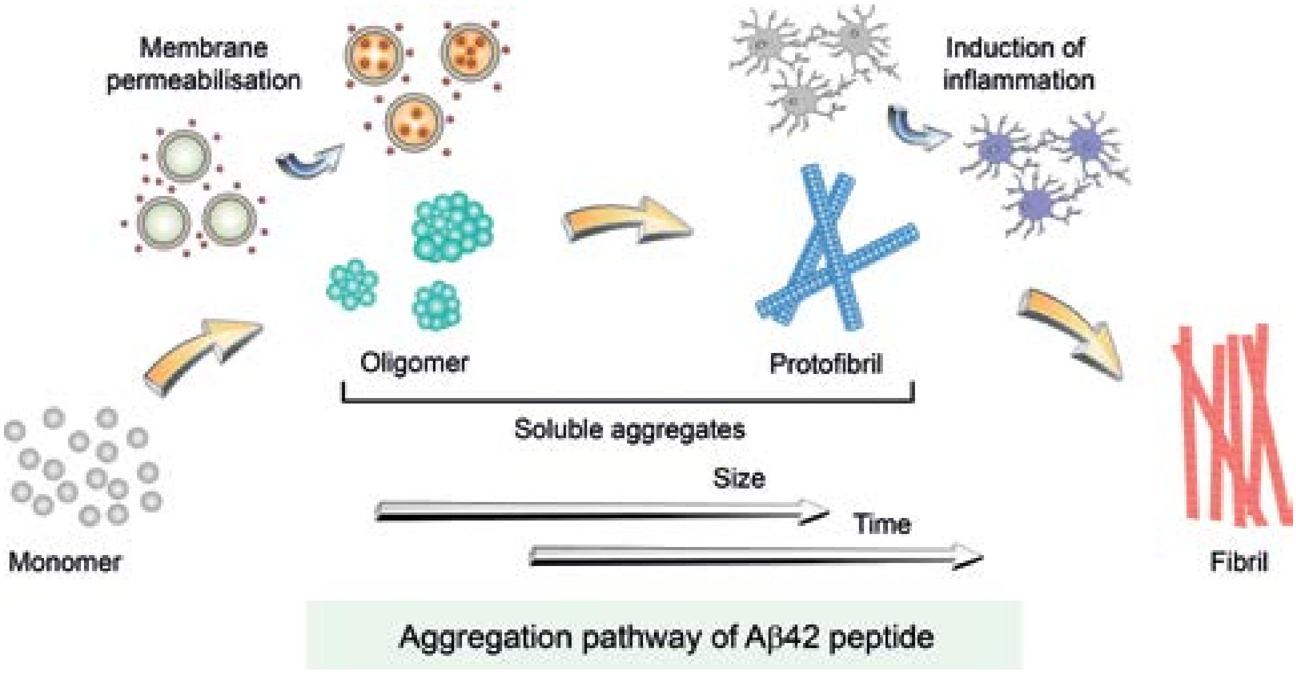
"We are not looking for a single Achilles' heel, but Achilles' heels plural."
Dr Suman De.

As their findings suggest that the different toxic mechanisms driven by different soluble aggregated species of Aβ42 may contribute to the onset and progression of Alzheimer's disease, the researchers argue that we need to tackle these aggregates as well in order to treat patients effectively. And that may involve a whole cocktail of therapeutic agents. "We're not looking for a single Achilles heel, but Achilles heels *plural*," says corresponding author Dr Suman De, a postdoc in the Klenerman research group.

As he explains, "in patients with Alzheimer's disease, some of the proteins in our brain that usually behave normally somehow start to misbehave and clump together. That's a clinical sign of the disease. Those protein clumps take years to form, but during the process other soluble species of aggregates also form, and they are more harmful to neurons.

"These species of aggregates are very small and not very stable: they form, then quickly break and convert to different shapes and structures. As we are aware that the toxicity of something is often a function of its shape and structure, we set out to study these species. We wanted to see what is really going on here and whether those changes of shape and structure equate to different toxicity mechanisms and could contribute to disease pathogenesis."

This was what the researchers did in a project spanning scientists from the Klenerman group and Centre for Misfolding Diseases here, as well as the University's Department of Veterinary Medicine, Cavendish Laboratory and UK Dementia Research Institute. When they looked at the aggregates in-vitro, the researchers saw that depending on their shape – for example, whether they are globular or linear – these species kill cells in different ways.



The more globular forms can permeate the cell membrane, "like a wasp making a hole in your skin when it stings you," Suman says. They also found size was key. Smaller aggregates were more powerful in disrupting lipid bilayers and permeating the cell membrane. But as these aggregates increased in size and underwent structural changes during the aggregation process, their toxicity changed. The larger aggregates were less potent at permeating cell membranes and more effective in inducing inflammation in nerve cells.

Research offers "much-needed new insights"

"I think this is a really important finding and provides much-needed new insights into the toxic aggregates," Professor Sir David Klenerman says. "The different toxicities of the aggregates may be why, at different stages of the disease, you see different symptoms. Knowing this, we can then consider the question of how we target these aggregates."

The researchers went on to experiment with treating these aggregate species with rationally-designed antibodies. In their research, they showed that the smaller aggregates that tend to induce membrane permeability can be inhibited by antibodies that bind to the C-terminal region of amyloid-beta, while larger aggregates that cause an inflammatory response in brain cells called microglia cells, can be stopped by antibodies that target the N-terminal region of amyloid-beta. These observations may help give a new direction to research that seems to have hit so many stumbling blocks in the last few years.

"One problem with trials is that one needs new tools to detect the toxic oligomers and target them therapeutically," says Professor Michele Vendruscolo. "Now we have shown that one antibody binding one side of the oligomers inhibits one mechanism of toxicity, while another antibody binding another side of the oligomer modifies another mechanism.

"So with this study we anticipate that we will need multiple therapeutic agents to stop the multiple pathogenic processes originated by the oligomers."

Suman De, David C. Wirthensohn, Patrick Flagmeier, Craig Hughes, Francesco A. Aprile, Francesco S. Ruggeri, Daniel R. Whiten, Derya Emin, Zengjie Xia, Juan A. Varela, Pietro Sormanni, Franziska Kundel, Tuomas P. J. Knowles, Christopher M. Dobson, Clare Bryant, Michele Vendruscolo & David Klenerman. *Different soluble aggregates of Aβ42 can give rise to cellular toxicity through different mechanisms*, Nature Communication (2019).
DOI: 10.1038/s41467-019-09477-3

Women in Chemistry

We invited alumni back to the department for a special event marking the UN International Day of Women and Girls in Science. They joined students and postdocs in discussing the progress we've made towards gender equality in the scientific workplace — and what still needs to be done.

In organising our first-ever Women In Chemistry event, we were partly inspired by the story of alumna Effie Cooke who studied chemistry in Cambridge in 1895 but was unable to pursue it as a career post-marriage. As a panel of alumni and departmental speakers revealed, while things have improved since then, women in science still face significant issues in their careers.

The eight women discussed positives — like the female scientists who had inspired them — and challenges, such as those of combining careers and parenthood. Many mentioned experiencing imposter syndrome, including when they were returning to work after a career break. They revealed how they had arrived in their chosen fields (which ranged from academic research and teaching to law and scientific publishing); how they had achieved their current positions; and how mentoring and leadership programmes had helped them.

In the afternoon, students and postdocs from across the department joined alumni for a *Question Time*-style debate on topics such as 'How do we change recruitment and funding in academia to provide a level playing field?' The atmosphere on the day was hugely positive, as was the feedback the department received afterwards. Watch this space for details on how we'll be following it up.

Alumna Sally Curran, now a Senior Patent Director at AstraZeneca, was one of our speakers.

"I was delighted to be invited to participate, though as it was almost twenty years since graduating, and I had not set foot in the department since, there was a certain apprehension as imposter syndrome set in. Why on earth did they ask me?

As it turned out, there was no need to worry — the department was reassuringly familiar, as the faces of department staff were apparently untouched by time. (It must be something in the air?) And the welcome from attendees was warm and friendly.

The topics and speakers were varied and wide-ranging, but certain themes cropped up time and time again: imposter syndrome, work-life balance, fear of failure and hesitancy to venture beyond our comfort zone.

They were addressed by some excellent and inspiring stories from staff and alumni on tackling new challenges and overcoming adversity, interspersed with advice gained from (sometimes bitter!) experience in both academia and industry. I left feeling energised and with a renewed sense that we are fortunate to be a part of the department's diverse community.

Though the day focused on women specifically, the audience was diverse and many of the topics discussed were relevant regardless of gender.

It was notable that support and attendees from within the department were not limited to women only: a very good sign that an event like this is not just held to recognise diversity, but also about ensuring inclusion of all voices.

I hope there can be future events where diversity in chemistry – be that gender, race, sexuality, diversity of background etc – can be our focus."

Images on facing page: top left, Professor Melinda Duer, Ali Stoddart and Sally Curran taking part in the afternoon debate. Top right: Dr Jenny Zhang sharing her experiences as a woman in science. Bottom left: 1890s chemistry student Effie *(front row, left)* with her contemporaries from Newnham. Bottom right: Alumni enjoyed meeting up at the networking sessions.

Inspiring female scientists

A female professor here described as "generous, supportive, and particularly encouraging of the ambitions of her female co-workers" received a 2019 Suffrage Science Award on International Women's Day in March.

Melinda Duer, Professor of Biological and Biomedical Chemistry, received her award during a ceremony at The Royal Society. The biennial Suffrage Science Awards celebrate women in science and engineering and encourage others to enter science and reach senior leadership roles.

Melinda has led pioneering research into the molecular structure of bone, and the underlying chemical changes in the tissue of blood vessels that cause them to harden as we age, leading to heart disease and stroke. She was one of 12 women in Engineering and Physical Sciences recognised at the ceremony for their work in helping and inspiring other females in the same field. The recipients are chosen by the previous award holders both for their scientific achievements and their ability to inspire others.

Melinda was nominated by Sharon Ashbrook, Professor in Physical Chemistry at the University of St Andrews, who said: "Melinda has been a role model to generations of students and early-career staff in her department and the wider research field.

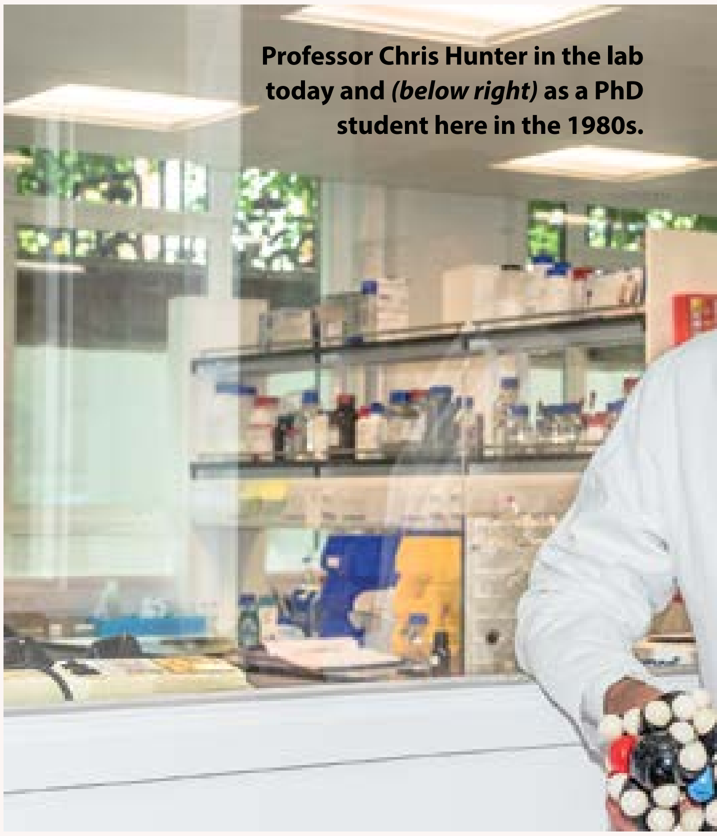
She has great enthusiasm for her research, really enjoys working closely with all her students, and is extremely encouraging to younger researchers. She provided significant help and support when I began my academic career and she particularly encourages the ambitions of her female co-workers. I probably would not have made the choices that have led to the career I have enjoyed without her support."

Melinda said: "This award means a huge amount to me. That someone I regard as an outstanding scientist feels I had a positive influence on their scientific career is just an amazing feeling. "

Coming full circle

Professor Christopher Hunter FRS

Chris Hunter received his PhD here under the supervision of Professor Jeremy Sanders in 1989. Twenty-five years later, after a highly successful career at the University of Sheffield, he returned to the Department as Herchel Smith Professor of Organic Chemistry and set up the Hunter Lab – where his former supervisor now helps out.



Professor Chris Hunter in the lab today and *(below right)* as a PhD student here in the 1980s.

Arriving in Cambridge in 1983 to study Natural Sciences, Chris Hunter originally planned to specialise in Physics. But some inspiring tutors in this department (among them Dudley Williams, Stuart Warren, Anthony Stone and a young David Klenerman) and "a well-taught and organised course" helped change his mind.

But it was his PhD supervisor here, Jeremy Sanders, whose influence was really pivotal. Chris's PhD work with Jeremy led to a paper listed as one of JACS' 125 most cited papers of all time and started him on a career in research that has been recognised by a clutch of prestigious awards.

And this all started, he recalls, when "Jeremy gave a final year course on NMR spectroscopy." Chris was so interested, he was considering a PhD in protein NMR spectroscopy when instead, Jeremy offered some projects on artificial photosynthesis and supramolecular catalysis. "Supramolecular chemistry was then a very new field," Chris says. "The idea was to make things using non-covalent interactions (metal coordination, hydrogen bonding and π-π interactions) instead of covalent bonds." He set off on this path, supervised by Jeremy.

Spotting the killer experiment

"Jeremy was a 'hands-off' supervisor, but he really liked NMR spectra: he was very keen to see the latest set of spectra from any experiment, to get down to the nitty gritty. And he was very good at spotting the killer experiment to do next," Chris says.

"We started out making quite complicated molecules by conventional synthesis, but soon realised we could make more interesting systems by using self-assembly – by mixing components that associate spontaneously. That was exciting, especially because it worked.

"At the time," Chris adds, "there was one class of non-covalent interaction – π-π interactions – that was very poorly understood. There were many ideas in the literature, but nothing was consistent with the full spectrum of experimental data."

Landmark paper

His subsequent experimental measurements on π stacking interactions between porphyrins allowed Chris to build a model to explain the nature of aromatic interactions, and to show how this model was generally applicable to many different systems. This chapter in Chris's doctoral thesis led to a landmark paper that has been cited over 4,000 times: *The Nature of π-π Interactions.* [CA Hunter, JKM Sanders, J. Am. Chem. Soc. (1990), 112, 5525-5534.]

Even so, after completing his PhD, Chris wasn't initially sure what he

wanted to do. He took up a lectureship at the University of Otago in New Zealand and established his research group – and two breakthroughs followed. First, he applied the aromatic interaction theory developed in the π-π *Interactions* paper to explain for the first time how the three-dimensional structure of DNA varies with sequence.

A happy accident

And then there was the happy accident that made him decide to stay in academia. "I accidentally made a catenane," he laughs. "I was actually trying to make a macrocycle – and I got a very high yield of what turned out to be the catenane. I didn't know what it was at first, but it had a spectacular NMR spectrum, and I knew it was going to be interesting.

"Catenanes are mechanically interlocked molecules, and at the time, you could only make them by the Sauvage method using metal coordination or by the Stoddart method using π-π interactions. I had discovered the third way to make them, which was using hydrogen bonding. That's the moment when I thought, 'Ah, maybe I'm going to be an academic – I can actually do it.' "

In 1991 Chris returned to the UK and the University of Sheffield. During his 23 years there, Chris received numerous awards for his work including the RSC Corday-Morgan Medal and Tilden Prize. He was appointed Professor of Chemistry there in 1997 and elected a Fellow of the Royal Society in 2008.

In 2014 Chris returned to Cambridge to take up the Herchel Smith Professorship of Organic Chemistry, following the retirement of previous holder Professor Sir Alan Fersht.

"I had a lot of support from people in this department: my entire group came with me and a suite of labs was refurbished to our specifications. It was a really positive experience," he says. He named his new lab after an inspirational scientist here who had greatly influenced him, Dudley Williams.

Since moving back to Cambridge, the focus of Chris's research has shifted to molecular evolution. "I'm interested because all of the nanotechnology that we call biology is based on polymers of different building blocks, where the properties are encoded by the sequence," he explains.

"We could do the same thing with synthetic polymers. The idea is that the sequence of building blocks defines the three-dimensional structure, which defines the properties of the molecule. The trouble is that the number of different sequences is astronomical, even for relatively short polymers. So how do you find the interesting ones, when the relationship between sequence and properties is a complete unknown?

"The solution is to use the way that Nature discovered functional polypeptides – that is by molecular evolution. We have recently found a way to replicate sequence information in synthetic polymers. This chemical version of PCR is the first step to evolving synthetic polymers with interesting functions."

Supervisor turns postdoc

And Chris's return to Cambridge also brought an unexpected bonus when his former supervisor asked to join the Hunter lab as a 'postdoc'. "Jeremy still loves seeing the latest set of NMR spectra," Chris says. "He has a lot of experience and the perspective that comes with that."

And how has their relationship changed? "Jeremy has always had a real interest in the science, and that's still the same, we have great discussions. His supervising style was never telling people what to do – he always made suggestions. And he is still making suggestions."

- *The Herchel Smith Professorship in Organic Chemistry is funded by a generous bequest from Herchel Smith, who studied organic chemistry under Lord Todd. His gifts to the University of Cambridge have provided financial support in perpetuity for five Professorships, and a programme of studentships and postdoctoral fellowships.*
- *You can read more about the Herchel Smith fund at: https://www.herchelsmith.cam.ac.uk/*

Anika Krause

Women in Chemistry

Her parents encouraged her to pursue her interest in science and the Sheldrick Scholarship in Chemistry at Jesus College is helping her do that. Anika Krause, a PhD student in our Atmospheric Chemistry Research Group, discusses her work in assessing the impact of air pollution on human health– and how it's made her more aware of what's in the air we breathe.

My father first encouraged my interest in science. He's very good with his hands and did everything around our house himself, such as putting in the plumbing and electrics. So he understands the physics of how things work, even though he is not a scientist. (He's a driving instructor: he and my mother grew up in East Germany where there was not a great choice of jobs for people.) I think hearing my dad explaining such things to me when I was young helped promote my interest in science.

In high school I was good at both science and languages. But when I was choosing what to study, my parents really encouraged me into science. (My mother had wanted to be a pharmacist when she was young, but wasn't allowed.) At the time, I loved Latin as much as maths and science, but they advised me that science would offer far more job opportunities.

I've always been interested in environmental issues. So while I was doing my Master's in Germany, I looked for a research project to link my environmental interest with my chemistry studies. When I read about Professor Rod Jones's Atmospheric Chemistry Research Group here in Cambridge, I asked if I could join it for six months as a visiting student. Rod said yes. I felt very welcome within the team and enjoyed the research project I worked on so much I decided to stay on and apply for a PhD. I am now in my third year, working with wearable personal air-quality monitors.

We are using these sensors to accurately measure people's exposure to polluting gases and particles in the air at high spatial and temporal resolutions, outdoors and indoors. This will help us to provide reliable evidence about the harmful impact of airborne pollutants on people's health. Part of my work is to characterise the performance of these monitors — including the evaluation of detection limits, temperature or humidity effects, and cross interferences with other air pollutants.

I needed funding to support me through my PhD. When I heard about the Sheldrick Scholarship at Jesus College — a Chemistry scholarship that had just been created specifically for students who had recently completed their MSc degree at a German university — it was so perfect for me, I didn't quite believe it was real at first. I thought someone was making it up!

Later, I was able to meet the donor, Mr John Sheldrick, when he visited Jesus College. Like his older brothers George and William, he studied Natural Sciences at Jesus. It was a pleasure to meet him. He asked how I was getting on with my research, whether I still enjoyed what I was doing (which, he emphasized,

was most important), and if everything was working out alright with the scholarship. I am very grateful to him.

The downside to studying air pollution is that it makes you hyper-sensitive about what you breathe. If I go into a metro now, I feel as though I can't breathe because I'm so aware of the dirt in the air. It's the same when I'm cycling through Cambridge and end up following a bus. I'm more aware of the pollutants in the air and how much pollution changes locally.

The upside is that I love to travel and my research gives me that opportunity. As an undergraduate, I went on a research trip to Brazil, a country I loved, and later on did research projects in Italy and Japan. These experiences increased my passion for different cultures, helped me become more independent and showed me different research environments.

Here I work on the AIRLESS project.
It's part of an international multi-university programme on "Atmospheric Pollution & Human Health in a Chinese Megacity". This aims to identify the concentrations and sources of urban air pollution in Beijing, as well as how people are exposed and how it affects their health. I've been out to Beijing twice to do project field work. I visited a semi-rural area on the city's outskirts where because people are poor, they cook on open fires made from any waste plastic or rubbish they can find. As a result, levels of indoor air pollution are extremely high. The villagers were sceptical at first about what we were doing – we looked rather exotic to them and there was quite a communications barrier. Nevertheless, we were warmly welcomed. One family gave me some of their home-grown fruit and vegetables, which were delicious. But at another meal, I was given Durian fruit. It stinks like rotten meat and made the room smell badly for ages afterwards!

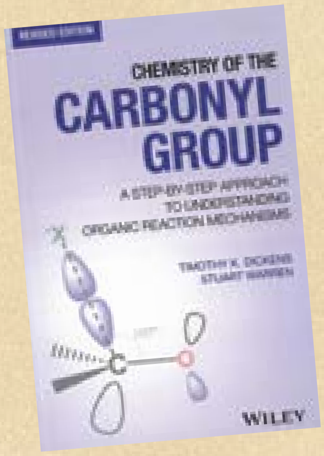
In future, I hope to work in environmental protection. Last summer I went to Berlin to measure people's exposure to air pollution. I joined a research project with the Federal Environmental Agency, partly to find out what it would be like to work for them. But I also did my own research, wearing my own personal air-quality monitor while sitting in metro stations. When I saw the results afterwards, they were super interesting: every time a train came in, there were peaks as the particle concentrations in the air shot up. (That's because the train pushes the air from the tunnel out into the station). And every time a train left, the concentrations fell again as the departing train sucked in fresher air from the exits.

I don't feel I've ever been badly treated as a woman in science. At least, not that I'm aware of. But I appreciate the way the University of Cambridge supports women (and postgrads generally) by offering courses in professional development. These have given me more confidence and will help me in future when I'm going for jobs or negotiating a salary. I'm more aware now that I should be assertive and ask for what I think I deserve.

- *John Sheldrick set up the Sheldrick Scholarship partly in memory of his late brother William, who received his PhD in Inorganic Chemistry here and subsequently moved to Germany, where he became Professor of Analytical Chemistry at the Ruhr University Bochum in 1989. We know some of our alumni also recall John's oldest brother George, a demonstrator and lecturer here from 1966 to 1978. John says: "George became a fellow of Jesus College and was given his University appointment at a very young age. When I came up to the college in 1967 (and my brother William was doing his PhD), George did the tutorials in Chemistry for me and the other Jesuan Natural Sciences students in my year. He left Cambridge to become Professor of Structural Chemistry at Göttingen University in 1978. He is very well known internationally and still active as an emeritus professor."*
- *To find out more about setting up a Studentship in Chemistry at your own college, please contact: chemhod@hermes.cam.ac.uk*

Classic texbook gets a makeover

For more than 40 years, chemistry undergrads have worked their way, pencil and paper in hand, through an iconic guide to synthetic chemistry. Here Dr Tim Dickens, who recently revised it, talks about why he thinks the book is still essential reading – and about the app that it may yet turn into.



Every December, Dr Tim Dickens would give *Chemistry of the Carbonyl Group* — Stuart Warren's iconic textbook on organic reaction mechanisms — to his first-year students at Peterhouse and ask them to work through it over the Christmas holidays.

Spending time walking step by step through the fundamental reactions of the carbonyl groupin order to inform their subsequent understanding of other reactions may not seem like the most exciting way for students to spend the festive period. But according to Tim, who is Director of Studies for Chemistry at Peterhouse and Head of IT here in the department, it is well worth while.

"The book is an essential aid to understanding organic chemistry," he says. "The movement of electrons as a chemical reaction takes place is perhaps the hardest general concept in organic chemistry. But once students have grasped it – and this book gives them a really good grounding in the mechanisms involved – they can rationalise what's happening in other chemical reactions and start making predictions." "The book really raises their confidence in organic chemistry," he adds. "I notice the sea change in them every January when they come back from the break having worked through it."

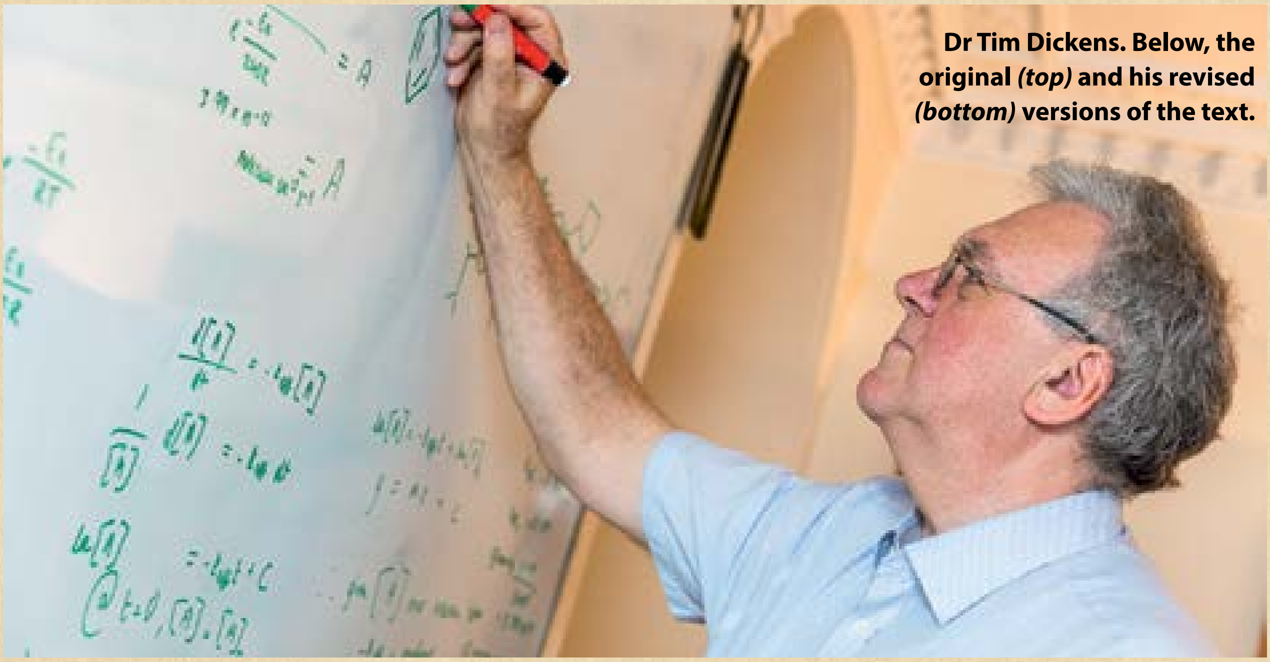
However, though he had long been impressed with the book's concept and content, Tim was increasingly finding the presentation a problem. Stuart Warren, a renowned lecturer and researcher here from 1971 until his retirement in 2006, had first produced *Chemistry of the Carbonyl Group* back in 1974. After 40 years, it was badly in need of a facelift.

"Stuart created the original in black and white, on a typewriter, using carbon copy paper and drawing all the diagrams by hand," Tim explains. "The content was great: very little of it needed to change. But the presentation was extremely basic. I was almost embarrassed about giving it to my students."

So he approached Dr Warren with the idea of producing a revised edition "and Stuart was very supportive." Thereafter, for the next 18 months, Tim would shut himself up in his study in his spare time and redraw Warren's diagrams "with the help of Russell Currie, who set up the Chem Draw software for me."

The resulting Revised Edition, published by John Wiley & Sons Ltd in time for the start of the 2018-19 academic year, got Stuart Warren's approval. "He gave me some wonderful support," Tim says. "I discussed parts of it with him as I went along, and he graciously put me in touch with former students who had first used the book themselves and are now regarded as experts in their academic fields."

One was Jonathan Clayden [now a Professor at


Dr Tim Dickens. Below, the original *(top)* and his revised *(bottom)* versions of the text.

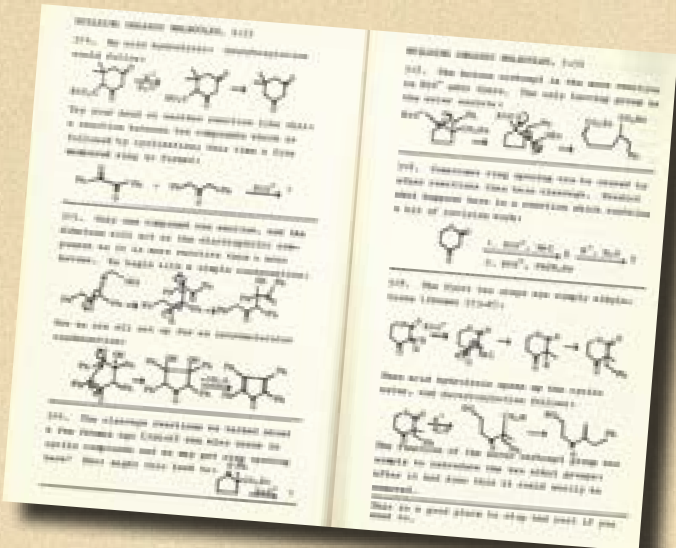
Bristol] with whom Tim was able to discuss the representation of tetrahedral angles and charges on atoms.

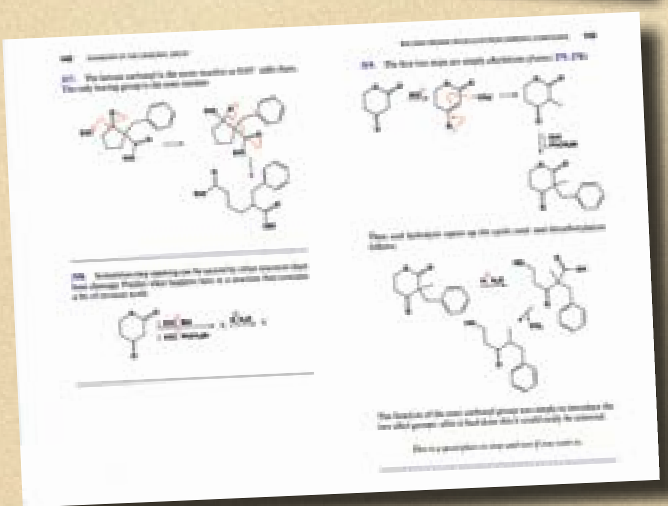
And current students like it too. Part 1B Natural Sciences student Ivan Phanada had originally planned to study chemical engineering but opted for chemistry after working his way through the book. "It made me realise my passion for organic chemistry and I now want to stay in it," he says.

"In future I plan to explore further the role of organic chemistry in biological systems, and how many of the reactions and processes that confer and govern life are driven by simple organic reactions, just like those introduced in this book."

And for Tim meanwhile, revising the book may not be the end of the story. "My son (who himself used the book as a chemistry student at Oxford) is still trying to persuade me to convert it into an app with multiple choice answers, and a mechanism that stops you advancing any further through the programme if you don't get the answer right."

And might he work on that? "I don't know. My wife was very patient with me," Tim says. But when I'd finished, she did say she hoped I wasn't going to do another project like this..."





"Outside the lab, I...

...cox the Men's Boat Race crew."

Natural Sciences student Matthew Holland has spent the last few months juggling his academic work with being a member of the University Rowing Team. In April, he coxed the Men's Blue boat to victory in the Boat Race, two years after doing the same for the women's boat. The experience has been exhausting, he says, but it's taught him about hard work and perseverance.

Why Cambridge?
There's a family tradition of studying here. Several family members, including my parents, came to Cambridge so I've been visiting the city since childhood and I fell in love with the place. The buildings feel steeped in history – and you feel a part of that when you're a student here.

Why chemistry?
I was fortunate to have very good chemistry teachers at school who helped me understand the subject. I really enjoy it: it seems to me to offer the perfect blend between the rigour of a physical science, and the application and patterns of behaviour of a biological science. I love the fact that we have microscopic phenomena – molecules and atoms – whose behaviour we know so much about, even though we can't see them when we're working with them.

Studying here has been a challenge.
At school I found the subject reasonably straightforward, but at Cambridge I've had to really work to understand it. But that has taught me a lot about perseverance and the fact that there are no real shortcuts; you have to put in the effort to get the results you want. That's like the Boat Race. During the programme, we train seven hours a day every day in term time. There's no substitute for that: if we want to win, we have to do every single session. The race is really won in winter when it's cold, and you're wet and exhausted, and there's no-one cheering on the river bank.

That everyday training is tough – but the feeling of winning is absolutely unparalleled.
I can't describe what it feels like to cross the finishing line first! Mind you, the hangover afterwards is horrendous...

What's great about Cambridge is the opportunity to do high-level academic work and high-level sport in parallel.
Here I can study chemistry with some leaders in their fields while also rowing at an elite level – that's something you don't really get elsewhere This year, my supervisor for chemical biology is Professor Sir Alan Fersht *[a significant contributor to the study of enzymes and one of the founders of protein engineering]*. I get to talk to him in person about a subject he originated – that's quite cool! And at the same time, I'm coxing a boat that includes two Olympians, six World Championship titles, and two Olympic gold medals, amongst others.

I've had to be very disciplined with my timetabling to combine both academic work and sport.
But I think it's made me work better, by allocating

Matthew, below left, in the lab. Above centre, holding the Boat Race Trophy, and right being thrown into the Thames by the winning rowers. ***(Race photos: courtesy of Steve McArthur.)***

a specific slot of time to do a piece of work and not allowing myself to get distracted.

The department has been very supportive.
Chemistry lectures thankfully are in the morning, so I was able to fit them in between the early morning gym sessions and the afternoon training on the water. Supervisions and laboratory work were more difficult to juggle – I was coming into the laboratory at odd times, an hour here and an hour there – but the department and my supervisors were incredibly accommodating and willing to be flexible and work around me. I am really grateful for that, it made the process a lot easier.

Coxing a University boat crew is daunting, so the role of the cox teaches you to be confident.
If you're not, people detect that and then they don't respect you. But even so, it was a bit scary for me, sitting in front of James Cracknell for the first time. He was winning top-level races eight years before I was born – and I'm sat there, telling him what to do!
But actually, coxing is not a dictatorship. That's an illusion. I don't just sit at the back and tell everyone what to do. My job is to help the people in my boat perform to the best of their abilities and work as a unit. To do that I need to communicate effectively with everyone in that unit. So I'm in constant conversation with the coach, with the stroke, with the rowers. That's the challenge but also the fun part of it, learning how to communicate with other people and get the best out of them.

Though I love rowing, I would also love to pursue Chemistry further.
I've retired from the Boat Race now. And if I do well enough in Part II, I'd like to stay on for Part III next year. I enjoy doing synthesis in the laboratory but I'd like something that could be applicable to a biological system, so I'll be looking for a project on the border between chemical biology and synthesis.

"I'm fascinated by chemistry but I need to really work to get the results. The Boat Race is the same. It isn't won at the finish line – but in all those winter training sessions in the cold and wet, when there's no-one cheering for you on the bank."

Producing fuel from plastic waste

Taylor Uekert: "As I see it..."

Eight million tons of plastic enter the oceans every year. What if we could produce fuel from that plastic waste instead of throwing it away, asks Taylor Uekert, a PhD student with the Reisner Group.

Hydrogen is a promising green fuel, but it is currently generated from fossil fuels in an energy-intensive process that releases greenhouse gases. I am investigating a process called photoreforming, which aims to address these two issues by taking advantage of two of Earth's most abundant resources – sunlight and waste – to produce hydrogen.

Taylor Uekert sharing her research with children at Chemistry Open Day.

Waste reduction and renewable energy generation are two global challenges that I hope my research will someday help to address. It would be great to see this working on a larger scale with real-world waste (biomass, food, plastic, and so on) to produce usable quantities of hydrogen. There's a way to go until we reach that point, but it's certainly my goal for the future of this work.

I became hooked on nanotechnology during my first year at university. I went on to complete my undergraduate degree in Nano-engineering at the University of California, San Diego. During my four years there, I did a variety of solar energy-based research at the Laboratory for Energy Storage and Conversion, and completed summer internships at Oxford University and ZAE Bayern in Germany. These experiences enhanced my interest in the nano world and inspired me to apply to the Nanoscience and Nanotechnology Doctoral Training Centre (NanoDTC) at Cambridge for my PhD. I am now carrying out my PhD research in the Department of Chemistry.

"There's a moment when you see a person's expression change: when they understand precisely what you're talking about and realise just how awesome the science is."

When I moved to Cambridge from California I quickly realised I was only disappointed by one thing: the weather. Everything else far exceeded my expectations. Cambridge is an incredibly diverse and international community, which means that you are exposed to an enormous variety of backgrounds and experiences. This is important not only for research, where novel ideas and views are always necessary for innovation, but also on a personal level. I have learned about so many different cultures, and have made friends from more countries than I had thought possible before coming to Cambridge.

One valuable moment was when I bought a plastic water bottle from Sainsbury's, cut it into pieces, and used my photoreforming system to turn it into hydrogen. It is sometimes really easy to get stuck in a 'lab' mentality, where you become focused on the small details of your project and forget to look at the wider impact. Seeing this sample work was incredibly rewarding, because it made it clear that, as interesting as my project is for me personally, it could also have a real application towards mitigating waste.

One of my most interesting days was during the Chemistry Open Day. A group from my lab presented our research with solar panels, a fake sun (i.e. a projector), hydrogen-powered cars, and one of my photoreforming samples bubbling away as it produced hydrogen from paper. We talked with hundreds of visitors – kids, families and students – and shared with them some of the ways we are storing solar energy in hydrogen.

This was one of my most exhausting, and rewarding, experiences at Cambridge. There's a moment when you see a person's expression change, when they understand precisely what you're talking about and realise just how awesome the science is. There was the time a young boy said to me: "You can make hydrogen from grass? Wow!" Or the moment when a teenage girl whispered to her mom: "This is so cool! I'd like to work on this." Communicating science is not easy, but when done right it can have an enormous impact.

I encourage other women to take outreach opportunities when they appear. The visibility of women in STEMM is absolutely crucial to showcase the amazing work being done by female scientists, and to inspire other women and girls to pursue STEMM subjects as well. There is still an underlying sense that female scientists are a rare breed, but if we can show that increasing numbers of women are sticking with science and being perfectly successful, there is absolutely no reason for this stereotype to persist.

Science desperately needs more women who love what they are doing and pursue it despite the obstacles. There will be times when you're the only woman in the room, and there will be times when that is intimidating. But over time, that will change. It is already changing. So, continue pursuing what you love, because the vast majority of us scientists are rooting for you.

By Eleanor Dodd.

This article first appeared on the University of Cambridge website on International Women's Day 2019.

Tackling plastic waste

Researcher here leads new centre on re-thinking plastics production and use

Erwin Reisner, a Professor in this department, is leading one of the projects recently announced by the Science Minister to rethink plastics production and use, and tackle plastic waste. The government has identified producing less carbon intensive products, including plastics, as a key challenge area alongside reducing plastic waste. This will lead to a circular economy where greater emphasis is placed on 'use, reuse and recycle'. Professor Reisner is leading the Cambridge Centre for Circular Economy Approaches to Eliminate Plastic Waste which launched in February.

He and his colleagues recently demonstrated a new process using sunlight, water and a precious-metal-free photocatalyst to convert waste plastic into a renewable fuel source. Erwin says: "Waste plastic contains a large amount of stored energy that is currently being thrown away. Our work shows that we can use plentiful resources like waste plastics and sunlight to create hydrogen fuel and organic chemicals in a sustainable way."

The project on eliminating plastic waste includes the following core objectives:

- Sustainable feedstocks and materials as cleaner and more recyclable plastic alternatives
- Models for understanding plastic flows through the UK economy, society and environment to improve the recovery of plastics
- Innovating recycling approaches to recover the high energy-content of waste plastics by producing electricity with microbes and chemical fuels using sunlight

This is a multidisciplinary research initiative involving a number of departments and programmes across the University and is funded by the Plastics Research Innovation Fund.

Science Minister Chris Skidmore said: "We have all seen the devastating effects that plastics waste has on our environment, threatening the biodiversity of our oceans and introducing micro-plastics into the food chain. We are committed to tackling this problem, from developing a plastic-eating bacteria to finding new ways to recycle."

Turning towards the Sun to create renewable fuels

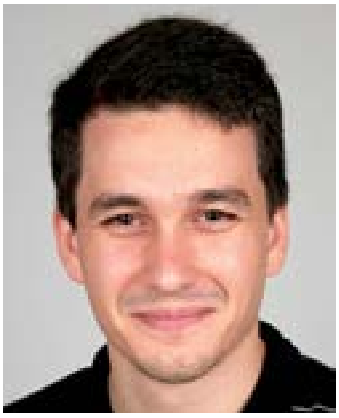
Reisner Group

Scientists in the Reisner group researching effective and scalable devices to capture the sun's energy and convert it into renewable fuels say they have taken a step forward.

As reported in *Nature Catalysis* in April, researchers here have developed a molecular catalyst-based photocathode that uses solar energy to convert CO_2 into (industrially useful) carbon monoxide – and does so without the use of precious metals.

Other molecular photocathodes showing the ability to reduce CO_2 from water have contained precious metals. But this device instead combines a photoelectrode made of the abundant element silicon and a molecular catalyst based on the metal cobalt. Unusually, their device displayed catalytic CO_2 reduction activity not only in hydro-organic solvent but also in pure CO_2-saturated water.

Proof-of-concept
"As a proof-of-concept and a landmark that is quite something," says postdoc Julien Warnan, one of the lead authors of the paper.



"As a proof-of-concept and a landmark, this is quite something."
Dr Julien Warnan

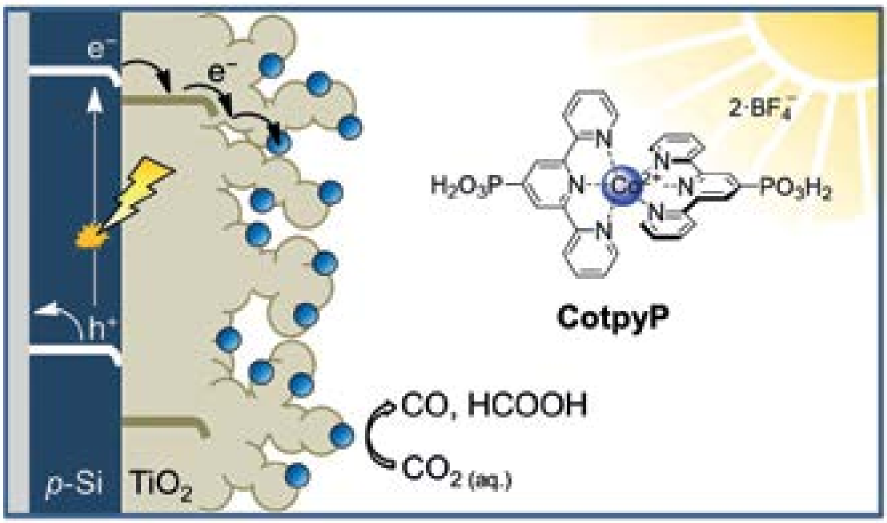
"CO_2 is not very soluble in water, which is why other research teams have carried out these reactions in organic solvents – like acetonitrile – in which CO_2 is more soluble. Organic solvents also avoid the parasitic reduction of water into hydrogen, which usually makes selective CO_2-reduction in water challenging. This is the first molecular-based photocathode without precious metals to demonstrate the ability to reduce CO_2 in water."

This project is part of the group's work on the solar-driven conversion of CO_2 and water into renewable fuels and chemicals as a route to storing the Sun's energy. Reducing the amount of CO_2 is of environmental benefit and if converted into carbon monoxide, it can then be used to produce alternative fuels (for example, via the Fischer-Tropf process).

Quest for renewable fuel production
In this project, the researchers wanted to address a particular contemporary challenge in the quest for renewable fuel production: the selective reduction of CO_2 with low-cost solar-driven photoelectrochemical devices. They chose silicon for the light-absorbing electrode in their device as silicon is abundant in the Earth's crust and, thanks to its use by the photovoltaic industry, is becoming ever-cheaper to produce. And they chose a molecular cobalt catalyst, as it was both transparent (so it wouldn't screen the silicon and stop it absorbing light) and selective (so that the device would solely make carbon monoxide).

As the researchers note in their paper, *Solar-driven reduction of aqueous CO_2 with a cobalt bis(terpyridine)-based photocathode*, "Achieving scalable and selective photoelectrodes for aqueous CO_2 conversion without generating hydrogen from competing proton reduction has yet to be accomplished. CO_2-reducing molecular catalysts offer a distinct advantage over heterogeneous materials as they often combine high product selectivity with high efficiency."

In addition to silicon and a molecular cobalt catalyst, the researchers employed a titanium dioxide mid-layer in their device to provide a



substantial surface both to anchor the catalyst onto, and to protect silicon from forming an insulating silicon oxide layer at the interface with the solution. They found that when irradiated with solar light, the silicon cathode injected electrons into the mid-layer which then shuttled them to the anchored cobalt catalyst. In turn, the catalyst then started to reduce the CO_2.

Performance exceeds previous reports
As the researchers reported in the paper, they were very pleased with the performance of their device. "To date, reported molecular-based photocathodes performing CO_2-reduction remain scarce... and continue to rely on precious-metal-containing components," they say. "Despite not containing precious metals, the performance of our CotpyP-functionalised silicon photocathode exceeds the previous reports... towards CO_2-reduction products and stability."

And this, they said, has shown that this line of research offers promise. "Demonstrating aqueous CO_2-conversion for more than one day with the cobalt-centred molecular catalyst photo-driven by silicon is an excellent basis for achieving high-performance and scalable systems in future development."

The research also threw up another interesting and unexpected finding: that the catalytic mechanism was discovered to be different from what had previously been reported in the literature – apparently because of the way it was immobilised onto the surface of the photocathode.

This is also explored in the paper, with the researchers reporting on how they investigated this finding using spectroelectrochemical infra-red and resonance Raman studies. "Contrary to what is suggested in the literature," says Julien, "when we applied potential and monitored what was happening on the catalyst, it stayed intact, it didn't degrade – that is, we didn't lose any part of the molecule – during the catalysis. This is quite novel.

In other research, the catalysts are not anchored to the surface of the photocathode. So what we show is that the anchoring itself might have a novel impact, offering new characteristics and better features."

Given the positive findings from this project so far, where will it go next?

Room for further improvement
"There is still a lot of room for improvement in the design of this photocathode – for example, we can't deliver as much current as we would like and the selectivity is still not as good as we would hope," Julien says.

"So we will be using what we have learned from this research to try to develop other photocathodes and to immobilise more catalysts on the surface of electrodes and monitor how they react when we apply potential."

Jane J. Leung, Julien Warnan, Khoa H. Ly, Nina Heidary, Dong Heon Nam, Moritz F. Kuehnel and Erwin Reisner. *Solar-driven reduction of aqueous CO2 with a cobalt bis(terpyridine)-based photocathode* , Nature Catalysis (2019). DOI: 10.1038/ s41929-019-0254-2.

Inspired by their mentor

Alumni hope to do for DNA synthesis what their supervisor did for DNA sequencing.

As a PhD student researching nucleic acid structures, Michael Chen found it both costly and difficult to obtain the synthetic genes he needed. He and his benchmate decided to address the issue and are now building a business to help scientists write synthetic DNA on the benchtop.

As a PhD student on the NIH Oxford-Cambridge Scholars Program in Professor Sir Shankar Balasubramanian's group, Michael Chen was studying the molecular and structural biology of G-quadruplexes (G4), the quadruple-helix structure that DNA and RNA can fold into.

G-quadruplex–forming sequences are present in the regulatory regions of nearly 40% of all human genes. Because they are implicated in a number of oncogenes (i.e. genes that have the potential to cause cancer), G4 are of growing interest to pharmaceutical firms as potential drug targets.

According to Michael, we don't yet understand enough about how these structures control protein expression and cell behaviour. "There's some understanding that different types of nucleic acid structure can negatively influence cell behaviour," he explains. "But it's difficult to prove that something exists within a cell without interfering with it during observation. So while trying to detect the G4 structure in a cell, for example, you often end up promoting its formation."

Cells have to unfold G-quadruplexes (and many other structures) to access the genetic information stored within DNA and RNA molecules. They do so by a class of proteins called helicases. To better understand how cells recognize and unfold G-quadruplexes, Michael was working to crystallise the interaction between a protein, the RNA helicase DHX36, and the G-quadruplex that it binds to, while being co-supervised by Shankar Balasubramanian here and Dr Adrian R. Ferré-D'Amaré at the National Institutes of Health in Bethesda, Maryland.

As he explains: "Having crystal structures would allow researchers to better understand what they are targeting and how one might interfere with G-quadruplex biology with small molecules in order to effect therapeutic use."

For this work, he needed to buy and use synthetic genes. But he and his Balasubramanian lab bench-mate Gordon McInroy were finding them difficult to get. "I needed quite a few very long pieces of biologically-relevant DNA for my research," Michael recalls. "I was having to wait four to eight weeks to get them and they cost a significant amount." At weekends the two of them, together with Michael's Churchill College friends Jiahao Huang and Radu Lazar, would discuss their problems with buying synthetic genes. As they did so, they began to see a way of turning their problem into an opportunity.

"We said to ourselves 'Can we make this better?' And we decided we could." They joined the Accelerate Cambridge programme at the Judge Business School for a crash course in business, and to connect with the local business network. And after completing their PhDs, they struck out on their own. In summer 2018 they moved into a facility – part lab, part office – on the Cambridge Science Park, where they are now growing their biotech firm Nuclera Nucleics. The company was initially helped by government support through

Michael Chen in the lab at Nuclera, left. Facing page, an illustration of the crystal structure of DHX36

several Innovate UK grants, "which were very, very helpful," Michael says. A few months ago, the company took a leap forward, closing a Series A round of venture capital financing.

It is now Michael's ambition that Nuclera will do for DNA synthesis what Shankar's spin-out Solexa (which commercialised the high-speed gene sequencing methodology he developed with Professor Sir David Klenerman) did for DNA sequencing. "Solexa revolutionised the DNA-reading market; we'd like to do the same in the DNA-writing market."

"Ten years ago, the DNA sequencing industry depended on Sanger sequencing," Michael says. "It was great technology, but could only read gene-length DNA fragments. And the companies offering it were service-based: you sent your DNA in, they did a reading from it and sent it back. Solexa revolutionised sequencing because it could read whole genomes. It delivered orders-of-magnitude increases in the capability it delivered to end-users, and it was instrument-based and miniaturised."

He argues that it is because of such developments that the DNA-reading market size has increased 50-fold. That, he says, will be mirrored by an increase in the DNA-synthesis market. He hopes Nuclera will be one of the companies driving that change by "re-thinking how DNA synthesis is done – in a bench-top format, rather than a service format, and delivering orders-of-magnitude increases in capability. We're developing a portable bench-top DNA synthesis printer that can do 10,000 base pairs in a single day for $1,000."

It hasn't all been plain sailing. But he says the rigour of the PhD programme helped him and the company's co-founders develop the sticking power they needed to carry on through the lean financial times.

"The PhD was fairly challenging. There were many moments that I thought, 'Is this going anywhere?' That helps your resilience: you need a bit of grit to stay in science. For example, people have tried before to crystallise the helicase I was working on and not succeeded because helicases are notoriously difficult to crystallise (as they are very dynamic proteins). So that took many years to resolve.

"It's been the same with Nuclera," he adds. "We went along for quite a while with very uncertain financing, until our Series A financing round."

Michael did ultimately succeed in crystallising DHX36. (*See the crystal structure illustrated on the facing page*.) "I was the first scientist ever to have visualised a natural protein bound to a G-quadruplex, and also to have crystallised any kind of helicase with an unusual non-classical structure." This achievement is being marked by the RNA Society: in June, Michael will go to its annual conference to receive the Scaringe Graduate Student Award for 2019. When he found out about the honour earlier this year, he described himself as "ecstatic".

He will then return to Cambridge from the conference in Krakow to continue building Nuclera. He is not far away, geographically, from this department and he and Gordon still retain a link with it as their former supervisor, Shankar Balasubramanian, has been very helpful.

"He has very heavily influenced the enzymatic DNA synthesis field and it's been very good to have him acting as an informal adviser," Michael says.

M.C. Chen, R. Tippana, N.A. Demeshkina, P. Murat, S. Balasubramanian, S. Myong, and A.R. Ferré-D'Amaré. "Structural basis of G-quadruplex unfolding by the DEAH/RHA helicase DHX36", Nature 558, 465 (2018), doi:10.1038/s41586-018-0209-9.

Staying in touch

Want to keep up with the department and what we're doing?
Visit our 'alumni' web pages.
Check out our YouTube channel.
Keep in touch via Twitter.

Twitter:
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YouTube:
https://bit.ly/2A3D3UK

Alumni website:
www.ch.cam.ac.uk/alumni

The gift that goes on giving

How You Can Contribute

A legacy from our alumnus Dr Herchel Smith has made a significant and lasting contribution to the work of this Department. It has enabled us to offer chairs here to two very gifted researchers. The Herchel Smith Chair of Medicinal Chemistry is occupied by Professor Sir Shankar Balasubramanian, one of the pioneers of high-speed gene sequencing. The Herchel Smith Chair of Organic Chemistry is occupied by Professor Christopher Hunter who (as you will have read on pages 16-17) has been pushing forward our understanding of non-covalent chemistry since he was a PhD student here.

And Dr Smith's gift goes on giving: it also supports the research pioneers of the future through a series of Studentships and Fellowships.

A legacy could open up a world of opportunity to future students, researchers and academics, helping to provide the environment and tools they need to achieve great things. A gift in a Will to support the Department of Chemistry can have significant tax advantages as, since the University of Cambridge has charitable status, legacy gifts from UK taxpayers won't count towards the taxable value of your estate.

For further information about the impact of a legacy, and guidance on how to leave a gift to the Department of Chemistry in your Will, please see www.ch.cam.ac.uk/support-chemistry/content/give-now

Or contact Head of Department Dr James Keeler at chemhod@hermes.ch.cam.ac.uk

Guess who...?

Many of our alumni enjoyed poring over old departmental photos at the annual reunion and trying to recognise their lecturers and contemporaries.

So as a competition, we are reproducing one of those pictures here. It shows part of the Department of Organic, Inorganic & Theoretical Chemistry 1972-3.

How many faces do you recognise? If you would like to do so, email your list of names to news@ch.cam.ac.uk The person who correctly identifies the most people in this photo will receive two free tickets to the Chemistry Alumni Wine Tasting on Friday 27 September. (*See details on the next page.*) The original photo will be on display there, complete with names. Have fun!

Save The Date for...

...our annual Alumni Wine-Tasting

Friday 27 September
Poster Exhibition: 5:30 - 6:00 pm
Wine-Tasting: 6:00 - 8:00 pm

It's wine tasting, Jim, but not as we know it....
Bad puns, good snacks, a fiendish wine quiz – plus an opportunity to meet some of our PhD students and learn about the latest research taking place in the Department.

These are all on offer at our annual Alumni Wine-Tasting this September. Enjoy your first glass of wine as you stroll through our students' poster exhibition, chat to them about their work and hear a short talk from one of our researchers. Then take part in our 'Call My Bluff' wine tasting where you'll hear three 'experts' describe the attributes of the unusual and delicious wines you're tasting. But there's a catch: only one of them is telling the truth. Can you and your table work out who it is?!

We do hope you can come and join us.
Tickets £10. Full programme and booking at: https://chemistrycallmybluff.eventbrite.co.uk