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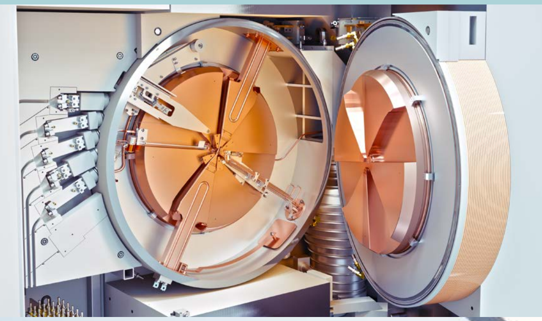

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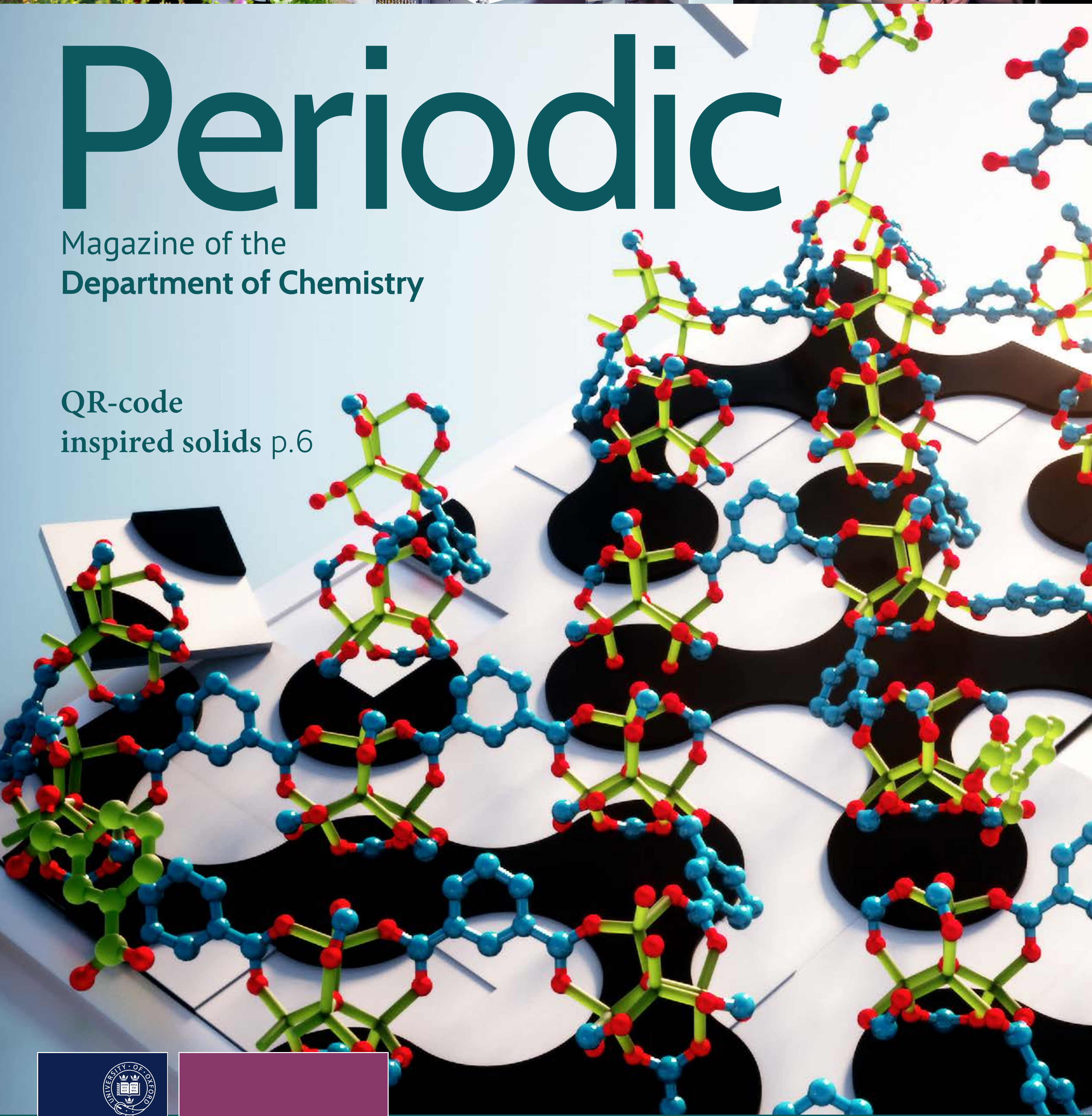

UNIVERSITY OF OXFORD

DEPARTMENT OF CHEMISTRY

Issue 11
2023 – 24

Professor Mark Brouard

Welcome to the 11th issue of *Periodic* magazine. By the time you read this, Oxford Chemistry will have a new Head of Department, Professor Steve Faulkner, whose editorial you can read on the facing page.

As I step down from my role as HoD, I would like to thank all the alumni and friends of the Department who read *Periodic* for your continuing interest in Oxford Chemistry. It has been a great privilege to serve as Head of Department over the past eight years, and the Department has seen many changes during my term of office. Some of those events like the pandemic have been beyond our control, but during that time I was extremely impressed by the commitment and dedication of my colleagues, whose cooperative efforts ensured that we were able to work through that difficult time in as normal a manner as possible.

Many of the developments over recent years were brought about by my extraordinarily talented colleagues – the establishment of the Ineos Oxford Institute was led by Professor Chris Schofield, and Professor Dame Carol Robinson has become the first Director of Oxford's Kavli Institute for Nanoscience Discovery. In 2018 our new Chemistry Teaching Laboratory opened, so that we now have a state of the art facility for a truly integrated undergraduate practical course.

The Department has attracted record numbers of applicants for our undergraduate programme in recent years, and we have been able to provide more scholarships, and increased support for postgraduate students. Much of the latter has been made possible through philanthropic giving by Oxford Chemistry alumni. Research students form the backbone of Oxford Chemistry, driving forward critical work across the whole breadth of chemistry and enabling us to address some of the world's most pressing challenges. I would like to express my sincere thanks to all those alumni who have so generously given their support to foster the next generation of brilliant scientists.

As I step down, I do so in the knowledge that as a department we are very well placed for future challenges. We have an outstanding leadership team in place which has been enhanced by the appointment of an Associate Head of Department for People, a position previously held by Professor Steve Faulkner and now in the very capable hands of Professor Kylie Vincent. During my tenure I have been delighted to be involved in the recruitment of the very best new academics; we have made nearly 20 academic appointments, of whom over 40% are female. We are proud to be working towards a more equal gender balance and pleased that our continuing efforts have been recognised by a renewed Athena Swan Silver award.

Within the wider University, we have worked with our colleagues on the development of a strategic plan for the Mathematical, Physical and Life Sciences Division. This supports Chemistry's vision for new builds that will eventually enable us to vacate the much cherished but no longer fit for purpose old laboratories and establish world-class new facilities for 21st century research.

For me, I am delighted that I will be able to spend more time on research and with my research group in the coming years. I will continue to attend alumni events, and will be pleased to be able to do so without having to give a speech! I look forward to catching up with alumni and friends of the Department in the very near future. ■

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From the new Head of Department

Professor Stephen Faulkner

Welcome to my first editorial for *Periodic*. For me, this has been a month of doing things for the first time and with all of them, Mark Brouard is a very hard act to follow. Over the last eight years, Mark made epic contributions to the development of the Department. These were busy years, and geopolitics and a pandemic ensured they weren't easy. We're all deeply grateful for his calm and effective leadership, and his ability to keep smiling come what may. After completing two terms of office, Mark is now able to concentrate on his own research and is smiling even more! Our job now is to build on Mark's successes.

Chemistry can explain and change the world around us on a scale that relates to everyday life. Our goal is to explore new chemistry and answer fundamental questions, and to build on this to address some of the problems which affect the modern world. In this issue, you can read more about how we're doing this, using new ideas and concepts to develop new science. The Ineos Oxford Institute is already translating fundamentals into practical applications, and our commercialisation of research fuels economic growth while committing to developing sustainable chemistry.

This is a year of changes, and we also have two new Associate Heads of Department. Kylie Vincent has taken over from me as Associate Head for People, while Martin Galpin becomes Associate Head for Teaching. It is a pleasure to welcome them, secure in the knowledge that they are ideally suited to their roles. Martin takes over from Nick Green, who is retiring after guiding our teaching since 2006. Nick isn't the only member of academic staff retiring this year: Richard Compton, Mark Moloney and Philip Mountford are also leaving us after many years of dedicated service – we look forward to seeing all of them for many years to come.

We can also celebrate a year of success for our researchers. Oxford chemists have published more than 450 papers, and have been recognised through a number of prizes and awards. As you'll see later in the issue, Andrew Goodwin has been elected as a Fellow of the Royal Society, Hagan Bayley received the Royal Society Buchanan Medal, and members of the department at all career stages have been recognised by national and international awards.

We welcome Profs. Michael Cotterell and Michail Stamatakis who joined us in September, and Prof. Meera Mehta who will join us in time for Hilary Term. They bring new expertise in atmospheric, computational, and main group inorganic chemistry: we're very lucky to have them and look forward to watching them flourish.

Obviously, there are challenges as well as opportunities. The success of any department depends on people and ideas; while the above demonstrates that there is an abundance of the latter, we still have to secure a means of funding the best graduate students to join us. Furthermore, since the beginning of 2022, utilities bills have increased by more than threefold, adding to the financial pressures that affect all lab-based subjects in the UK. We also need to address the need for modern lab space for researchers based in the older buildings. We've got lots of ideas to address these challenges, and hope to be able to share some of the solutions with you over the coming months and years.

It was a pleasure meeting some of you during the alumni weekend in September, and I hope to meet many more of you through the coming years. Members and former members of this department are the source of its reputation, and we build on the results of past successes and on the qualities of the people who've gone before. I'd love to hear more from you, and look forward to taking the next steps with your help and support. ■

News and achievements

For more news throughout the year head to **www.chem.ox.ac.uk/news**

Professor Andrew Goodwin has been elected as a Fellow of the Royal Society for his work on understanding and exploiting the dual roles of flexibility and disorder in functional materials.

The work of five Oxford chemists was recognised with Royal Society of Chemistry Awards, which celebrate outstanding work and achievements in advancing the chemical sciences:

Dr Josef Boronski received the Dalton Emerging Researcher prize for his groundbreaking investigations into actinide-cyclobutadienyl chemistry, leading to the preparation of a σ-aromatic cluster featuring direct actinide-actinide bonding.

Professor Tom Brown received the Khorana Prize for his major contributions in the nucleic acid field, including the synthesis of biocompatible artificial DNA, and molecular tools for genetic analysis and diagnostics.

Professor Darren Dixon received the Tilden Prize for the discovery, development and applications of iridium-catalysed reductive functionalisation of amides and lactams.

Professor Stephen Fletcher received the Merck, Sharp and Dohme Prize for the development of asymmetric Suzuki-Miyaura-type and other catalytic cross-coupling reactions with racemic starting materials.

Associate Professor Ludmilla Steier received the Materials Chemistry Early Career Prize for seminal contributions to the understanding of defect chemistry in semiconducting materials and interfacial energetics in photocatalytic and photovoltaic devices.

Professor Susan Perkin was named Award Laureate in the 2023 Blavatnik Awards for Young Scientists in the UK in recognition of her experimental work using a custom-built instrument to determine the properties of fluids. You can watch a short video about Susan's work at **youtu.be/karw1tY1-jg**

Professor Dame Carol Robinson was one of a handful of distinguished scholars worldwide to be elected a Member of the American Philosophical Society. She was honoured for her pioneering work in mass spectrometry techniques for over three decades.

Professor Fernanda Duarte Gonzalez received the Novartis Early Career Award in Chemistry. This award is given annually to outstanding scientists within 10 years of having established an independent academic research career in chemistry.

Professor Robert Hoye was named one of MIT Technology Review's Innovators Under 25 for 2023.

Dr Martin Galpin was one of the winners in this year's Teaching Awards in the Mathematics, Physical and Life Science Division. Martin has recently been appointed as the next Associate Head of Department (Teaching), and you can read more about him on page 18.

The team behind PERIODically podcast, on the experience of having periods while studying for a Chemistry degree, were highly commended in the Best Initiative category at the MPLS Division's Equality, Diversity & Inclusion awards. Fletcher group postdoc Dr Laura Cunningham also won the Outstanding ED&I Champion (Staff) category, while PERIODically team member Charlie Simms was commended in the Student category.

You can listen to the PERIODically podcast at **tr.ee/oBD_IgBdOs**.

At the Vice Chancellor's Awards for Environmental Sustainability, Chemistry was awarded the Sustainable Laboratories Championship Award for integrating sustainable practice into our research, going above and beyond to effect real change. The award was collected by EA to the Head of Department Sue Henderson, who drove forward much of this important work.

See p.24 for the ways in which individual research groups were also very successful in implementing the Laboratory Efficiency Assessment Framework (LEAF).

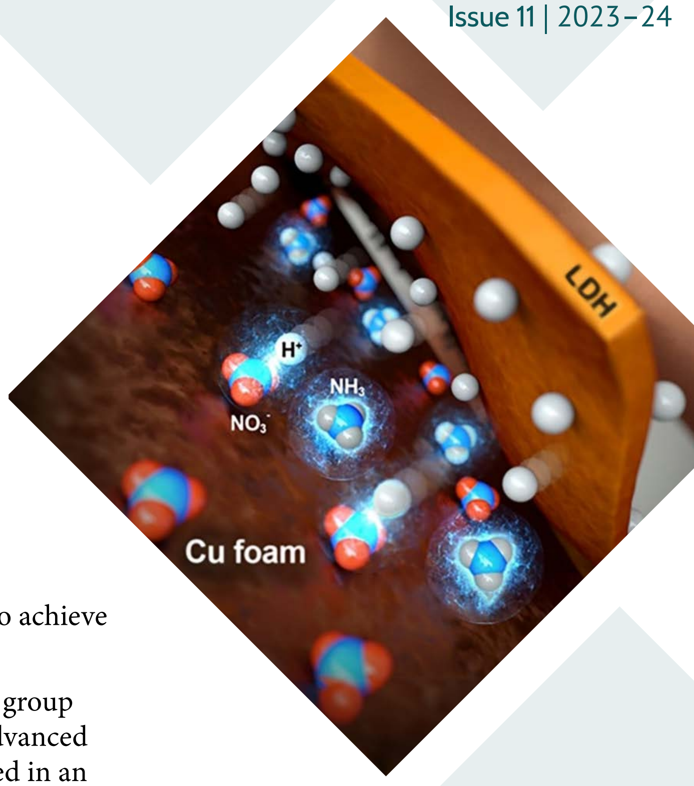
New research

Giorgia Fiorini reports on some of the latest stories from the Department.

O'Hare group

Nitrate reduction

An alternative to the Haber–Bosch process.



doi.org/10.1039/D2EE03461A

Ammonia (NH_3) production is of great interest due to its industrial uses, for instance in agriculture and textiles. It is mainly produced via the Haber–Bosch process: hydrogen reduction in the presence of nitrogen and metal catalysts. The main limitations of this process are the high energy demand to produce the hydrogen needed, the methane emissions, and the related environmental issues linked to the latter: 1% of total global energy-related CO_2 emissions come from NH_3 production.

Due to the lower energy required to reduce nitrate ions (NO_3^-) in solution, nitrate electrochemical reduction is of interest as a more sustainable alternative to the Haber–Bosch process. Despite its advantages, nitrate reduction's uptake has been limited by the high concentrations of NO_3^- electrolyte required, as well as the high operating voltage needed to achieve efficient NH_3 production.

Researchers in the O'Hare group have recently developed advanced electrode systems, described in an article published in *Energy & Environmental Science*. These electrode systems, as far as the researchers are aware, work at the highest energy efficiency reported to date.

Their electrodes are made up of layered double hydroxides (LDHs) and a copper foam. LDHs are formed on the copper foam and can be used as suppliers of the hydrogen radicals needed for NO_3^- reduction in dilute solution (see image).

The novel idea behind these hybrid electrodes relies on having an LDH layer to prevent copper inactivation, a process commonly observed in copper metal electrodes. The LDHs separate the sites of radical production and NO_3^- reduction.

Their results provide not only an effective electrode for nitrate reduction in solution, but also confirm the role LDHs can play in facilitating both production and transfer of hydrogen radicals for a variety of catalytic reactions. This research is poised to play a pivotal role in the future realization of sustainable ammonia production by harnessing clean electricity generated from renewable energy sources.

In an advancing field, it is anticipated that this research will contribute significantly to the development of efficient and scalable technologies, facilitating the widespread adoption of sustainable ammonia production methods in the near future. ■

Williams group

Towards more sustainable elastomers

Synthesis of bioderived, recyclable and high-performance thermoplastics.

doi.org/10.1002/anie.202210748

Plastics play a central role in our lives. Despite this, it is difficult to synthesise sustainable polymers that can be recycled chemically without loss of properties, and that maintain high performance.

Thermoplastic elastomers (TPEs) are an important class of materials with the beneficial mechanical properties of cross-linked rubbers plus the recyclability and processability of thermoplastics. Today's thermoplastic elastomers can be found in car tyres, hospital tubing, and household goods, amongst others.

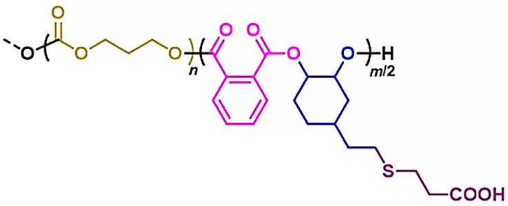
A long-standing challenge in TPE chemistry is to develop more sustainable and recyclable alternatives to widely used polyurethanes or vulcanized rubbers, both of which have highly desirable properties but are very challenging, or impossible, to recycle. Dr Georgina Gregory and Professor Charlotte Williams have published methods to make high-performing and fully recyclable TPEs using natural raw materials.

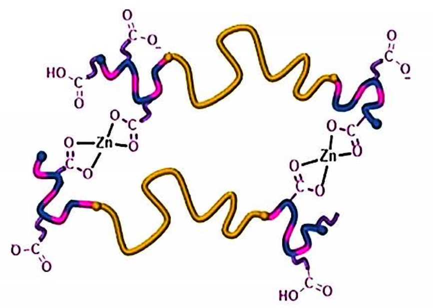
Their TPEs are block polymers with well-defined structures, featuring carbonate and ester linkages. The team also developed a modified ionomer structure that binds Zn(II) ions (see figure). They are produced in an efficient one-reactor process, using monomers derived from natural resources like CO_2, carbohydrates and citrus peel. The team use highly active and selective Zn(II) and Mg(II) catalysts, developed previously in the Williams research group, which can be switched to construct 'hard' and 'soft' blocks in the structures.

In this work, the polyester-b-carbonate materials could compete with the performance of rubbers and urethanes, whilst maintaining the ability to be mechanically recycled over several cycles without compromise to properties.

Key to the high performance of the Zn(II)-functionalised TPEs are strengthening intermolecular interactions. The polymers were investigated in collaboration with experts at Diamond Light Source to reveal phase separated nanostructures that are responsible for improving their properties. All the samples were processable, and were recycled successfully, including chemical recycling to produce monomers.

This work addresses a long-standing challenge in bio-derived polymer chemistry: the efficient matching of properties of the highest performance materials while ensuring efficient recycling. You can read more in *Angewandte Chemie*. ■





Left-hand side and centre: representation of COOH-functionalised thermoplastic elastomers (TPEs) showing the poly(trimethylene carbonate) chains (yellow) combined with other polyester chains (pink and blue) with COOH-functionalisation (purple). Right-hand side: the Zn(II)-functionalised TPEs exhibit crosslinking between polymer chains.

Goodwin group

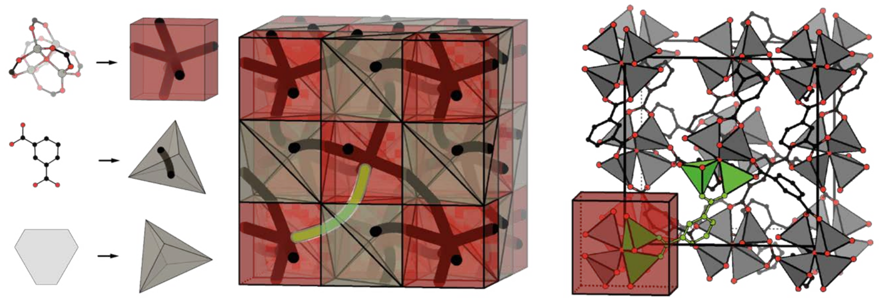
QR-code inspired solid

'Geometrical frustration' as a tool to build chemical Truchet tilings

doi.org/10.1126/science.ade5239

Data storage in barcodes and QR codes exploits visual patterns related to so-called Truchet tilings. Described in 1704 by Sebastian Truchet as a single square decorated with differently oriented tiles on either side of the diagonal, Truchet tilings now encompass any periodic covering of space with tiles that are decorated to reduce their symmetry (for example, the black and white strips in a barcode).

In an article published this year in *Science*, researchers from the Goodwin group, in collaboration with colleagues from Sydney, London, Bremen and Florence, report their work building an atomic-scale realisation of a three-dimensional Truchet tiling using crystalline metal-organic frameworks (MOFs) as a platform.



Truchet tile (centre) and atomic (right) representation of the local crystal structure of TRUMOF-1. Atomic representations of the building units that make up TRUMOF-1 are given on the far left.

Crystalline materials are formed by atoms/molecules oriented in space in a regular, periodic fashion; they can be thought of as periodic tilings in three dimensions. MOFs are crystalline systems made up of nodes and linkers whereby the geometry can be controlled. MOF-5, for example, generates a tiling of space by cubes made up of OZn_4

nodes connected by organic linkers (benzenedicarboxylate, 1,4-bdc).

The researchers synthesised a derivative of MOF-5, called TRUMOF-1 (see figure), replacing the linear linker 1,4-bdc with its bent analogue 1,3-bdc, thereby lowering the symmetry of the system.

Using single crystal X-ray diffraction, the average structure of TRUMOF-1 was found to be disordered, as the linker adopts many different configurations. The researchers were able to characterise the local structure of TRUMOF-1 using diffraction experiments and theoretical calculations, finding it to consist of periodically arranged nodes of OZn_4 connected aperiodically by the disordered 1,3-bdc linker.

These results demonstrate the possibility of synthesising Truchet MOFs – the system can be thought of as geometrically "frustrated", consisting of a component predisposed to form an extended network (OZn_4) and another predisposed to form cages (1,3-bdc).

The concept of geometrically frustrating the competing effects of two different structure-directing components to generate a complex state may be relevant in other systems and allows investigation of this aperiodic connectivity on material properties and, potentially, the design of a variety of functional systems.

Of particular interest is the observation that each crystal will have a different connectivity, and thus carries unique pieces of information. This raises the question of whether TRUMOFs may have an application in memory storage. Prof. Neil Champness from the University of Birmingham commented "A truly impressive study which has far-reaching implications for MOF chemists and beyond". ■

Duarte group

New tool predicts binding sites

Molecular dynamics study of drug resistance in COVID-19 virus protease

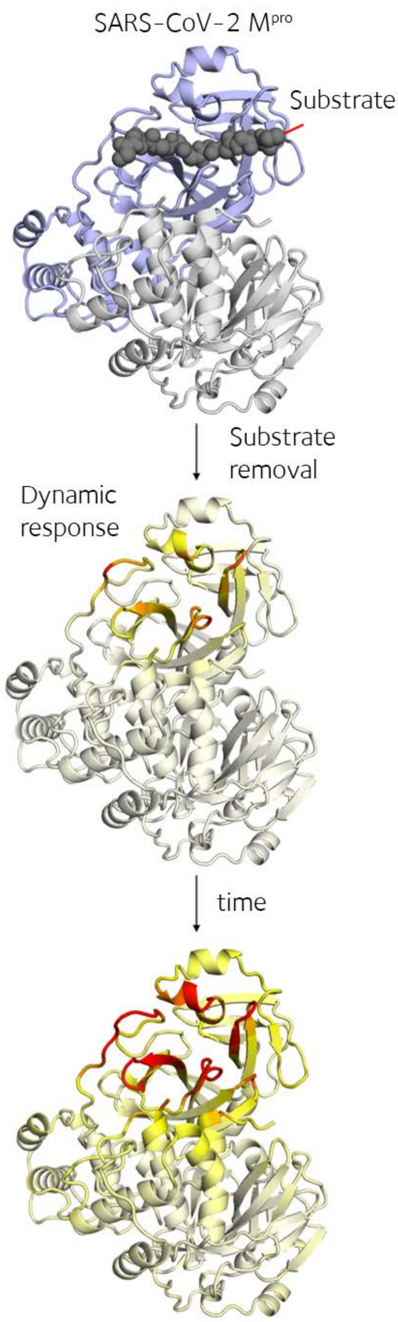
doi.org/10.1021/jacsau.3c00185

One of the key actors in the replication of SARS-CoV-2, the virus responsible for COVID-19, is the main protease (known as M^{pro}). Because of its significance, M^{pro} is a key target for drug development. However, drug-resistant variants of this protease have emerged, challenging the efficacy of existing drugs. It is unclear how M^{pro} binds to its substrate and how these emerging variants might affect this process. Understanding these processes is critical for designing more efficient drugs.

Researchers from the Duarte group, in collaboration with colleagues from Oxford and Bristol, recently published a study in *JACS Au* that investigates how M^{pro} responds to the presence or absence of a binding substrate using a technique called dynamical nonequilibrium molecular dynamics simulations (D-NEMD). This method enabled the team to understand how the removal of substrates impacts the conformation and movement of M^{pro}.

The simulations revealed that, upon removal of the substrate, M^{pro} undergoes conformational changes that affect both the active site and regions further away, known as allosteric sites, where molecules can bind and alter the enzyme activity. Experimental data had previously proved the existence of the same allosteric site in M^{pro}, showing the latter to be a target of the antiviral drug pelitinib.

These findings demonstrate the power of this computational technique to investigate structural changes upon perturbation and identify important allosteric sites relevant to drug resistance in SARS-CoV-2 M^{pro}. This knowledge is valuable for developing strategies to combat drug-resistant variants. ■



Propagated dynamic response of M^{pro} to the removal of its substrate, measured by D-NEMD. Greater movement of the alpha chain carbons in the protein is indicated by darker yellow and red colours in the second two structures. The M^{pro} conformational changes are communicated to sites of allosteric inhibition and drug resistant mutations.

Quantum entrepreneur

Wenmiao Yu (Balliol, 2015) is co-founder and Director of Business Development at Quantum Dice, an award-winning technology spinout from Oxford University. In 2023, Wenmiao and colleagues were selected for the Technology category in the Forbes "30 Under 30" Europe List, and Wenmiao was elected to the UK Young Academy network. Wenmiao talks to *Periodic* about her passion for entrepreneurship and her advocacy work for diversity in quantum technologies.

How did your MChem degree prepare you for your current career?

I really liked the Oxford course, which gives students autonomy in the fourth year to choose a research area of interest. It was a unique experience: being embedded in a research group and carrying out my own experiments that I had full responsibility over. My Part II thesis was joint between the Compton group in Chemistry and the Department of Materials, and I was able to interact with postdocs and graduate students to learn a lot about group work and scientific collaboration.

Throughout my degree I did internships during the holidays, and learned how scientific innovation from the lab is turned into a commercial product. In my last year I took part in the student entrepreneurs programme that Oxford University Innovation (OUI) and Oxford Science Enterprises (OSE) ran together. This programme opened up a lot of the patents that Oxford University owned – students could choose a particular piece of technology that they were interested in commercialising, form a team, and then spend four weeks building an initial business plan around it. That was July 2019 and was where I met my Quantum Dice cofounders.

I chose the patent for a quantum random number generator because, during my degree in chemistry, I had done the quantum supplementary course and gained a background in the scientific language around quantum technologies. So, when I did the startup programme I had a basic understanding of the fundamental principles, which was very helpful.

My role since then has been focused on the commercialisation of the technology: venture capital fundraising, finding market applications for a quantum random number generator, and also doing a lot of science communication – working out how we can describe and demonstrate the value that this technology has to stakeholders in corporate organisations.

Can you explain what Quantum Dice's technology does and how it can help us?

We live in an increasingly digitised world; the World Economic Forum estimates that by 2025 there will be over 25 billion devices connected worldwide – mobile phones, security cameras, laptops and so on – and these are all connected via telecommunication networks.

Any additional smart device connected to a network introduces a new point of vulnerability, potentially allowing hackers to download data that is being transferred or stored in corporate data centres, and leading to leaks of sensitive information. This is an increasingly important problem; IBM reported that last year the global average cost of a single data breach was over $4.3 million.

All encryption protocols need a source of random numbers to make encryption keys. Existing random number generators are failing because they are either pseudorandom number generators, which are vulnerable to bias and brute force attacks, or they are classical hardware-based random number generators, for example those based on radioactive decay, which are slow and similarly vulnerable to attack.

What we do at Quantum Dice is leverage the fundamental probabilistic nature of quantum mechanics to offer a true random number generator. We have a unique patent developed in Oxford called Source Device Independent Self Certification (DISC). This protocol monitors the physical device and reacts in real time to any changes – for example from a third party heating it up or shooting microwaves at it, or simply from the components degrading over time. What DISC is able to do is account for these changes and ensure that the random numbers used in the encryption keys are only coming from a quantum process.

Ours is the world's fastest quantum number generator – over 2.6 gigabits per second – with our closest competitor currently around 1 gigabit per second. This is useful in situations with a high volume of data traffic to be encrypted, such as 5G networks.

Do you feel that quantum science is generally well understood?

I think it is really well understood in academia, but from a market perspective the quantum technologies industry is fairly nascent, and is only now slowly making its way from academia into industry. I spend a lot of time explaining that there's more to quantum technology than quantum computers.

The UK government recently announced a £2.5 billion investment strategy into quantum technologies over the next 10 years. Another boost is that there will be dedicated government funding for businesses and research institutions to develop quantum technologies, ranging from quantum computers to quantum sensors and quantum random number generators.

Is there a gender imbalance in quantum technology, and if so what can be done to improve things?

Yes there is. We are currently working together with another quantum company at the Oxford Innovation Centre to set up an initiative for women working in quantum technologies in the Oxfordshire region. Recently we had a focus group with undergraduate students brainstorming how we could improve gender diversity in the Oxfordshire quantum workforce. This is an initiative that we hope to grow; we want the technology's ecosystem to be as actively gender inclusive as possible. We need all kinds of people in quantum, and a wide variety of roles are available.

Tell us about your work with the Oxford Women in Business society.

I have been mentoring undergraduates at various stages of their degree through the Oxford Women in Business Society. This involves regular meetings during term time to help guide their thought processes when deciding what to do after university, or which internships to go for. In my cohort of mentees some were interested in a career in startups, and it was really rewarding to share my personal experience.

Of course it is a bilateral process, and I also learned a lot from them. My main takeaway was that so many of the students were interested in finding links between different disciplines. From an entrepreneurship point of view that's really valuable, no matter what career you go into.

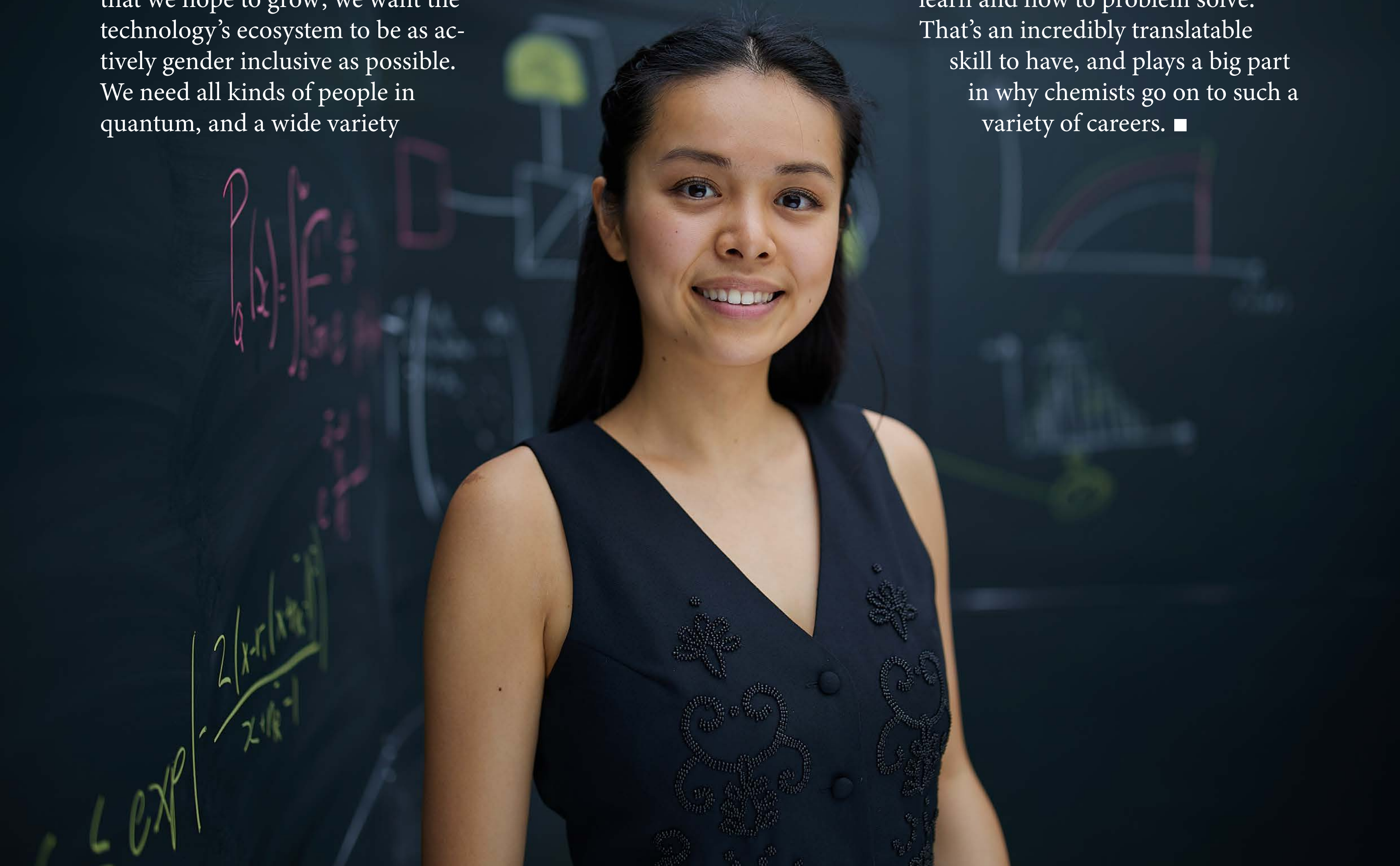
What's next for you?

For Quantum Dice, we are looking to grow the company while retaining a base in Oxfordshire. We want to help develop the quantum tech industry in the UK by doing meaningful proof of concepts for technology trials with some of the larger corporates, helping them understand how they can adopt quantum technologies right now.

From a personal perspective, I am passionate about giving back to the entrepreneurship ecosystem, because when I first started it really supported me. I've been able to do that through mentoring, and I want to help as many students as possible. Along with another company we hope to set up an industry mentoring system where people working in different functions in quantum companies are matched with university or school students.

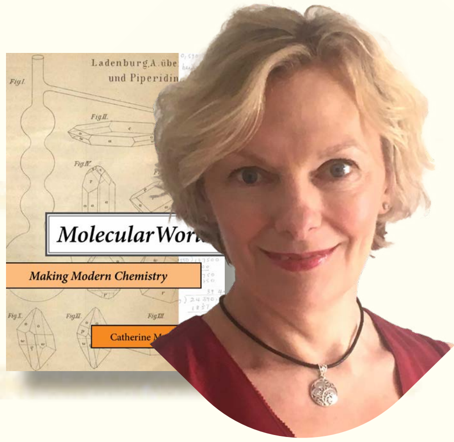
Looking back on your career path so far, what was the main thing that you took away from your time at University?

The highlight of my course at Oxford was the final year project. In many ways I find that conducting scientific research – testing a hypothesis and making modifications to the process step by step – is similar to the early stages of a startup. One of our tutors told us in a tutorial that the chemistry degree at Oxford teaches students how to learn and how to problem solve. That's an incredibly translatable skill to have, and plays a big part in why chemists go on to such a variety of careers. ■



Molecular World

Dr Catherine Jackson's new book *Molecular World: Making Modern Chemistry* (MIT Press, 2023) reveals how 19th century chemists made the world molecular and 3D, learning to mimic and move beyond nature's constructive power. Jackson is Associate Professor of the History of Science at the University of Oxford and teaches the History of Chemistry to Part II students in Chemistry.



How does your work change our understanding of how modern chemistry developed?

Existing histories claim that new theories change what chemists can do. For example, they attribute organic synthesis to the theory of chemical structure introduced in the mid 1800s. My work shows instead how novel experimental approaches, combined with what I've called "laboratory reasoning", enabled chemists to bridge wet chemistry and abstract concepts, creating the molecular world.

My account is built on a series of practice-based breakthroughs, including chemistry's move into lampworked glassware; the field's turn to synthesis and subsequent struggles to characterize and differentiate synthetic products; and the gradual development of institutional chemical laboratories.

I developed this historical reassessment by studying the investigation of alkaloids by German chemists Justus Liebig, August Wilhelm Hofmann, and Albert Ladenburg. Stymied in his own research, Liebig in the 1840s steered his student Hofmann into pioneering synthesis as a new investigative method. Hofmann's practice-based laboratory reasoning produced a major theoretical advance, but he failed to make alkaloids. That landmark fell to Ladenburg in 1886. And it was only after his successful synthesis that Ladenburg turned to the cutting-edge theory of aromatic structure.

In telling the story of these scientists and their peers, *Molecular World* reveals organic synthesis as the ground chemists stood upon to forge a new relationship between experiment and theory – with far-reaching consequences for chemistry as a discipline.

What inspired this study?

I started out as a synthetic organic chemist, with a PhD in polyketide biosynthesis supervised by Jim Staunton in Cambridge. It's a great sadness that Jim is no longer with us. When I began studying the history of chemistry, I expected to find a persuasive account of my own science. I didn't – and that was a wonderful opportunity for me!

If I'd known writing something different would take 20 years' demanding work, I might have thought twice. But thankfully, I didn't. And it's been a fantastic journey, with amazing mentors – beginning with Hasok Chang, who supervised my PhD in history of science at UCL – and inspiring colleagues like Sam Gellman at UW–Madison. Doing anything original is hard and it's always the people around you who keep you going. Jim knew that. I think he'd be pleased.

Will your work give a new perspective to chemists today?

I certainly hope so! As chemist, historian, and educator, my mission is to bring the lessons of history alive in the present. The past is bursting with creative strategies used by chemistry's great innovators, all of whom began as students, many of them from excluded minorities.

I've presented on *Molecular World* around the world, and the message that the big names once struggled to overcome barriers very like the ones chemists now face is engaging – not least because it's true!

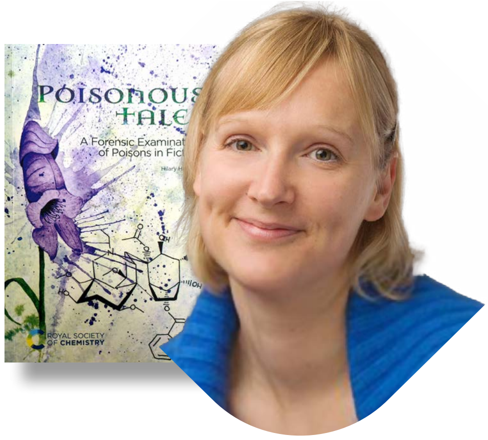
What's next for your research in the History of Chemistry?

I'm currently working on two related strands. The first is an article that applies the approach I developed in *Molecular World* to August Kekulé's development of aromatic structural theory in the 1860s. That's a key story in the history of chemistry and it's ripe for reevaluation.

What's at stake, and what's to be gained, when chemistry and history come together? That's the question driving the new project I'm developing with Professor Angela Russell, here in Oxford. We've called it "Stronger Together," which rather gives away what we believe! We want to translate history into innovative best practice in chemistry, helping address issues of equality, diversity and inclusion. And we want to engage historians with fresh perspectives on chemistry's central role in the production of modernity, fostering mutual understanding in a time of rising chemophobia. In fact, this project's already begun, in the form of some history of chemistry teaching I'll be offering in Chemistry next year. That's a very exciting development! ■

Molecular World: Making Modern Chemistry is published by MIT Press and is out now.

Poisonous Tales



Dr Hilary Hamnett's *Poisonous Tales* (RSC, 2023) uncovers the science behind the use of poisons in fiction. Hamnett is Associate Professor of Forensic Science at the University of Lincoln, having worked for seven years as a forensic toxicologist on thousands of cases involving drugs and poisons. She holds a chemistry degree and a DPhil in biological physics from the University of Oxford.

Poisonous stories have been captivating us for centuries. From Harry Potter to Charles Dickens, Shakespeare to Alice in Wonderland, there are countless fictional cases where deadly chemical compounds play a starring, and often tragic, role.

In her first book, Oxford Chemistry alumna and forensic toxicologist Hilary Hamnett guides us through the macabre world of literary poisonings, asking whether the chemicals listed in her fictional casebook could really have the deadly effects the authors claimed.

Hamnett explains that in many cases, writers' limited scientific knowledge means that the effects of poisons are "as fabulous as the story, and [bear] little resemblance to reality". She brings her real-world experience to bear on these fantastical cases, trying to decide which poisons may have played a role in a literary death or crime.

We are guided expertly through 11 fictional case histories, each involving a different chemical and different manners of death: suicide, accident, murder, death in custody... Hamnett helps us to investigate the crime scene, including the victim's symptoms, before taking a deeper dive into the poisons themselves, other works of fiction where they crop up, and how they might appear in real life toxicology cases and modern medicine – all illustrated with dozens of photos of the poisonous plants (some taken at Oxford's Botanic Garden and Arboretum).

Romeo and Juliet's apparent "murder-suicide", James Bond's sip of a foxglove-poisoned martini in Casino Royale, the madness of the Hatter in Alice in Wonderland: Hamnett shows us that many of these fictional cases, when viewed through modern forensic toxicology, are unlikely or unrealistic. Of course, as Hamnett points out, this "doesn't mean we can't still enjoy our fiction ... but real poisoning cases often lack the finesse and romance of their fictional counterparts."

This book contains an impressively detailed consideration of countless chemicals, biological effects, and real-life toxicology reports, all of which adds to the thoroughly convincing and enjoyable guide to the world of fictional poisonings from a world expert on the subject. ■

Poisonous Tales – a Forensic Examination of Poisons in Fiction is published by the Royal Society of Chemistry and is out now.

Hamlet and Henbane

In Shakespeare's famous tragedy, Hamlet's father is murdered by his brother Claudius with poison in the ear:

...in the porches of mine ears did pour
The leperous distilment, whose effect
Holds such an enmit wi'th' blood of man...

The fictional poison is named as "hebenon", and Hamnett compares it with real-life plants henbane, hemlock, and yew. Henbane (see image to the right) is known as a favourite of witches: "hags were thought to burn the plant, and inhale the fumes conjuring up the spirits and demons they needed to perform magic spells and brew up potions".

In Hamlet's case, we conclude that henbane is the most likely poison because it has been shown to quicken blood coagulation, something that the ghost of Hamlet's father complains of:

with a sudden vigour it doth posset
And curd, like eager droppings into milk,
The thin and wholesome blood.

As with many toxic encounters in fiction, the poison represents something more than a painful death: "in *Hamlet* it becomes an all-embracing metaphor of the corruption and decay of the Danish Court."

CRL turns 20

The Chemistry Research Laboratory (CRL) was opened by Queen Elizabeth II in 2004. It was designed to offer top-notch facilities for chemistry research and was partially funded through an innovative intellectual property deal. Professor Graham Richards CBE FRS, who chaired Oxford's Chemistry department from 1997 to 2006, spearheaded the project and shares his experiences of funding and leading this significant endeavour.

When I became Oxford's first Chairman of Chemistry I had a massive task in my in-tray. We badly needed new research facilities, mainly to replace the historic Dyson Perrins Lab. Architectural practice RMJM came up with a notional cost of £60 million, and this notion would probably have remained just that had it not been for the timely introduction of the Joint Infrastructure Fund (JIF) from the research councils and Wellcome Trust.

The maximum we initially dared ask for was £30 million, but the Department's advisory council, which included former director of The Wellcome Trust Dame Bridget Ogilvie and ex-AstraZeneca research director and chairman of the BBSRC research council Peter Doyle, counselled asking for the full £60M. We did, and were awarded £30M, the biggest JIF grant given to anyone – had we asked for £30M we would likely have received £15M.

So, providing we got planning permission, the project would become a reality. RMJM drew up detailed plans with help from some of the major pharmaceutical companies. Getting approval was not straightforward, but we eventually won through by a single vote, thanks to the expertise of former Oxford Lord Mayor Maureen Christian. Maureen was a strong proponent of modern architecture who knew exactly how to play local government politics, and it was she who broke the ground with a JCB.

Alongside this massive start to the funding, we received contributions from a HEFCE scheme (around £10M), the EP Abraham Trust (£0.5M), the Wolfson Foundation (£3.5M), and a generous contribution of £250,000 from Thomas Swan, a Brasenose chemistry friend. Even with all of this, we still had a shortfall of more than £20 million.

Innovative IP deal

Together with Melissa Levitt of the University Development Office I approached Dave Norwood, an entrepreneur and chess grandmaster who had backed several university spin-outs and recently sold his company to London stockbroker Beeson Gregory. In this extraordinary period before the dotcom bubble burst, financiers were fighting to put money into high-tech ventures. We came up with a plan for the company to provide chemistry spin-outs, and after some haggling – a nervous

Queen Elizabeth II opens the Chemistry Research Laboratory in 2004, alongside members of the Department including Prof. Graham Richards CBE (left).

business when playing with a chess grandmaster – we settled on £20 million for half the University equity for a 15-year period.

Surprisingly, the hardest part of the deal was convincing the University. The difficulty was that nothing like this had ever been done before, but in the end a decisive registrar, David Holmes, saw it through. I also had to convince my colleagues that the deal was in their best interests – complicated, because news of the deal was a price-sensitive topic that could not be revealed until the market was informed.

With hindsight we were extraordinarily lucky with the timing, and all parties have done well out of the arrangement. Chemistry has produced an amazing number of spin-outs, with Beeson Gregory providing access to funds and business advice and receiving a good return, and the University receiving over £100 million. So successful was the partnership that when Beeson Gregory merged with Evolution, the new group set up a subsidiary called IP2IPO which made similar deals with ten British universities. IP2IPO was itself floated as an independent public company, before moving to the main London Stock Exchange as the public company IP Group.

Building the CRL

In all we raised £64.5 million without any contribution needed from the University, meaning we had sufficient funds to do the job properly without cutting corners. Building firm Laing O'Rourke did a wonderful job, with novel techniques meaning that construction could go up and down simultaneously, saving time. During the building works site manager Mike Morris did a great job of keeping our neighbours and the Oxford citizenry happy; I never received a single complaint. The skills of our building manager Richard Jones ensured that we were in the building in time for a Royal opening in February 2004.

Success, growth, and the future

After almost 20 years of use, it is clear that we have what is possibly the best university chemistry laboratory in the world. I believe that the biggest change in world science during my career was the commercialisation of research, in the sense of creating new companies or licensing research. This is an area in which I have been much involved, and in the early days it was not looked on with favour; setting up a company was a naughty thing to do. Now such activity gets credit in research assessment measures, but it is not without dangers. Any activity where large sums of money are involved runs the danger of dishonesty and conflict.

Despite worries that commercialisation might drive scientists to overly applied areas of research, most successful companies created have come from blue skies research, rather than the obviously commercial. It is this rise in the number of new high-technology companies that will provide jobs for today's postdocs and, with care, the development of the national economy. ■

A fuller account of this time in the history of the Department of Chemistry is available in Graham Richards' book, *A Scientific Life*, published by AuthorHouse.

The Jamie Ferguson Chemistry Innovation Awards

The second year of the Jamie Ferguson Innovation Awards delivered ideas that tackle plastic waste, drug discovery, and bad coffee. The were established in 2022 by Oxford University Innovation (OUI) and the Department of Chemistry. Building on Chemistry's legacy for innovation and impact, these annual awards are a platform for entrepreneurial students to create positive change and impact from their work.

The awards are named in honour of our late friend and colleague Dr Jamie Ferguson, Deputy Head for Physical Sciences at Oxford University Innovation, who tragically passed away during the COVID-19 pandemic. Jamie was a friend and mentor to many at OUI and supported the Department of Chemistry for over a decade, where his love of innovation and passion for entrepreneurial spirit helped Chemistry to become one of the most commercially engaged departments at Oxford.

The 2023 Jamies winners showcased a diverse range of groundbreaking ideas and demonstrated a remarkable commercial ingenuity. The winners are:

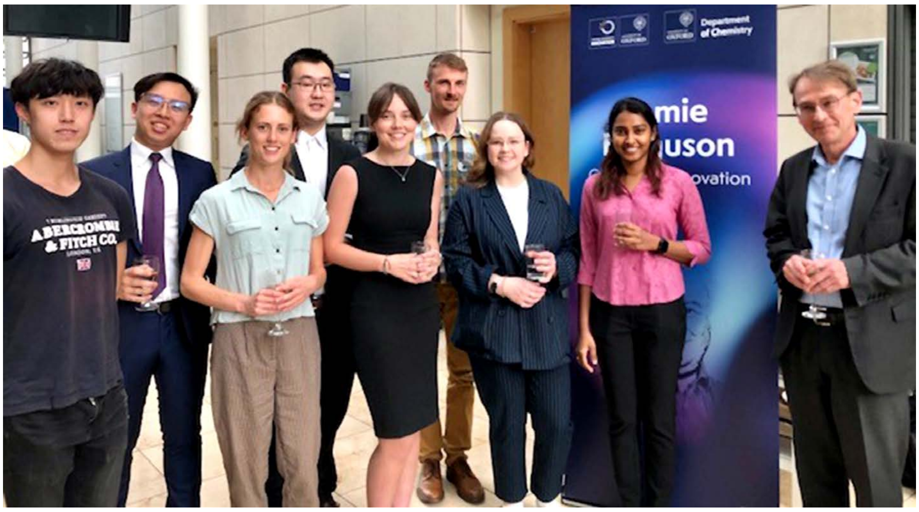
- Jack Howley, for a safer and more cost-effective method for manufacturing quantum dots, promising significant advancements in this cutting-edge technology.
- Clement Collins Rice, for a new approach to tailor-making polymers for the circular economy, addressing performance degradation during recycling and ensuring the preservation of desired characteristics.
- Ryan Herold, for a novel approach to drug testing using enzymes, offering a more accurate representation of real-world conditions and providing valuable insights for drug discovery.
- Elliot Bailey, for a novel approach to decaffeinating coffee, leaving it tasting like coffee, which is not commonly achieved with current decaffeination methods.

In addition to the four main awards, a special award was presented to Annina Lieberherr for her proposal to improve access to academic posters for the visually impaired. Her novel idea highlighted an important accessibility issue within the academic community.

The judging panel, consisting of renowned experts and industry professionals, including staff from OUI, Rawan Farwana from Oxford Science Enterprises, and Oxford Chemistry professors Kylie Vincent, Claire Vallance, Dermot O'Hare and Tom Brown, had the challenging task of selecting the winners from a pool of exceptional presentations.

Each of the winners received a £500 prize, a commemorative trophy made by Chemistry's glassblower Terri Adams, and support form OUI to further develop their ideas towards commercialisation and implementation.

Rev. Cath Spence, one of the judges from OUI, said: "The standard of presentation was phenomenal, with a high level of engagement and confidence displayed by the



Winners of the Jamie Ferguson Chemistry Innovation Awards for 2022 (right) and the 2023 winners alongside the judging panel (below).

participants. It is truly inspiring to witness the entrepreneurial spirit and commercial potential emanating from these young researchers. The future looks promising."

The Jamie Awards are now in their second year. 2022 saw four winners – Katherine Laney, Amber Truepenny, Tobias John and Xingzao Wang – present ideas ranging from materials science to combatting disease, and promising developments are already happening.

Xingzao Wang reported that he has reached a preliminary agreement with Oxford Nanopore Technology to support his investigation into the compatibility of the photo-nanopore in their current MinION device.

Katherine Laney said: "The Jamies taught me a huge amount from the moment I applied. I have gained valuable insights into patents and guidance in pitching and have gone on to pitch to a number of people including Oxford Nanopore CEO Gordon Sanghera. I am currently working with OUI to begin the process of patenting, and hope to turn this technology into a scientific spin out company."

All the winners were strongly positive about their experience, and we hope that the awards continue to grow from strength to strength.

Mairi Gibbs, Chief Operating Officer at Oxford University Innovation, said: "Through his deep commitment to foster innovation at Oxford, Jamie left behind a legacy of impact which has seen some of the brightest ideas from Chemistry become reality.

"These awards celebrate that legacy by forging a path for future innovators in Oxford's student body to have a positive impact in society. We are proud to support their journey and look forward to witnessing the realisation of their innovative ideas." ■

Rebecca Morelle

Oxford Chemistry alumna Rebecca Morelle (St Anne's, 1997) is the BBC Science Editor. Recently, she talked to current Oxford Chemistry students Padraig Meehan and Isabella Richards about her time at Oxford, her career, and the world of science journalism.

What does a typical day look like for you at the BBC?

There isn't a typical day really! Some days are spent filming and interviewing, for instance I've just been filming researchers at the University of Southampton analysing plutonium levels in sediment samples, as well as recording in a bog on the Isle of Wight, as part of a report on the Anthropocene.

Other days are spent editing our material, going through all the material we've shot while writing a script and chatting to my producer in person or over Zoom. The Anthropocene story was quite a hard one to tell because there quite a few unfamiliar concepts to explain in a two minute news package.

Other days are totally unexpected – when we heard about the missing Titan submersible, we had to drop our plans and spend most of the next week on that story. I was doing reports for the News at Six and Ten as well as live updates for the news channel and writing online content. So, if I ever think I'll have a day catching up with my emails, something normally pops up and I don't actually end up doing that!

How did you go from your Chemistry degree in Oxford to a career at the BBC?

I knew by the end of my Master's degree that I wasn't really cut out for a life in the laboratory. But, I loved the bigger picture around the work I was doing and I really liked talking about it. I went to work for the Science Media Centre (SMC), which is a press office for science that was just setting up in London. Around that time things like genetically modified foods and the MMR jab were in the headlines, and there was a general feeling that scientists' voices weren't being heard, so the idea was that the SMC would facilitate scientists speaking to the media.

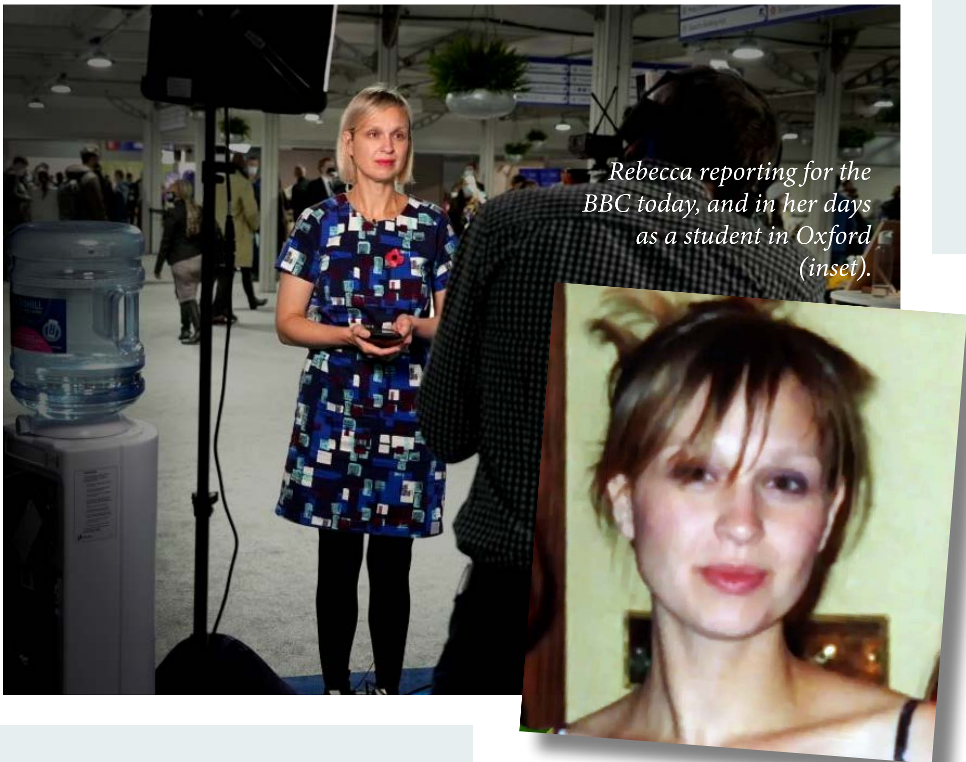
I worked there for a few years and loved it; it was fascinating and we were at the centre of big science stories. We helped journalists put their stories together, and I became interested in becoming a science journalist. I was lucky enough to be able to join the BBC on a science bursary set up in memory of Ivan Noble, a writer who sadly died of a brain tumour. He had been one of the first people to blog about his experiences of illness, something that is more common now but was quite unusual at the time.

I stuck around at the BBC – I spent a few years working online, a few years working as a video journalist, a few years doing a lot of radio and live TV, and then in the last few years I've been Science Editor. I've done lots of different roles, but science has been the common thread.

What advice would you give to a student who wanted to start a career in scientific journalism today?

Things have changed so much since I started out, and my advice would be to be flexible – there are different jobs available now compared to when I left university. Back then, if you wanted to be a science journalist there were far fewer outlets; you could either work for specialist press like New Scientist or Nature, or go to write for a newspaper, or work at the BBC.

There are so many roles in science communication now, from being a press officer to working in museums, as well as many more opportunities to do your own stuff, for example on social media. Although that last one isn't a salaried job, there are lots more places to start writing and get your voice heard.



Rebecca reporting for the BBC today, and in her days as a student in Oxford (inset).

Don't worry if you don't know exactly what to do when you start out; be prepared to try different things and use all opportunities available.

What are your main memories from being at Oxford?

I had such a nice time at university! I made great friends and had a lovely tutor, Professor Jon Dilworth. I was never very good at the practicals that we used to do in the Dyson Perrins Lab – I still remember the smell! But it was all so interesting, as well as being hard work, with a very intense period of exams at the end – we did eight exams over three days at the end of the third year.

I never got into team sports and clubs, partly I think because chemistry has quite a heavy timetable compared to other subjects, and partly because I didn't really know what to expect at Oxford – I was the first person in my family to go to university, having been to a comprehensive school in Hertfordshire. But I had great fun hanging out with friends, many of whom I keep in touch with. They have gone into all sorts of different careers – some stayed in research, others went into law or finance or the City.

In the fourth year I was working for Prof. Martin Westwell, who got me into science communication through Café Scientifique meetings in Oxford. I made lots of friends at St Anne's, and I met my husband at Oxford too. We have a five-year-old now, and I'm hoping to bring her back to Oxford soon for a look around.

How do you distil scientific content for audiences that don't have a scientific background?

Chemistry runs through very many of the things I do, but there aren't many stories I cover that are straight chemistry. So, I find myself in the same position as many of the viewers, where I don't have a pre-existing detailed knowledge of the science. I think part of it is having the confidence to ask the right questions and keep going until I fully understand.

I really like explaining things and telling stories and being able to take a difficult concept and make it understandable. TV news packages are short and you have to be able to tell a whole story in them, so it's quite a good challenge for the brain. I'm always interested in the stories and they are often very positive in contrast to the main news agenda which can be quite gloomy; a lot of science is about great discoveries and human endeavour.

How do you think field of science journalism will change in future?

It is changing massively. When I started out there were TV news bulletins and radio news which everyone watched and listened to, and online news was just developing. Now there's so much more – we're doing a lot of streaming straight to website live pages with bite-sized updates, as well as social media. It's all very fast moving, and just when you get the hang of one thing, you find everyone has moved on to the next one.

When you ask people what news they're interested in they wouldn't necessarily tick the box for science if they didn't enjoy it at school, and despite this the stories tend to do very well. For example, we did a story about some amazing new photogrammetry scans of the wreck of the Titanic, and we found that 6.5 million people looked at the story online. Even though people wouldn't necessarily rate science as an interest, we find that it does capture people's imagination.

What skills that you gained from your chemistry degree do you think are most helpful in your job now?

I think being able to digest lots of information quickly is very useful, and knowing about the processes of science – how it works in the lab, writing scientific papers, and understanding how scientists work together – that all helps. More and more in science that journalistic skill of translating the story for a wider audience is part of the job; adding on a bit of science communication to the end of your lab work is important now.

It is important not to be afraid of tackling hard things. When I was doing my chemistry degree I sometimes thought "I'm never going to understand this", but then I realised that if you go at it enough you eventually do understand. Doing a chemistry degree teaches you not to be fazed by things that at the outset look really tricky; you realise that you can get your head around it.

Are there any areas of science that you particularly enjoy?

I love all of it! The space stuff, the deep oceans, the natural world – I enjoy it all. When you work on a story you get really absorbed in it. One of the nicest things about my job is that I get to visit many places and meet such interesting scientists, hearing all about their research and their personal stories. If I ever stopped being interested, it would be time for me to move on. ■

www.chem.ox.ac.uk/morelle

Hear more from Rebecca in our video interview, online now at the link above.

Profile: Dr Martin Galpin

Dr Martin Galpin is Chemistry's new Director of Studies and Associate Head of Department (Teaching), having taken over the role from Professor Nick Green, who will begin his well-deserved retirement next year. Martin talks to *Periodic* about his (very busy) new role.

What are the main responsibilities of the Director of Studies?

My overall role will be to lead and shape the Department's teaching of our undergraduate and postgraduate programmes. This includes the responsibility of developing and looking after our unique, world-class MChem degree, on both the practical and non-practical sides, all the way from admissions to the end of the Part II year.

I'll also maintain strategic oversight of the Department's graduate studies programmes, including matters of funding and graduate scholarships. I think it's very important to keep in touch with the student body, and to lead by example, so I'll continue to give some lectures in the Department and some tutorials for my college.

You were previously Deputy Director of Studies and will be already familiar with the complexities and challenges of the role. What do you feel are the main challenges, and how do you see things progressing over the next few years?

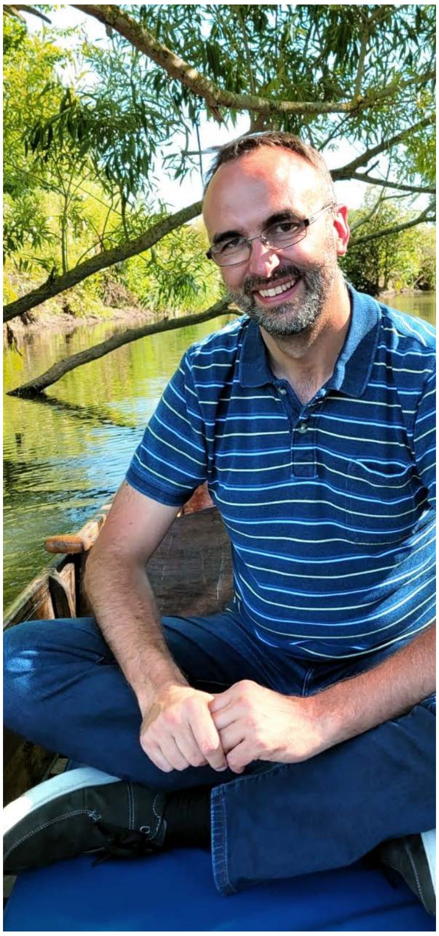
Chemistry is a wide-ranging discipline, so one of the main complexities is in bringing the pieces together, to form a coherent course that suits the needs of all our students. Each of our academics and students has their own view about what should go into the undergraduate degree, and a big part of the job is listening to people, seeking compromise, and building consensus. I'm lucky to work with a great team in the Chemistry Faculty Office and the Chemistry Teaching Laboratory, whose hard work and support will make the job much easier.

We face many specific challenges in running our programmes. Three questions to which we must devote particular attention are: how do we recruit students with outstanding academic potential from all backgrounds, how do we best use our resources and precious time to teach them, and how do we assess our diverse group of students fairly?

The resource question is particularly difficult to answer: teaching students through Oxford tutorials and practicals, giving undergraduate students the opportunity to spend a whole year on a Part II project, and funding graduate students to complete DPhils, are all very expensive. As such, we are immensely grateful for the generous financial support from our alumni, which helps us to fund and support many excellent, deserving students.

Despite the challenges, it's an exciting time for teaching in the Department. In the last few years, we have appointed several new teaching academics, and a number of our teaching staff are helping to understand and develop teaching methodology via chemical education research.

I'm also keeping a particularly close eye on advances in artificial intelligence: I think AI has a huge potential to change the way we teach and assess students, and it will be interesting to see how things develop in this area over the next few years.



Can you tell us a little about your wider interests?

Music keeps me occupied a lot of the time – listening, playing the piano, singing, and going to as many live music events as I can. I'm a bit obsessed by jazz. I also love to go sailing with my friends, which I find to be a great distraction from work! ■

Dr Martin Galpin (Keble 1997) studied for his MChem in the Department of Chemistry at Oxford, before moving to Balliol College in 2001 to undertake his DPhil with Professor David Logan. He continued in the Logan group as a postdoctoral research associate and held a Junior Research Fellowship at Worcester College from 2006 to 2010. In 2011, Martin took up the position of Departmental Lecturer in Mathematics for Chemistry and was appointed to a Supernumerary Fellowship at University College. In 2017 he became Deputy Director of Studies, and became Director of Studies in September 2023.

Women in Chemistry

Earlier in the year, we spoke to some of our students, staff and alumnae to mark International Day of Women and Girls in Science (IDWGIS). 11 February was adopted by the UN to promote full and equal access and participation of women in the fields of Science, Technology, Engineering and Mathematics. You can read a few highlights of these conversations below – head to our full set of profiles for more: **bit.ly/women-in-chemistry**

Dr Vivienne Cox DBE (St Catherine's, 1977) is Chair of Victrex and the Rosalind Franklin Institute– she believes that women add a different dimension to groups or teams, in chemistry and in so many other areas.

"The skills I learnt as a chemist have been invaluable – clear, logical thought, acting on evidence, ability to reason – these have served me well throughout my career.

"Chemistry is a powerful language to describe and communicate with the world around us. It's important to encourage girls and women to study and work in chemistry – they can bring new perspectives and ideas that lead to innovation and progress in an increasingly interdisciplinary field.

Prof. Yujia Qing (Brasenose, 2012) did her DPhil at Oxford Chemistry in Hagan Bayley's lab, and she is now an Associate Professor of Organic Chemistry at Lady Margaret Hall.

Jordan Oliver (Keble, 2019) completed her Part II research project in Stephen Faulkner's laboratory, looking at how metal complexes can be used to image diseases like cancer and stroke. For Jordan it was her A-level chemistry teacher who initially encouraged her to consider Chemistry as a further education and career option.

"My inspirational A-level teacher helped me to see the opportunities Chemistry could provide far beyond the classroom. Women studying chemistry provide a community of thinkers and a new generation of role models for young girls, meaning one day we can eliminate the gender imbalance in science.

"One thing that would provide great support for all aspiring chemists, not just young girls, is making it normal to ask for help. Everybody is different and has their own challenges to face – talk about those challenges and let people know that struggling does not mean failing!

Dr Laura Cunningham is a postdoc in Stephen Fletcher's research group, and one of the Department's Equality, Diversity & Inclusion Fellows. As well as this she is President of Oxford Women in Chemistry, which celebrates and encourages diversity and inclusion in the Department and promotes the achievements of woman scientists.

Prof. Claire Vallance believes that chemists have a unique perspective on solutions to global issues. "I think we need more people in the world who are trained to think like scientists – to balance and evaluate the available evidence and make informed decisions. Women are half the population, so it will be difficult to achieve this aim if we don't keep encouraging more girls and women to study science subjects".

"I'm a strong believer in 'you have to see one to be one'. It's really important to have visible female role models, so that girls from a young age can see that chemistry and other sciences are career options for them.

Building Bridges

The Department of Chemistry is leading a collaborative project between the University and external partners to support an enriched science curriculum at primary level and to nurture the next generation of scientists, regardless of their background.

Chemists have a strong sense that our subject underpins modern life. Many young people however, and particularly those with little exposure to science from their family background, struggle to see chemistry as relevant to their everyday life or to potential careers. A multi-faceted collective approach is therefore required to support young people from under-represented backgrounds to pursue a pathway in STEM (science, technology, engineering and mathematics).

Schools participating in the Building Bridges project, an innovative schools science project spearheaded by the Department of Chemistry, are able to deliver annual sustained curriculum arcs on scientific themes. These activities expose students to chemical sciences research, everyday applications of chemistry, and possible careers.

Through a series of in-school activities and talks delivered in the spring, and a visit to Oxford for hundreds of school students this summer, Building Bridges supports teachers in UK primary schools with pupils suffering high levels of disadvantage due to socio-economic deprivation, disability, racial and religious bias, or with limited family support for science. You can read about how the Building Bridges project's first year went, and plans for the future, on the facing page.

This scheme is part-funded to mid-2024 by the RSC's Chemistry for All fund and runs in collaboration with the Oxford Botanic Garden and Arboretum (OBGA) and the Ashmolean Museum, as well as Wadham, Hertford and Balliol colleges.

Piloting in Gloucester has shown that our model works effectively, and we will be expanding the project to other areas of the UK from September 2023. Next year's theme, *Into the Blue*, will focus on analytical chemistry and colour, and will include links to photoredox catalysis, an active area of research within several groups in the Department. ■

If you would like to support the work of the Building Bridges project in whatever capacity, please get in touch with Saskia O'Sullivan (Educational Outreach Officer) at **outreach@chem.ox.ac.uk**.



The project's history starts with the development of a suite of science activity boxes known as OXbOXes that support science curriculum teaching. Our ChembOX, focused on solutions, mixtures, and separation in the Year 5 curriculum, was co-developed with partner primary schools and has been in regular use since 2022. Summer 2023 saw the successful launch of EarthbOX (Earth Sciences) aimed at Year 3, with BOX of Sparks (Physics) scheduled for September, and BOX of Stuff (Materials) for 2024.

Our 2023 enrichment arc focused on Climate, Energy, Food and Medicines under an overarching *Green Planet* theme. School-based activities kicked off in earnest during British Science Week (10–19 March 2023). Throughout March and April, we visited each of our partner schools, delivering a Science Assembly showcasing the incredible work of the Department on green fuels and ammonia, sustainable polymers, carbon capture, and medicinal chemistry.

Across May and June, we provided our partner primary schools with a series of cross-curricular classroom activities including:

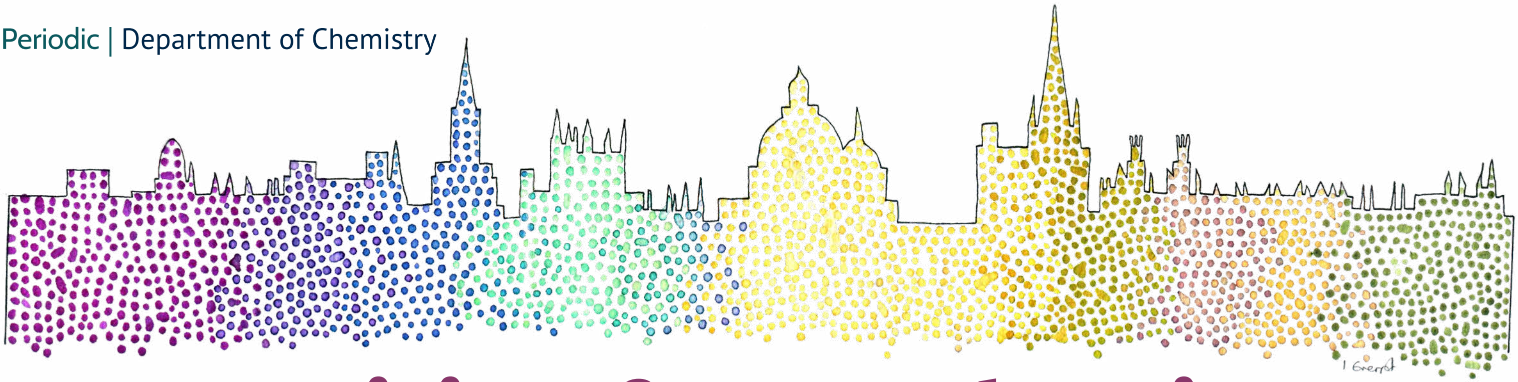
- *Palate for the Planet*, where participants enjoyed videos from the Oxford Botanic Garden's team explaining the origin of staple foods, matched scents to pictures and a world map, before calculating carbon footprints.
- *Edible Towers*, with each of the 28 classes involved growing 12 different plants from seed and considering their health benefits.
- *Creative Chemistry Crests*, which invited participants to learn more about Oxford colleges by completing quizzes and creating droplet artwork of the college crests with red cabbage pH indicator.
- *Kill or Cure?*, and *A Gruesome Mystery*, two newly created board games that familiarised students with Oxford locations and developed their scientific skills and awareness of botanical and chemistry-related careers.
- *The Poison Garden* rounded off in-school activities with a video tour of the Poison Garden at Alnwick Gardens, Northumberland.

This year's theme culminated in a week of visits to Oxford by Year 6 and Year 7 students in our partner schools. Nearly 600 students visited in the first week of July, taking part in a series of workshops at Wadham, Balliol and Hertford colleges, as well as the Oxford Botanic Garden:

- *Meet the Green Planet Researchers* sessions were hosted at Wadham, where our visitors met members from the Williams, Flashman and Aldridge Groups, as well as two groups from the University of Reading. Researchers were able to develop their own public engagement skills, with each group sharing one key message about their work.
- *Curious About Careers*, a session exploring the breadth of scientific careers, took place at Balliol and Hertford.
- *The Treasure Trove*, based at the Oxford Botanic Gardens, included an investigation of staple foods, a tour of the Garden's Rainforest House, and self-directed exploration of the medicinal beds.

Given the importance of parental influence and support in the aspirations of young people, we also created a guide to free activities in Oxford aimed at a summer day trip, encouraging students, families, and teaching staff to visit Oxford again. ■





Inspiring future chemists

62 workshops at **16** Oxford colleges challenged **1,443** pupils

1,952 created art in our Creative Chemistry Tent

100+ competed in our first Oxford Chemistry Race

What a fantastic session! Was really nice to see the students have the opportunity to take ownership of their learning and learn through discovery!

Teacher commenting on our Puzzle Boxes

12 live lecture-demonstrations on departmental research

9 CheMA*stery offer-holder support sessions

116 pupils learnt about sustainability in Plastic Fantastic?

21 Schools Workshops engaged **840** pupils

175 students competed to create a **45** s chemical clock

1,521 school pupils wowed by Green Planet assemblies

6 online, interactive Chiral Chemistry workshops

37 academic sessions given over **3** days of a UNIQ summer school

I really enjoyed seeing the breadth and diversity of Chemistry research … I feel as though my appreciation of Chemistry has been really increased by the series.

Explore Chemistry participant

26 countries represented at online conferences

1 roadshow to coastal Yorkshire and rural Northumberland schools

1,300+ enjoyed Explore Chemistry talks and Q&As

Your generous support allows us to reach out to the next generation of chemists.

www.chem.ox.ac.uk/support-outreach-and-access

The power of a DPhil

Continuing our series on DPhil students' careers and experiences, alumnus Ashley Stevens (Corpus Christi, 1964) shares how his DPhil shaped his career.

My DPhil stood me in very good stead throughout a rich, diverse and satisfying career in the business side of the chemical industry.

I fell in love with Chemistry in school and got a scholarship to Corpus. In my Part I exams I shared the Gibbs Prize with two others, so it was natural to consider an academic career. I went on to do a DPhil with Bob Gasser in the then PCL titled "Some Chemical Applications of Ultra High Vacua Techniques".

At that time, physical chemistry was primarily about building and fixing machines, and I found I was not good at that. So, I decided to get into the business side of the chemical industry, and joined P&G's industrial chemicals division.

In 1982, my mentor within P&G quit to join one of the early Boston-area biotech companies. A few months later I followed, and have lived in Boston ever since. My DPhil gave me credibility to talk to molecular geneticists about their science.

After nine years in biotech I decided to return to academia, and get into technology transfer. I ran the Technology Transfer Operations of the Dana–Farber Cancer Institute, part of the Harvard Medical School, for four years and then moved to Boston University, where I stayed for 17 years. Having a DPhil was critical for academic scientists to give someone from the administrative side of the institution their time and cooperation.

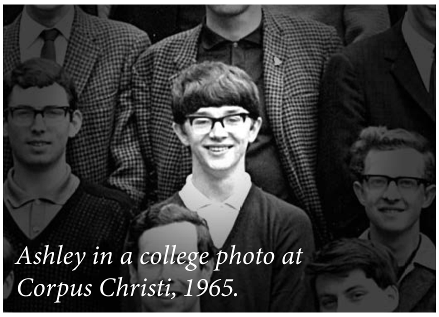
Along the way, I had an adjunct appointment in Boston University's School of Management, where I taught technology commercialization. The spirit of enquiry I got at Oxford never left me, and I've researched and published extensively on knowledge transfer, entrepreneurship, and economic impact. My career has gone full circle, and I finished up spending half of my professional career in academia after all. In all of these activities, the DPhil was critical to gaining credibility and respect.

For 25 years I've had a flourishing second career as an expert witness in intellectual property disputes in the life sciences, with a particular specialty in disputes involving an academic institution. Insisting on being called "Dr Stevens" (and having a British accent!) is very helpful in setting the tone of depositions.

In addition to Bob Gasser, the other people I was close to and visited during my trips to Oxford are Graham Richards and the late Sir Brian Smith [for an obituary see page 30]. Graham was a tremendous mentor to me and asked me to be the first MD of Isis Innovation in the mid-80s. I'd not considered technology transfer then, and didn't want to return to the UK, so I passed, but it was funny how a few years later I decided to follow that path. In retrospect, it's clear that Oxford wasn't convinced of the sustainability of commercialization in the late 80s, and I'm glad I didn't take the job.

30 years on, Oxford has the largest dedicated venture capital fund of any university anywhere – Oxford Science Enterprises – with over £850 million raised in two funds. Clearly, innovation in Oxford is sustainable.

Although I nominally retired in 2012, I am still working pretty much full time as a consultant. I cannot describe just how diverse, full, rich and satisfying a career I am having (tense intentional), and my DPhil has been vital to every phase of it. ■



Ashley in a college photo at Corpus Christi, 1965.

Graduate students help shape the work of every research group, levering fundamental science to enhance understanding and address global challenges. We are enormously grateful to alumni and friends whose support has enabled new research students to begin their studies at Oxford Chemistry. If you would like to find out more about how to support the education and training of outstanding research students at Oxford Chemistry, please visit the QR code to the right.

If you would be willing to share your experiences and reflections with a current DPhil student please contact **alumni@chem.ox.ac.uk**. We hope to publish future interviews and stories on the Chemistry website, and we are always keen to hear from former students of the Department.

LEAF: Sustainable, efficient laboratories

The Department of Chemistry participates in an innovative scheme to drive forwards our laboratory efficiency.

The Department of Chemistry started work on the Laboratory Efficiency Assessment Framework (LEAF) in the academic year 2021–22, gaining seventeen Bronze awards, two Silver, and one Gold. In 2022–23 groups submitted applications for nine Bronze awards, fifteen Silver, and two Gold.

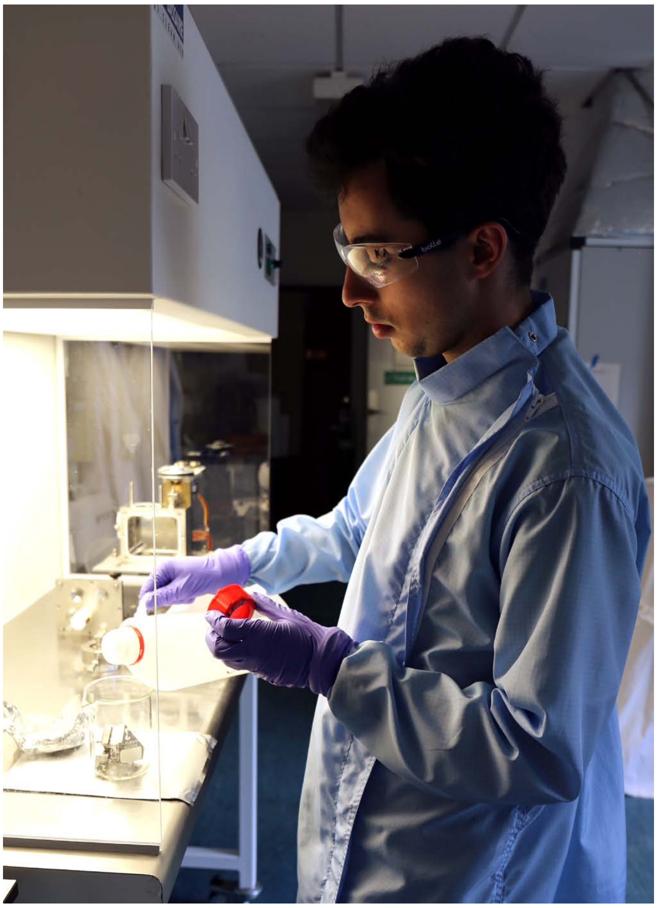
Tailored by lab specialists at University College London, LEAF is an online platform that helps users identify practical steps to make their lab more sustainable. Participants must meet a set of criteria to reach Bronze, Silver, or Gold standard in turn, and can estimate the carbon and financial savings their actions have achieved. It covers equipment, space use, ventilation, procurement, waste, samples and chemicals, and is usually undertaken by individual research groups.

Susan Perkin's research group joined the LEAF project at the outset, achieving Bronze in the first round of awards and Silver in the next. Work in the Perkin group focuses on solving problems of environmental sustainability and energy storage through fundamental research involving the physical chemistry of electrolytes. The group works in three labs in the PTCL and currently has two postdoctoral researchers, two DPhil students, and two Part II students.

Kieran Agg, second year DPhil student in the Perkin group, has been coordinating the group's effort. He explained that the LEAF protocols enabled group members to take a critical look at all their processes and identify ways in which they could minimise the carbon footprint of their work whilst continuing to perform careful science.

The LEAF criteria include items such as purchasing, water and solvent use and waste streams, and the Perkin group have found ways to make significant changes in these areas, for example by identifying and using a type of laboratory gloves that can simply be rinsed and reused instead of being sent to landfill after a single use. All waste is monitored and separated, and the group takes full advantage of the Department's recycling scheme. Participation in the LEAF scheme has enabled the Perkin group to recycle more of their waste and reduce their harmful solvent consumption by 75%.

Kieran says that the LEAF project so far has been a very worthwhile exercise. "When you have established scientific protocols, you have to work out ways in which you can make adjustments without altering the effectiveness. It has been very rewarding to work together as a group to achieve positive change and we definitely plan to continue our efforts in this area; we already have our sights on the Gold award next year." ■



INEOS OXFORD INSTITUTE

ANTIMICROBIAL RESEARCH

The future of antibiotics

Antibiotics are a vital foundation of modern medicine. Like all living things, however, the bacteria that cause infection have adapted to their surroundings over time. Addressing this vital issue is the work of the Ineos Oxford Institute for Antimicrobial Research (IOI).

Once easily treatable infections and injuries are becoming more dangerous. This is because of antibiotic resistance, whereby bacteria evolve in a way that makes antibiotic drugs harmless to them. It is estimated that in 2019 over 1.2 million people globally died from drug-resistant infections.

Bacteria can survive antibiotic treatment in several ways. Some neutralise the antibiotic before it can do harm. Others have learned to quickly pump antibiotic out of their cells. Yet others can change their outer structure so the antibiotic cannot attach and kill them.

New antibiotics are urgently needed to fight the epidemic of antibiotic resistance. Dr Monisha Singha is a synthetic chemist at the IOI working on antibiotic combination treatments. These include an antibiotic and an inhibitor, with the inhibitor preventing specific bacterial enzymes from breaking down the antibiotic before it has its desired effect.

Metallo-ß-lactamases are bacterial enzymes that breakdown ß-lactam antibiotics like carbapenems, used to treat serious multidrug-resistant infections when other antibiotics like penicillin have failed. Currently, there are no no clinically approved metallo-ß-lactamases inhibitors – this is what the IOI team are working on.

The first step is to design an inhibitor compound. “It’s important from the very first step, before we get into the lab, to consider the drug’s intended purpose for the patient,” says Dr Singha. “There is no point synthesising a new drug which works in theory but will be toxic to the patient. We work closely with the IOI team in Biology to use their expertise on how molecules might interact inside a cell and inside the human body to inform drug design.”

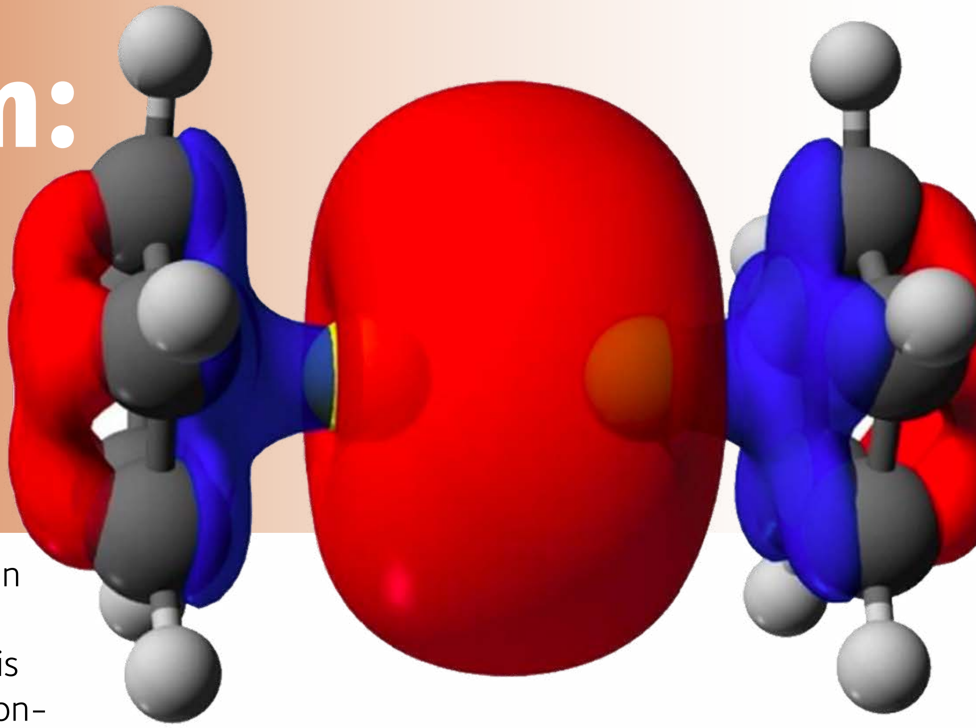
Since 2017 only 12 new antibiotics have been approved. Of these, 10 belong to classes with known resistance mechanisms that decrease their effectiveness. IOI collaborates closely with industry to ensure that research in the lab can be translated into action against growing global health threats.

“If there are too many steps in the synthetic process, if the starting materials are expensive or not easily available, then this increases the cost of production and decreases likelihood of pharmaceutical companies investing in getting a drug to market,” says Dr Singha. “Finding new drugs is hard; finding new drugs that meet all our requirements that are also appealing to pharma is very hard.”

Clear routes for collaboration to enhance drug development are integral to the IOI as an interdisciplinary institute. “It is so exciting to be creative with molecule design at this stage of the drug development process,” says Dr Singha. “I always find it very rewarding to make a molecule that may never have been synthesised before, and working so closely with biologists is crucial to our success.” ■

You can find out more about the work of the IOI online at **www.ineosoxford.ox.ac.uk**

Beryllium: A new bond



Beryllium, element number four in the Periodic Table, is the second lightest metal, but its chemistry is the least well-developed of all non-radioactive elements. Chemists and physicists have tried to synthesize Be–Be bonds for more than 100 years, but they have remained elusive. Only recently have fleeting, highly unstable Be–Be interactions between beryllium atoms in the gas phase been detected.

In a study published in *Science*, a team from Oxford Chemistry explain how they have prepared the first stable compound containing a chemical bond between two Be atoms. The compound the team has synthesised, diberyllocene, is stable both as a solid and a vapour, and the Be–Be bond has been unambiguously established using X-ray crystallography.

The chemistries of the lightest elements – the first and second row of the Periodic Table, hydrogen through neon – form the basis for fundamental models of chemical bonding and reactivity. These models are used to explain the chemical properties of the world around us, such as how catalysts work and how biological systems like our bodies function, and to make predictions about hitherto unknown compounds and materials. The development of fundamental new compounds of these lighter elements (such as beryllium) is critical for testing and refining these models of chemical bonding.

The molecule that the team prepared in this study, diberyllocene, has been the subject of many experimental and theoretical studies over the past fifty years. This is the first time it has been synthesised, in a great leap forward in main group chemistry. The fact that it has taken so long to validate such a fundamental bonding interaction (a missing link in the element–element bonds in the second row of the Periodic table) had led chemists to question whether it was even possible, despite theoretical support for its feasibility.

Dr Josef Boronski, lead author of the study, said: "As beryllium is such a light element, its chemistry is idiosyncratic and often incomparable to that of other metals. It has been such a privilege to get the first glimpse of an unseen facet of this element. Although there have been numerous unsuccessful attempts to prepare diberyllocene, given beryllium's capacity to form highly covalent bonds we're finding that the beryllium–beryllium bond is rather strong. However, diberyllocene is still an extremely reactive molecule and I'm sure a thorough exploration of its chemistry will yield many surprising results."

The team have shown that diberyllocene is stable in the solid state and (when heated) in the vapour phase. Given the many unsuccessful previous attempts to prepare beryllium–beryllium bonds, the stability of the compound itself is remarkable and means that it can be studied by a range of analytical techniques. Diberyllocene was also shown to act as a reductant that can be used to synthesise beryllium–metal bonds.

Simon Aldridge, Professor of Main Group Chemistry, said: "Studies of fundamental compounds of this type might not always be fashionable these days, but they are critical to our understanding of key underpinning concepts in chemical bonding and reactivity."

The team now hope to further investigate the fundamental chemical reactivity of the beryllium–beryllium bond, including using it to generate new beryllium–element bonded compounds, and to explore the properties of such materials. This will allow them to test our current understanding of chemical bonding and reactivity for the lightest elements and metals. ■

Read more in *Science*:

doi.org/10.1126/science.adh4419

Special delivery

The UK's first research-dedicated cyclotron is being installed in the Department of Chemistry.

The particle accelerator will allow researchers to produce radioisotopes on-site, enabling experiments that were previously unfeasible due to the short half-lives of radioactive samples.

The cyclotron project is central to the new OxIME initiative (Oxford Imaging Methods Epicentre). Developed by Prof. Véronique Gouverneur FRS, Prof. Daniel Anthony (Pharmacology) and Prof. Ben Davis FRS (Pharmacology and the Rosalind Franklin Institute), OxIME aims to unite experimental and physical science innovations with molecular imaging for the investigation of biological questions on a University-wide basis.

The UK already has a nationwide network of radiopharmacies. Primarily clinical facilities, they run at near full capacity, which means that fundamental research – crucial in the development of new radiotracers – is often deprioritised. To tackle this, the team acquired a research-dedicated compact cyclotron and radiochemistry facility to accelerate innovation both in radiochemistry and PET ligand discovery, a model which is the first of its kind in the UK.

The cyclotron that is currently being installed in the Rodney Porter Building can produce fluorine-18 and several other short-lived radioisotopes in a rapid, automated, and safe manner.

One of the Gouverneur group's research streams focuses on the chemistry of fluorine-18, a radioisotope with applications in medical imaging, drug discovery, and R&D. Fluorine-18 is required for positron emission tomography (PET), which produces detailed 3D images of the inside of the body, helping us to track biological processes and playing a key role in clinical diagnosis and assessment.

A user base of numerous research groups from Oxford, the Universities of Bath, Bristol, Cardiff, as well as industry, has already been identified. The lab's unique model will support all manner of novel and impactful PET radiochemistry research, ranging from the fundamental to pre-clinical and translational. Having a cyclotron in the Department of Chemistry will allow us to independently produce radioisotopes for our research activities, and expand our research portfolio to shorter half-life radioisotopes such as carbon-11, nitrogen-13, and oxygen-15.

This project has been funded jointly by an EPSRC strategic equipment grant, the University of Oxford's John Fell Fund, and departmental funding. ■

The cyclotron was moved into the Rodney Porter Building (bottom left) by crane in July 2023.

Hazard-free fluorochemicals

A team based out of Oxford Chemistry have developed an entirely new method for generating critically important fluorochemicals that bypasses the hazardous product hydrogen fluoride (HF) gas. Their innovative method, inspired by the biomineralization process that forms our teeth and bones, could achieve an immense impact in improving the safety and carbon footprint of a growing global industry.

Fluorochemicals are a group of chemicals that have a wide range of important applications – including polymers, agrochemicals, pharmaceuticals, and the lithium-ion batteries in smartphones and electric cars – with a $21.4 billion global market in 2018. Currently all fluorochemicals are generated from the toxic and corrosive gas hydrogen fluoride (HF) in a highly energy-intensive process. Despite stringent safety regulations, HF spills have occurred numerous times in the last decades, sometimes with fatal accidents and detrimental environmental effects.

To develop a safer approach, a team of chemists at the University of Oxford alongside colleagues in Oxford spin-out FluoRok, University College London, and Colorado State University, took inspiration from the natural biomineralization process that forms teeth and bones. Normally, HF itself is produced by reacting a crystalline mineral called fluorspar (CaF_2) with sulfuric acid under harsh conditions, before it is used to make fluorochemicals. In the new method, fluorochemicals are made directly from CaF_2, completely bypassing the production of HF: an achievement that chemists have sought for decades.

In the novel method, solid-state CaF_2 is activated by a biomineralization inspired process, which mimics the way that calcium phosphate minerals form biologically in teeth and bones. The team ground CaF_2 with powdered potassium phosphate salt in a ball-mill machine for several hours, using a mechanochemical process that has evolved from the traditional way that we grind spices with a pestle and mortar.

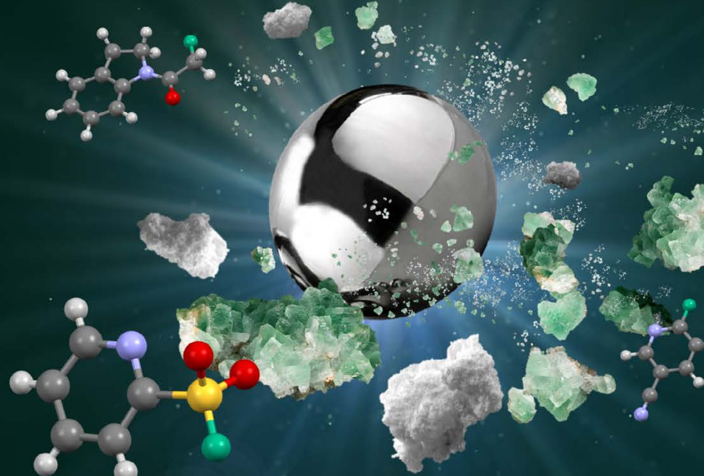
The resulting powdered product, called Fluoromix, enabled the synthesis of over 50 different fluorochemicals directly from CaF_2, with up to 98% yield. The method developed has the potential to streamline the current supply chain and decrease energy requirements, helping to meet future sustainability targets and lower the carbon footprint of the industry.

Excitingly, the solid-state process developed was just as effective with acid grade fluorspar (> 97%, CaF_2) as it was with synthetic reagent grade CaF_2. The process represents a paradigm shift for the manufacturing of fluorochemicals across the globe and has led to the creation of FluoRok, a spin out company focusing on the commercialisation of this technology and the development of safe, sustainable and cost-effective fluorinations. The researchers hope that this study will encourage scientists around the world to provide disruptive solutions to challenging chemical problems, with the prospect of societal benefit.

Lead author Prof. Véronique Gouverneur FRS who conceived and led this study said: “The direct use of CaF_2 for fluorination is a holy grail in the field, and a solution to this problem has been sought for decades. The transition to sustainable methods for the manufacturing of chemicals, with reduced or no detrimental impact on the environment, is today a high-priority goal that can be accelerated with ambitious programs and a total re-think of current manufacturing processes. This study represents an important step in this direction because the method developed in Oxford has the potential to be implemented anywhere in academia and industry, minimise carbon emissions e.g. by shortening supply chains, and offer increased reliability in light of the fragility of global supply chains.” ■

Read more in *Science*:
doi.org/10.1126/science.adi1557

Find out more on YouTube:
youtu.be/9kgPmXti7RE



Professor John Goodenough

Professor John Goodenough, oldest ever Nobel Laureate and world-renowned lithium-ion battery pioneer, died in June 2023 at the age of 100.

Professor Goodenough was Head of the Inorganic Chemistry Laboratory (ICL) at Oxford from 1976–1986, and it was during this time that he and his group conducted ground breaking research that led to the widespread use of lithium-ion batteries, and a revolution in modern life.

Working in the ICL with Koichi Mizushima, Phil Wiseman, and Phil Jones, Prof. Goodenough expanded on previous work by M. Stanley Whittingham. He found that by using Li_xCoO_2 as a lightweight, high energy density cathode material, he could double the capacity of lithium-ion batteries. The seminal work conducted at the ICL was commemorated in 2010 by a blue plaque from the Royal Society of Chemistry, designating the laboratory as a National Chemical Landmark.

After his departure from Oxford, Prof. Goodenough joined the University of Texas at Austin, where he continued his research career. In 2019, at the age of 97, he became the oldest ever Nobel Laureate, winning the Nobel Prize in Chemistry together with Akira Yoshino and Oxford alumnus M. Stanley Whittingham.

Members of the Oxford Chemistry community were saddened to hear of Professor Goodenough's passing, and his legacy is a continuing inspiration for all chemists. Those who knew Professor Goodenough held him in high regard.

Emeritus Professor Peter Battle said: "John Goodenough won the Nobel Prize for his work on the lithium-ion battery, but we shouldn't forget that he also made very significant contributions to our understanding of the electronic properties of solids, particularly the metal-insulator transition and magnetism. Mention of the former reminds me of the staccato noise of the chalk as he drew a dashed line on the board to represent a Fermi level, while his work in the latter field led to the formulation of the well-known Goodenough–Kanamori Rules. Finally, the most important thing to say about John is that he was a thoroughly decent and kind man." ■

Professor Sir Brian Smith

The Department of Chemistry was saddened to hear the news of Professor Sir Brian Smith's passing in May this year. He was 89. Emeritus Professor Keith McLauchlan looks back at Sir Brian's life and career.

Brian graduated at Liverpool University and after his doctorate there went as a post-doctoral fellow to the University of California at Berkeley. He worked with Professor Joel Hildebrandt before returning to the UK where he joined the Physical Chemistry Laboratory, initially as a research fellow. In 1960 he was made a lecturer and a Fellow of St. Catherine's College.

Brian was an inspirational and popular tutor and taught the future Nobel Prize winner John Walker. He wrote the first of his books, Chemical Thermodynamics, which was widely used in Oxford and beyond.

His research was on intermolecular forces, unusually with an eye for applications in human biology. This led to an interest in the mechanism of general anesthesia, inert-gas narcosis and decompression sickness.

By adding a third component to the oxygen helium mix then in use he extended the depth at which deep sea divers could operate. Jacques Cousteau came to Oxford to consult him, and he also consulted with the U.S. Navy. His work also led to the introduction of safe general anesthetics, replacing the primitive ones still in use.

To everyone's surprise he then turned to administration, in which he seemed to have no prior interest but his natural charisma stood him in good stead and he became Chairman of the General Board, Master of St. Catherine's College and Vice Chancellor of Cardiff University in quick succession. In Wales he was a member of the Welsh Development Agency and the Higher Education Funding Council. Whilst VC at Cardiff he held the Welsh supernumerary fellowship at Jesus College, where he was a regular visitor. After retirement he continued to raise money internationally for the University.

Brian was a keen sportsman, including tennis, ski-ing, walking and climbing amongst his interests He went on the Oxford (and PCL-heavy) Himalayan Expedition. Even after retirement he chaired a number of Oxford clubs and committees.

Brian never lost his interest in physical chemistry and published two further books in retirement, *The Forces Between Molecules* (with Maurice Rigby, 2012) and *The Boltzmann Factor* (2016), which was particularly well reviewed.

Above all he was a greatly liked and appreciated colleague who maintained his sense of fun and adventure until the last. We all miss him. ■

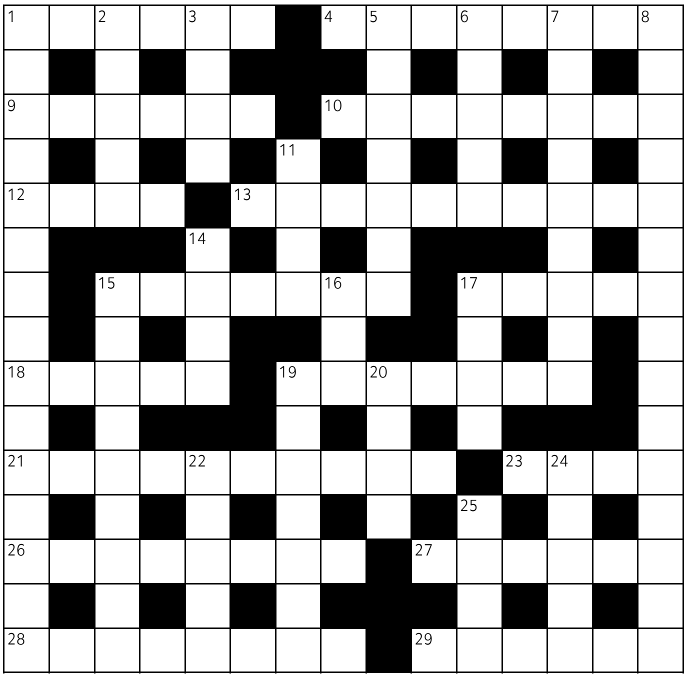
Chemistry puzzles

Across

1 #6 (6)
4 #1 (8)
9 Pleasure boat (6)
10 Greek hero (8)
12 Den (4)
13 Artist famed for chiaroscuro (10)
15 Refugee (7)
17 Portion (5)
18 Boat (5)
19 Horse commonly associated with car (7)
21 Most populous US state (10)
23 Palindromic 1970s band (4)
26 Frozen colloidal emulsion (3,5)
27 Water soluble base (6)
28 #7 (8)
29 #8 (6)

Down

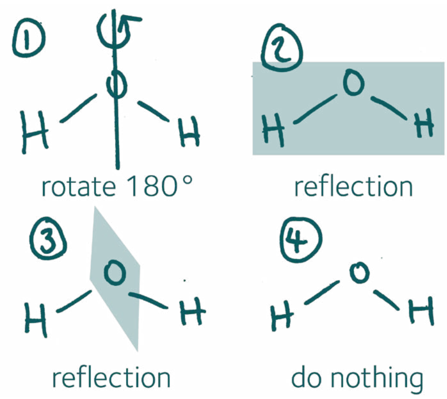
1 How liquids flow in narrow spaces (9,6)
2 Diameter halves (5)
3 Solely (4)
5 Distance measured in increments three feet (7)
6 Spanish wine region (5)
7 South China province (9)
8 Bringing private assets under public control (15)
11 Hearty meat sauce (4)
14 Not present or future (4)
15 Outstanding (9)
16 Second-tallest living bird (3)
17 Square space with buildings around edge (4)
19 Kent seaside town (7)
20 Intrinsic property of electrons, nuclei (4)
22 1996 film, 2014 TV series (5)
24 Surname of father and son Nobel laureates (5)
25 Effect passing through a surface (4)



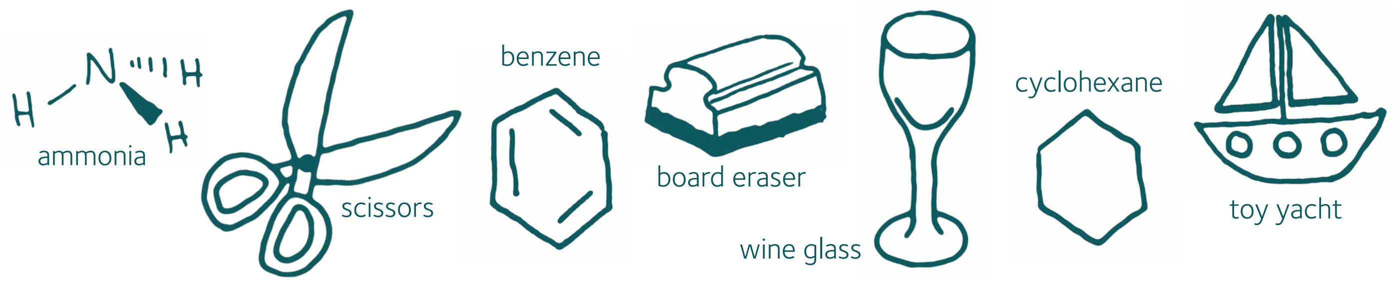
Symmetry challenge

Point groups are a shorthand way to describe all of the symmetry operations (rotations, reflections, inversions…) that can be performed on a molecule and result in an orientation indistinguishable from the starting one. Sound familiar from your student days?

Consider a water molecule (right): you can rotate it a half turn to swap the two hydrogen atoms and get the same picture back. This rotation is one of the *symmetry operations* in water's point group. You can also reflect the molecule, either in the plane of the three atoms or in a plane perpendicular to that, and get the same picture. These three operations together, plus the "do nothing" operation common to all point groups, make up the four symmetry operations in water's point group: C_{2v}.

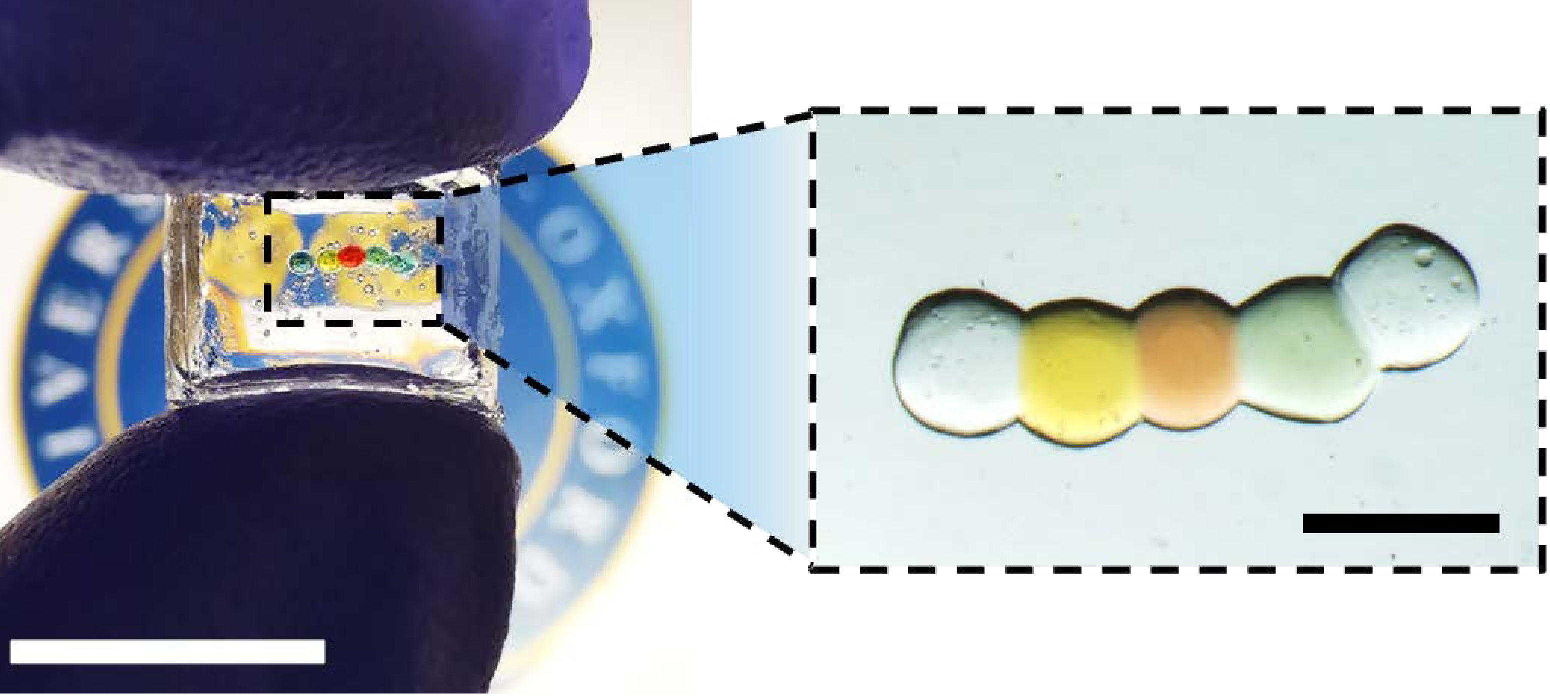


Can you identify which of the below have the same four symmetry operations as a water molecule, and no others, and therefore share the C_{2v} symmetry?



An extra challenge… For those objects above that don't belong to C_{2v} – to which point group *do* they belong? **symotter.org** has an excellent refresher on symmetry, if needed!

Answers to the puzzles are available by email: **chemistry-news@chem.ox.ac.uk**



Droplet batteries

A team based in the Department of Chemistry has developed a miniature battery that can regulate the biological activity of human neurons and power bio-integrated devices.

The researchers were inspired by the way that electric eels generate electricity, using internal ion gradients across the device. Their device, which is made up of droplets (pictured above in a stack of 28, and to the right in a smaller setup) is capable of altering the activity of cultured human nerve cells.

Dr Yujia Zhang, lead researcher on the study, said: "The miniaturized soft power source represents a breakthrough in bio-integrated devices. We have developed a miniature, biocompatible system for regulating cells and tissues on the microscale, which opens up a wide range of potential applications in biology and medicine."

Read more in *Nature*:

doi.org/10.1038/s41586-023-06295-y

Left: Enlarged version of the droplet power source, for visualisation. 500 nL volume droplets were encapsulated in a flexible and compressible organogel. Scale bar: 10 mm. Right: Zoom in view of an actual-sized droplet power source, made of 50 nL droplets. Scale bar: 500 µm.

Contact us

Periodic is published annually and distributed free to Chemistry alumni, researchers, staff, students and friends of the Department. We are always delighted to hear from readers, and if you have any pictures or stories you would be willing to share please do get in touch.

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DEPARTMENT OF CHEMISTRY

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