THIS JOURNAL IS PRODUCED WITH THE SUPPORT OF THE PARLIAMENTARY SCIENCE AND TECHNOLOGY INFORMATION FOUNDATION

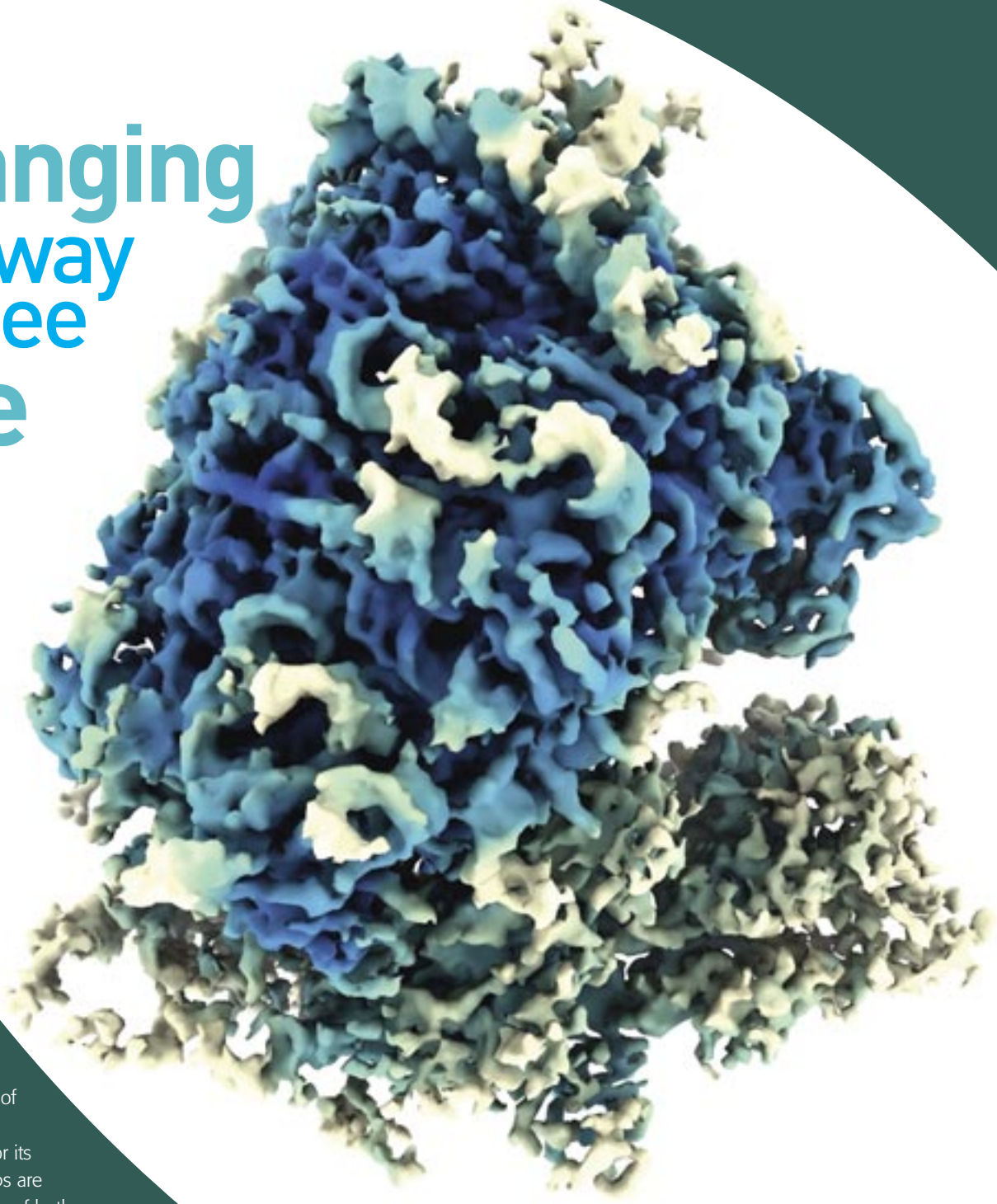
The Journal of the Parliamentary and Scientific Committee – All-Party Parliamentary Group

SCIENCE IN PARLIAMENT

sip

AUTUMN 2022

Changing the way we see life



The Rosalind Franklin Institute

Parliamentary and Scientific Committee

Bringing Science and Parliament together

Established 1939

Quantum Technologies

Described as a paradigm shift, quantum technology is the next big leap forward in humanity's technological prowess. This evening, we heard from four expert speakers on how this technology is likely to develop, and the government policies that are essential if the UK is to be a quantum science superpower. Prof. Ian Walmsley FRS, professor and Chair in Experimental Physics at Imperial College London, described the likely evolution of quantum technology over the coming years. Roger McKinlay, Director of the Quantum Technologies Challenge in the UK, spoke about what the UK has done so far to be leading on this technology, and what we need to do to keep this lead. Dr Ilana Wisby, CEO of Oxford Quantum Circuits (OQC), gave us insights into the pioneering work of OQC. Lastly, Dr Carmen Palacios-Berraquero, co-founder and CEO of Nu Quantum, spoke to us about what the government needs to allow companies like hers to continue their work. The Q&A session at the end centred around this central question of government help.

Quantum technology will be a game changer, and the key development from this area is quantum computing. Prof. Walmsley outlined the basic principles of this technology and how changing from a computer composed of classical bits to one composed of qubits results in a potentially far more powerful machine. Classical computers follow a roughly linear relationship between the numbers of bits available and the complexity of problems that can be solved. Whilst for a quantum computer, this relationship becomes roughly exponential, meaning far more complex problems can be solved with fewer bits.

OQC offer the first commercially available quantum computing platform with their QCaaS. Dr Wisby discussed how costumers can run algorithms using this platform and get an insight into quantum technology. The task for companies like OQC now, as Dr Wisby puts it, is to increase the number of qubits whilst keeping the error rate down. If achieved, companies will produce computers far superior to current supercomputers. It's expected that earlier quantum computers will emerge in 5 years, whilst fully fault tolerant machines will emerge in about 15 years, and so the next decade is crucial.

If the UK is to be a quantum superpower, the conditions for technological development need to be present. Mr McKinlay outlined how £1 billion has gone into the UKRI quantum technologies programme. The quantum strategy outlined by the government is up for renewal and is desperately needed for UK industry to keep its edge. In the US there has been around $2.1 billion of private investment in quantum. In the UK this figure is around $0.9 billion. The UK doesn't have a homegrown computer major like Google, and so other interventions will be needed if UK industry is to keep its edge. Dr Palacios-Berraquero also emphasised how we have been locked out of the EU quantum consortium, and both the US and China are investing more in quantum than the UK. Dr Palacios-Berraquero emphasised the need for a long-term UK quantum strategy to build confidence in investors, and how scaling-up funding is vital over the next decade to commercialise this technology.

The Q&A centred around the key question of what government can do to help this industry. All of our speakers agreed that a strong long-term quantum strategy that inspires is needed. Furthermore, efforts to increase interest and access for talent in the UK and abroad will be crucial in the coming decade as this industry tackles this great challenge.

Alfie Hoar
P&SC Discussion Meeting, 'Quantum Technologies'
4th July 2022

Stephen Metcalfe MP
Chairman, Parliamentary & Scientific Committee (All-Party Parliamentary Group)

A warm welcome to our Autumn 2022 edition.

It was with great sadness that members and the Council of the Parliamentary & Scientific Committee learnt of the passing of Her Majesty Queen Elizabeth II on the 8th September.

The seventy year reign of our longest-serving Monarch witnessed enormous changes in UK society and brought celebrated scientific advances.

We thank Her Majesty Queen Elizabeth II for her exemplary and devoted service to our country.

Our thoughts remain with His Majesty The King and the Royal Family at this time.

I was delighted to hear of the Prime Minister's appointment of Nusrat Ghani MP, as Minister for Science and Investment Security. We wish Nus well in her new and important role and look forward to working with her.

Looking ahead to our discussion programme, we plan to hold the majority of these events in Parliament with a few online during 2023.

I look forward to chairing two meetings in our Autumn programme: firstly, on Monday 31st October in partnership with the Institution of Mechanical Engineers, and on Monday 28th November, in cooperation with The Physiological Society. Both events will be held at the Palace of Westminster.

My thanks to Carol Monaghan MP for chairing the latest meeting of the Programme Committee to determine the discussion topics for 2023.

Our Administration and Programme Manager, David Youdan is arranging meetings for the first half of next year. Details will be sent to members and appear on the website shortly.

Preparations are well underway for the 26th annual STEM for BRITAIN which takes place on Monday 6th March. The application process for early-career researchers opened on 14th September. The closing date for submissions is Monday 28th November. I would ask all members to promote this showcase competition amongst colleagues and networks.

I am delighted that the British In Vitro Diagnostics Association will, for the first time, sponsor the Biosciences Gold prize and the Warwick Manufacturing Group, in a welcome return to STEM for BRITAIN, will sponsor the engineering awards. WMG will also become a member of P&SC.

I look forward to meeting you at our forthcoming events.

SCIENCE IN PARLIAMENT
sip

The Journal of the Parliamentary and Scientific Committee (All-Party Parliamentary Group).

Science in Parliament has two main objectives:

1. to inform the scientific and industrial communities of activities within Parliament of a scientific nature and of the progress of relevant legislation;
2. to keep Members of Parliament abreast of scientific affairs.

CONTENTS

The Journal of the Parliamentary and Scientific Committee (All-Party Parliamentary Group).

SEEING BIOLOGY IN CONTEXT

Dr Caitlin Higgott, Communications and Engagement Manager at the Rosalind Franklin Institute

Dr Harren Jhoti, President and CEO of Astex Pharmaceuticals UK

Dr Chun-wa Chung, Senior Director Structural and Biophysical Sciences, GlaxoSmithKline

Dr Maria M. Flocco, Vice President, Global Head of Mechanistic and Structural Biology at Astra Zeneca

Structural biology is a field which focusses on the shapes of the molecules which make life – from single proteins to complex and delicate complexes, to signals and communications flowing within and between our cells.

The field has been led by the UK since its earliest days. From the birth of X-ray crystallography – the technique which has underpinned some of the major 21st scientific breakthroughs across all disciplines, including building the world's first dedicated synchrotron light source at Daresbury, to the birth of cryo-electron microscopy – an arc bookended by Nobel Prizes for the Braggs in 1914 and for Richard Henderson and colleagues in 2017 – we have led the most adventurous developments in this field.

The emergence and development of cryo-electron microscopy led to what is commonly termed the 'resolution revolution' – providing researchers with new routes to observe structures in conditions ever closer to natural living cells. The technique has allowed us to view the building blocks of life to a greater level of detail than ever before and have made it possible to answer a whole array of complex biological questions.

However, as our knowledge of life has increased, new questions have emerged which we currently do not have the technology to answer.

A panel of experts was brought together by the Rosalind Franklin Institute to explore what industry needs from the field of structural biology, and to address how the UK can retain its intellectual and technological dominance in this fundamental field.

BIOLOGY IN CONTEXT

Seeing biology in context is overwhelmingly the most valuable long-term aspiration of industry. We have become adept at seeing individual proteins down to near atomic resolution, but our understanding of this protein is not complete until we can view it in its native environment, the cell.

This high-level goal has underneath it a variety of technological facets, with the key being interrogation of multiple information streams. Only such a holistic view will enable researchers to understand key drivers of disease – for example, how genetic features or expression levels translates to an atomic mechanism of disease and thus therapeutic action.

"Moving to a cellular context requires the ability to combine techniques and data sets on physiologically relevant samples. This is a development goal for the community. To provide true cellular context, structural biology will need to be tightly integrated with transcriptomics and proteomics. This will require spatially resolved mass spectrometry, which would also be a technological leap." Said Dr Maria M. Flocco, Global Head of Mechanistic and Structural Biology at Astra Zeneca.

In addition, combining this level of imaging detail with time domain, chemical, and structural data – would allow us to truly visualise complex processes, such as disordered proteins, high energy states, conformational equilibria and dynamics.

Moving to a true biological context will also enable the study of new and emerging modalities, such as RNA, vaccines and biologics, to be studied in detail on relevant samples. A recent example of this is the use cryo-ET and subtomogram averaging to examine differences in the shape of the spike protein in an activated and inactivated SARS-CoV-2 virus, which had implications for vaccine design (Liu et al., 2020).

The Franklin has led the UK effort in moving cryo-EM from a two dimensional to a three-dimensional, contextual view. To enable the UK to advance leadership in this field, we must continue investment in core technology, but also in labelling, complementary analysis

including mass spectrometry, and build pipelines to make this technology accessible to the widest possible group through training and dissemination. In time, this technology should move to a national user model, hosted appropriately.

LINKING STRUCTURAL BIOLOGY TO THE CLINIC

Linking structural insights to real patients with relevant cell models has the potential to be transformative in the clinic. This would enable a smooth link between histology to molecular mode of action, and from mode of action to target and modify disease, verified again by imaging.

Outside of the clinic, using tomographic insights to understand drug effects, particularly off target by examining effects on mitochondria and other key indicators of drug safety would make development more effective, and could transform phenotypic screening.

"The ability to utilise these enhanced imaging techniques could be transformational in the life science industry and allow us to understand the exact effects drugs are having on our cells. This will enable us to develop better drugs in a much shorter amount of time." Said Dr Harren Jhoti, President and CEO of Astex Pharmaceuticals UK.

Imaging techniques which are nascent require case studies and proof of concept work to allow industry to understand and make best use of emerging technologies.

HOW DO WE MAKE THESE DREAMS A REALITY?

There is need to develop chemical biology tools for structural biology, enabling the move to in situ analysis.

In addition to chemical tools, there is an urgent need for 'start to finish AI' – a set of tools which would automate more processes and enable industry to target human effort at the best problems.

"Not only do we need to harness the power of AI to analyse the copious amounts of data that we are now able to produce in a single experiment, but also for increasing the power of simulations to capture what experiments are worth performing. To implement this, we would need to leverage the exceptional power of predictive tools such as Alphafold and applying them in both simulated and real data sets, and pushing experimental structural biology into more challenging spaces is key to exploit AI in life science to its maximum potential." Said Dr Chun-wa Chung, Senior Director Structural and Biophysical Sciences, GlaxoSmithKline.

As automation increases leaving most challenging problems for scientists, we need to ensure that we are training enough skilled scientists to tackle these problems. The need for highly skilled researchers will therefore increase, not decrease.

HOW CAN THE ROSALIND FRANKLIN INSTITUTE HELP ACHIEVE THIS DREAM?

The Franklin, based in Harwell Oxfordshire, was established to create these disruptive technological discoveries. To do that we bring physical scientists together to answer key life problems.

We were not set-up to do drug discovery – the niche for the Franklin is in exemplifying what technology can do, and then passing the baton to industry or others. We currently have a number of tools which will move us towards the goal of seeing biology in context. As tools are now coming online, we will be partnering with researchers across the globe to produce compelling use cases and exemplars as we move into the next stages of development.

Also at the Franklin, we are training the next generation of early career researchers, through our PhD programme, early career researcher schemes and establishing researcher placements which will bring scientists to the Franklin from across the globe so they can learn about these cutting-edge techniques. Through these training routes, we aim to give many scientists the opportunity to develop the skills and leave a legacy to be proud of.

We know that the plethora of techniques we are developing will only be properly exploited by combining data sets in real time in an accessible way.

Reference

Chuang Liu, Luiza Mendonça, Yang Yang, Yuanzhu Gao, Chenguang Shen, Jiwei Liu, Tao Ni, Bin Ju, Congcong Liu, Xian Tang, Jinli Wei, Xiaomin Ma, Yanan Zhu, Weilong Liu, Shuman Xu, Yingxia Liu, Jing Yuan, Jing Wu, Zheng Liu, Zheng Zhang, Lei Liu, Peiyi Wang, Peijun Zhang, 2020. The Architecture of Inactivated SARS-CoV-2 with Postfusion Spikes Revealed by Cryo-EM and Cryo-ET, Structure, 28, 11, https://doi.org/10.1016/j.str.2020.10.001.

■

TRANSFORMING UK SCIENCE CAPABILITIES WILL REQUIRE SHORT TERM PAIN FOR LONG TERM GAIN

Richard Walker, Technical Director
Copyright of Diamond Light Source Ltd 2021

Isabelle Boscaro-Clarke, Head of Communications, Impact and Engagement at Diamond
Copyright of Diamond Light Source Ltd

For the past 15 years the UK's national synchrotron, Diamond Light Source, has been enabling and delivering world-changing science and innovation by leading academic and industrial groups in physical and life sciences from all over the world. To strengthen the UK's global scientific leadership and keep UK researchers and innovators at the forefront of discovery – as well as cementing its position as a world-leading research facility - Diamond is about to undergo a huge co-ordinated programme of development called Diamond-II.

This transformational upgrade will enable a huge expansion of UK science capabilities and its ability to contribute to global challenges. It involves combining state-of-the-art technology in a new machine, five new flagship beamlines and a comprehensive series of upgrades to Diamond's Instruments including optics, detectors, sample environments, sample delivery capabilities and computing. Following the commitment of £81.5 million funding from UKRI for the first phase of Diamond-II over the next 3 years, planning is already well underway in this major investment by UK Government and Wellcome.

"We are entering a new era of opportunity with the advent of fourth generation synchrotrons. Progress in accelerator technology means Diamond-II will offer the scientific community in academia and industry the opportunity to exploit much brighter light to peer into the structure of everything from vaccines to new engineering materials on all our beamlines and additional beamlines. Diamond-II will help inspire the next generation of STEM professionals and create new opportunities for researchers in universities, research institutes and industry, ultimately having a lasting impact on our society and the economy," comments Professor Richard Walker, Acting Senior Responsible Officer for Diamond-II and Technical Director at Diamond.

Diamond Light Source Aerial View - *Copyright of Diamond Light Source Ltd*

To match the extraordinary gains offered by the Diamond-II machine there will be a major renewal and upgrade of existing beamline technologies to meet the new scientific demands. Diamond-II will see enhancements in beam quality and beam stability through new X-ray optics and instrumentation, state-of-the-art sample delivery, and manipulation through the development of optimised sample environments and scientific software solutions that meet the beamline demands for the acquisition, visualisation and analysis of data. In particular, the huge gains in throughput for many experiments will necessitate a transformation in Diamond's ability to gather, manage and analyse the vast data volumes and data rates that will be generated.

The proposed Diamond-II new machine lattice will be based on Double Triple Bend Achromats (DTBAs). This means an increased brightness and coherence of a factor of up to 70 which will retain and enhance all beamlines while offering additional sources for five flagship beamlines, bringing the capacity up to 38 beamlines in total.

"Diamond's success owes a great debt of gratitude to the trust and commitment of its funding agencies the UK Research and Innovation's STFC (Science Technology and Facilities Council) and Wellcome who have provided ongoing support, are fully behind Diamond-II and have enabled its preliminary funding. This investment will set a course to strengthen the UK's global scientific leadership once delivered. However, we have to be prepared for the challenges of delivering the Programme in full with the substantial rise in inflation, challenging restrictions on salaries to recruit and retain staff as well as supply chain issues, in a difficult world situation and also in competition with other international facilities;" adds Professor Richard Walker

The upgrade is expected to take several years of planning, a dark period of 18 months during which there will be no synchrotron light for the user community, followed by a period to fully launch the five new flagship beamlines and a comprehensive series of other upgrades staggered over a number of years pre and post the dark period. This will bring a total of 38 instruments around the synchrotron ring as well as 11 electron microscopes to support the wide breadth of life and physical sciences delivered by the facility.

A SCIENTIFIC GRAND CHALLENGE

Diamond-II will offer users streamlined access to enhanced instruments for life and physical sciences. Professor Sir Dave Stuart, Life Sciences Director at Diamond and Joint Head of Structural Biology at University of Oxford, believes that Diamond-II will be a cauldron of life science research and development, integrating X-ray and electron scattering and imaging methods at all stages from sample preparation through to data analysis and interpretation. "The new machine will provide a dramatic improvement to the sensitivity and throughput of almost all life sciences beamlines allowing better delivery of existing methods, new methods and the possibility for additional beamlines to exploit the gains in brightness and coherence. These developments, alongside the continued developments in cryoelectron microscopy, where Diamond intends to retain a leading position, will enable not only more and better traditional science but also will drive the transformation from reductive in vitro science to integrative in situ, and ultimately in operando science that will transform our view of biology."

"This is a scientific grand challenge, and its tractability rests on the assumption that nano-scale structures form into hierarchical assemblies which dictate emergent biological phenomena. In practical terms our aim is to be able to drill down from a field of view of many microns to the atomic level and, finally work under physiological conditions to address not only the structure but also the dynamics of life," adds Professor Sir Dave Stuart.

The proposed programme will enable the new machine to not only accommodate both high-performance beamlines that are currently based on bending magnets but will also offer additional sites for up to five new beamlines, offering greater capacity and flexibility to accommodate new science drivers and communities well into the future. A further design feature is an increase in electron beam energy from 3.0 GeV to 3.5 GeV, driven by the new scientific opportunities provided by the consequential boost in brightness and coherence.

The machine upgrade will go hand-in-hand with developments of beamlines and supporting infrastructure to adapt to and exploit fully the potential of the new beam characteristics: in addition to repositioning beamlines, new optical components must be developed and/or installed to handle finer, brighter beams, and many detectors will have to be replaced to handle higher photon flux, much of which will be at higher energies. Brighter, finer beams will also demand sample delivery systems with higher throughput and more precise, stable positioning, higher flux at higher energy will require a wider range of operando sample environments, and there will also be a greater degree of integration with enhanced sample preparation facilities and complementary, often correlative measurements.

All this must progress in line with a greatly enhanced capacity for data storage and transfer as photon flux and detector rates go through step changes, together with greatly enhanced computation speeds to enable raw data to be visualised and processed on timescales that allow users to make informed decisions about experiments in near-real time, adding substantial value to the experiment. The transformation required for the speed of data analysis will require both improvements to

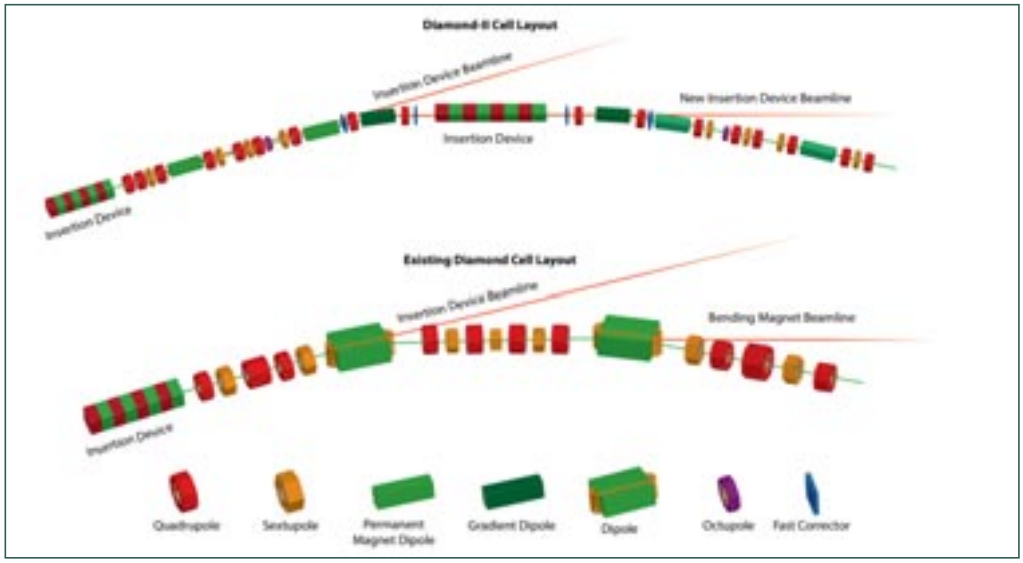


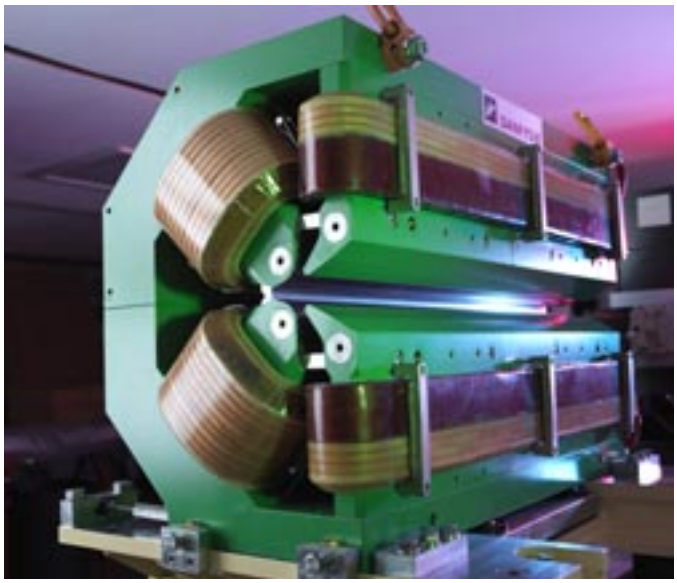
Diagram of the Proposed new Magnet Call Layout for Diamond-II – *Copyright of Diamond Light Source Ltd*

hardware and the development of more efficient data flows and algorithms, the latter increasingly exploiting AI methods to be developed in partnership with other facilities, institutes, university groups and industry.

To lead this programme, Diamond has appointed Rob Walden, a Chartered Engineer with over 20 years' experience in delivering business and process improvement programmes in the aerospace manufacturing engineering industry as well as several years as a senior projects advisor in central government. Rob explains more about the challenges around the upgrade to Diamond II in the current post pandemic economic climate:

SHORT TERM PAIN FOR LONG TERM GAIN

"The pandemic has affected everyone. In our case there was a general slowdown of the science with a focus on the delivery of critical time for the life sciences, so the main impact is felt in the level of outputs for the physical sciences. With regards to Diamond-II, we are working up the full business case for review by the Department for Business, Energy & Industrial Strategy (BEIS), UKRI and government in the coming months to clarify what the emerging timetable will exactly look like. The main challenge remains the control of inflation over the budget initially set.



Prototype Diamond-II Magnet - *Copyright of Diamond Light Source Ltd*

Full scale magnet model Diamond-II girder
Copyright of Diamond Light Source Ltd 2022

Planning and prototype work is underway with preliminary funding. Following the successful approval of the Full Business Case due to be submitted winter 2022/23, building works will begin in earnest with a dark period currently planned for 2026, depending on how quickly the full programme is confirmed by funding agencies.

"The timetable includes an 18-month period of shutdown, but we are working through the details and this period needs to be managed carefully with a mitigation plan in place for the scientific community as we appreciate, they will be deeply affected. But it is short-term pain for long-term gain.

LOOKING AFTER USERS

We are looking to create an interim plan for the user community as during our shut-down they may have to use other facilities. However, because of the high demand from Life Sciences we are proposing that we dedicate a facility called MX Bridge to ensure the demand is fully met. This is still under discussion, but we understand 'dark times' have to be managed in terms of engagement with the user community. Finally, we also want to maximise all the other instruments we have available at Diamond from electron microscopes to offline laboratories to make sure the science programme can continue where possible."

The Diamond-II programme is to transform Diamond and has six principal strategic objectives:

- Retain and build on a world-leading research facility and influence on the global stage through transformative technology;
- Provide a step change in ability to generate knowledge and ideas to solve 21st century challenges;
- Increase the capacity to serve a growing, increasingly diverse science community;
- Improve the efficiency and productivity of industrial partners, particularly in the health and energy sectors;
- Maximise the benefits of research institutes working together – both at the Harwell Campus and further across the UK as Diamond acts as a national and international hub for collaborative working;
- Inspire and develop the next generation of STEM professionals. ■

AN EYE ON COMMUNICATION

Heather Graz
University of Dundee, Division of Psychology and Department of Computing

MEET JOE

Joe (not his real name) is 50-something years old. He is a successful international sportsperson who represented his country for over a decade and now works as an adviser to businesses about disability-related issues. He is an employer and a taxpayer. Like many of us, he lives in his own house. In his own words, Joe describes his situation as: "I am the boss of my life".

Joe's challenges are similar to those experienced by people like Stephen Hawkins, Dodie Weir and Rob Burrow. He has a chronic, neurological condition that significantly restricts his ability to move easily with sufficient control to allow him to carry out everyday tasks independently. Joe has cerebral palsy (CP), a movement-based disability that manifests from early childhood rather than starting in adulthood. CP can affect movement by muscles throughout the body, including the head, neck, mouth and throat. This means that speech – by definition, a movement-based function – can be affected in people who have CP.

Joe's situation is that he has difficulty controlling the muscles of his mouth to produce speech and in moving independently. He employs a team of personal assistants to help with everyday activities that require controlled movement and uses communication devices to talk with other people.

CP is one of the conditions that can cause significant speech and physical impairments (SSPI). In the UK, an estimated 5% of the population have communication difficulties that substantially limit their independence and ability to direct their own lives (NHS England/ Specialised Commissioning, 2016). Almost 10% of the 4 million people in the USA who could benefit from using an alternative or augmentative communication system have SSPIs (Beukelman and Mirenda, 2013). Communication devices, strategies and approaches are often used to supplement and/ or replace speech in the presence of such SSPI-related communication difficulties. These are referred to as augmentative and alternative communication (AAC) devices, strategies and approaches, respectively when they add to or replace speech as a vehicle for communication.

SUPPLEMENTING OR REPLACING SPEECH

There is a plethora of aided (i.e. those that require tools or equipment in addition to the AAC user's body) and unaided (i.e. those such as Sign Language that only require the user to use their body) AAC devices, strategies and approaches (Sigafoos and Drasgow, 2001). These can be high-tech (e.g. electronic voice output communication devices) or low-tech (e.g. symbol sets on a communication board) by nature. AAC users will often use a combination of devices and strategies, depending on the situation that they find themselves in and/ or the resources that are available to them.

STATUS QUO OF AAC

As with many therapies and educational interventions, AAC has elements of both science and art. This offers flexibility to cater for individual differences across users but opens the discipline up to criticisms of having a weak and insufficiently scientific evidence base to diagnose, treat and monitor interventions. In everyday practice, it also remains the case that AAC devices and strategies are frequently dependent on availability of and or access to limited and thinly spread expertise.

These factors unfortunately translate into a poor match between available and/ or accessible technologies and individuals' preferences, interests, skill levels and available support. This impacts on attempts to demonstrate credibility of AAC interventions. If they are measured at all, outcomes of these interventions often show little or no benefit to the individual or those who support them.

This is a complex and deceptively nuanced situation with multiple factors contributing to the benefit from AAC use or lack thereof. Poor awareness of how to interact with individuals

Figure 1a High-tech aided communication device
Credit: www.thinksmartbox.com

Figure 1b Low-tech aided communication device
Credit: cornwall.gov.uk

using their AAC device, reluctance to change established processes and practices to accommodate AAC use, difficult-to-use or unhelpful AAC devices for a given individual, poor carer support and knowledge about the AAC device and limited economic resource to access the necessary AAC service provision can all compromise benefit from AAC devices and strategies.

This is where smart use of data science in combination with technology advances hold a lot of promise. The question is not if there is a role for data science and technology in the evolution of AAC effectiveness and provision but rather how data science and technology can be used to improve how AAC devices are chosen, implemented with individuals and their impacts monitored.

BRINGING THE SCIENCE AND ART OF AAC CLOSER TOGETHER

Data science and technology are increasingly offering opportunities to close the gap between science and art in AAC. The capacity of AI, machine learning and Big Data to recognise and extract patterns from large volumes of spectral data is, for example, being translated into databases of voice samples in voice bank applications that allow more personalised voices to be synthesised for people who use electronic voice output communication devices. This offers a wider range of voice choice for AAC users who are unable to use their own voice for communication. Companies such as Google (https://sites.research.google/euphonia/about/) are actively working in this field.

Efforts being made to create tools that allow actionable insights to be extracted from data in the absence of expert statistical and domain knowledge (Shang, et al, 2019) are increasing the range of data science and make it more broadly available as a vehicle for identifying patterns and conveying complex and complicated relationships between variables. Quantification and visualisation of these relationships by academic organisations (e.g. MIT) and commercial entities such as Einblick (https://www.einblick.ai/) and Tableau (https://www.tableau.com/tableau-login-hub) creates opportunity for practitioners to contribute to in-house streamlining of AAC systems.

The power of volume-based AI-driven prediction conceivably also holds potential for generating novel paradigms for conducting small-scale, personalised studies over the longer term. This would allow for personalised insights to be drawn credibly and used for the benefit of individual AAC users. Small-scale studies are currently frowned upon as being statistically weak.

Universal design principles in mainstream applications (e.g. Accessibility settings on mobile phones) are increasing access for all users irrespective of the presence of physical or sensory disabilities. In a similar vein, open-source programming is broadening AAC accessibility at community levels (Microsoft Open Source Jacdac project).

Tracking of eye gaze is a particular area where science and art can converge through use of data science and technology advances.

THE EVOLVING SCIENCE OF EYE GAZE

Studies tracking eye gaze have been reported for over a century. Video-based eye tracking combines an infrared-sensitive camera, an infrared light source and an algorithm to detect the centre of eye pupils (Mento, 2020). Most current video-based eye tracking systems utilise dark pupil technology and, on occasion, corneal reflection technology. Recent advances in this technology have resulted in significant improvements in eye tracking reliability in the presence of direct sunlight, spectacles being worn and speed with which eye position can be recaptured by the camera once it has been lost. For practical purposes these advances mean that eye gaze devices can be used more confidently for AAC with individuals who have SSPI both indoors and outdoors and when spectacles have to be worn. Pale blue eyes and the presence of certain muscle relaxant medications limit the reliability with which this technology can be used with certain AAC users.

Recent advances in eye tracking functionality now exists for PC, iOS, Android and iPad devices and access across operating systems and devices is a significant step forward for AAC users.

LOOKING TO THE FUTURE

In the short-to-medium term, AI- and machine learning-powered algorithms look set to continue advancing both the structure and the content of the

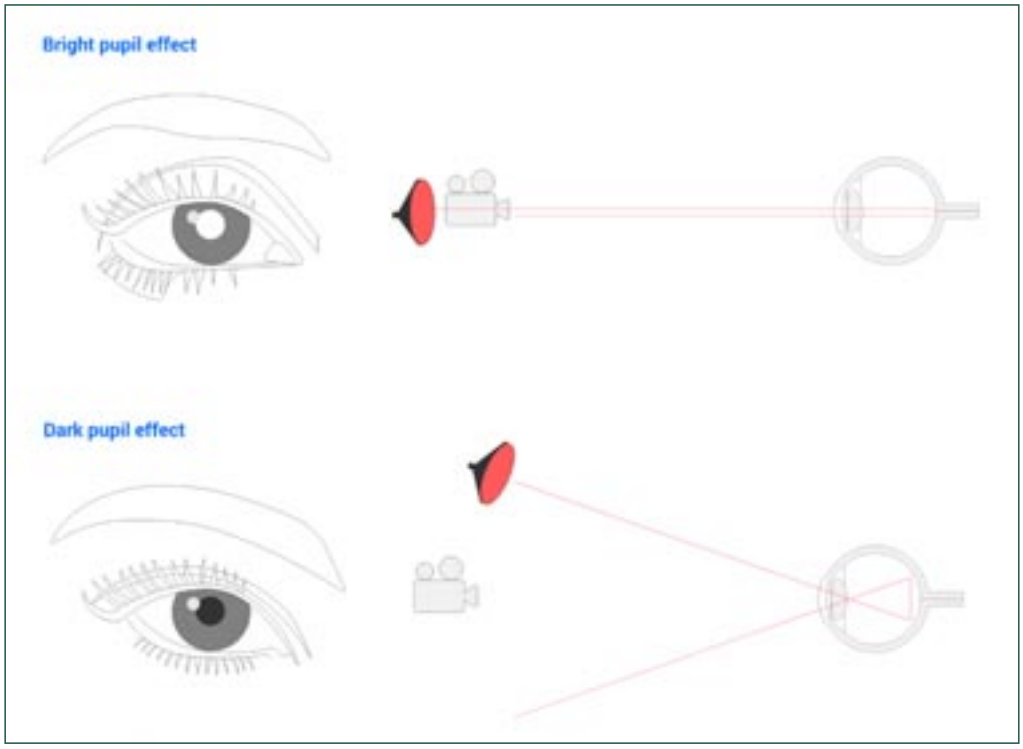


Figure 2 The physics of dark pupil eye tracking technology
Credit: Tobii Pro, cited on https://www.bitbrain.com/blog/eye-tracking-technology

AAC systems with text-to-speech and speech-to-text applications as well as empowering users with a voice in voice banking databases. Care will, however, need to be taken that the rapid expansion of technology does not disadvantage those who cannot access it but who would otherwise be ideal candidates to use it (e.g. those with SSPI whose speech is not clear enough for algorithms to recognise and transcribe it).

The democratisation of data science is an invaluable opportunity to both take advantage of and contribute to making speech output a reality for more people with SSPI. Joe sums it up: "I'll help with research. Maybe it doesn't help me but it will help those who come later".

References

Beukelman, D. and Mirenda, P. (2013) Augmentative and alternative Communication: *Supporting children and adults with complex communication needs.* Baltimore, MD: Paul H. Brookes Publishing.

Mento, A.M. (May 5, 2020) "This is how eye tracking technology works", Bitbrain, https://www.bitbrain.com/blog/eye-tracking-technology. Accessed 18 September 2022

Microsoft Open Source Jacdac project, https://microsoft.github.io/jacdac-docs/. Accessed 21 September 2022.

NHS England/ Specialised Commissioning (2016) *Guidance for commissioning AAC services and equipment*. Available at https://www.england.nhs.uk/commissioning/wp-content/uploads/sites/12/2016/03/guid-comms-aac.pdf (Accessed 16 November 2021).

Shang, Z., Zgraggen, E., Buratti, B., Kossmann, F., Eichmann, P., Chung, Y., Binnig, C., Upfal, E. and Kraska, T. (2019) "Democratizing data science through interactive curation of ML pipelines", SIGMOD '19: Proceedings of the Interbnational Conference on Management of Data, June 2019, pp. 1171 – 1188, https://dl.acm.org/doi/10.1145/3299869.3319863

Sigafoos, J. and Drasgow, E. (2001) "Conditional use of aided and unaided AAC: A review and clinical case demonstration", Focus on Autism and other developmental Disabilities, 16(3), pp. 152 – 161.

THE IMPORTANCE OF PHYSIOLOGY EDUCATION IN MAINTAINING A HEALTHY SOCIETY

Dr Helen Wallace
University of Liverpool

WHAT IS PHYSIOLOGY AND WHY IS IT IMPORTANT?

Physiology is the science of how our body functions. Understanding fundamental physiological principles is paramount to diagnosing and unravelling the causes of abnormal function and disease. This knowledge can then be used to develop successful treatments and preventative interventions with the goal of improving human health and maintaining a healthy society. Knowledge of physiology provides the foundation for research into unknown areas such as the impact of climate change on complex bodily processes. There are several unanswered questions, including what are the physiological responses to extreme heat and the implications on vulnerable groups such as pregnant women? People with respiratory conditions are more vulnerable to air pollution and changes in air quality, and more research is needed to determine how air pollution affects physiology processes such as cardiovascular function. As climate change continues to accelerate, understanding the impact on our health is paramount to both mitigating and adapting to our environment.

A report detailing the contribution of physiology education and training to the UK economy was launched in parliament on 7th June this year. The report detailed analysis carried out by independent economy agency Emsi Burning Glass for The Physiological Society and Academy for Healthcare Sciences, which found that physiology graduates contribute £22.6 billion to the UK economy every year [1]. This encompassed added income and jobs supported by physiological science related courses delivered by higher education. Examples of graduate careers from programmes with a physiology element, include healthcare professionals and frontline workers, researchers, and physiologists working in schools, hospitals, sports settings and universities. The report not only highlighted the value of physiology education to the economy, but society as a whole including social savings across healthcare, unemployment benefits and crime reduction.

TECHNOLOGY ENHANCED LEARNING APPROACHES TO PHYSIOLOGY EDUCATION

The inevitable impact of climate change on human health and the recent coronavirus (COVID-19) pandemic, highlight the importance of understanding complex physiological processes at the core of physiology education. Physiology is a core component of several university courses including medicine and medicine related programmes and science based biomedical and physiological sciences. The

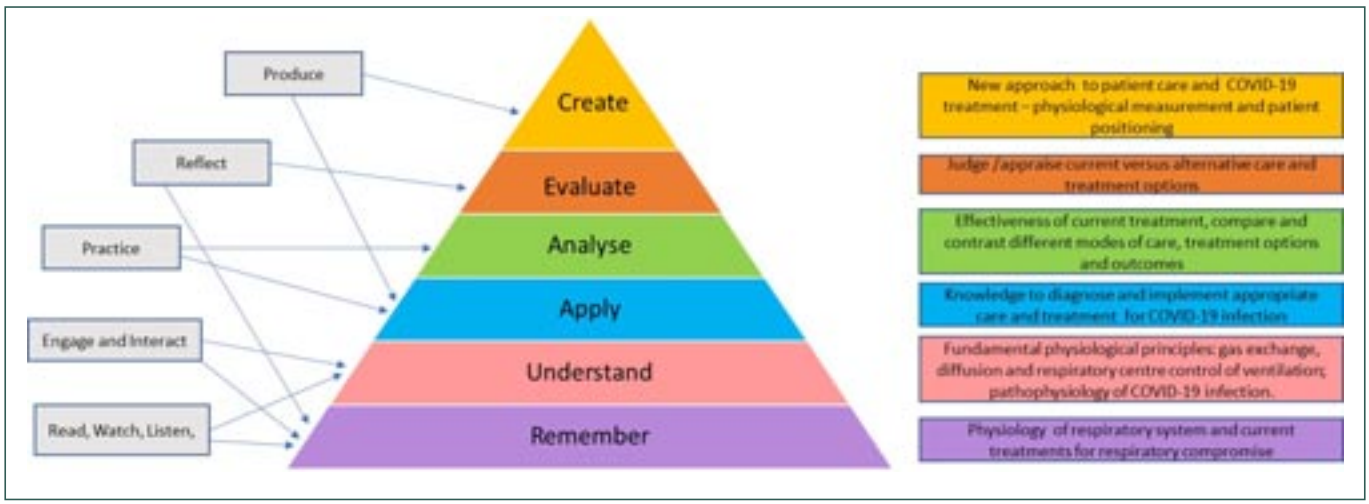


Figure 1: Revised Bloom's Taxonomy of learning objectives, showing examples of how these objectives can be achieved and a practical example of COVID-19 treatment.

aim of a physiology lecturer in higher education, is to explain often complex and intricate mechanisms in simple terms bringing together theoretical and practical elements, and interactions from the molecular and cellular level through to organs and systems in the body. Variations in Bloom's taxonomy[2] (Figure 1) form the framework for achieving learning to a higher level, so the learner will be able to make judgements, or create something new from acquired knowledge. This may encompass a new idea or a solution to a problem for example. Traditional large group lecturing presents challenges when teaching complex physiological processes and application to clinical scenarios. An example includes understanding and interpreting blood gas levels and identifying different clinical presentations and their causes such as respiratory acidosis. Students often struggle to grasp certain concepts which have been repeatedly reflected in assessment performance and student evaluations. Moreover,

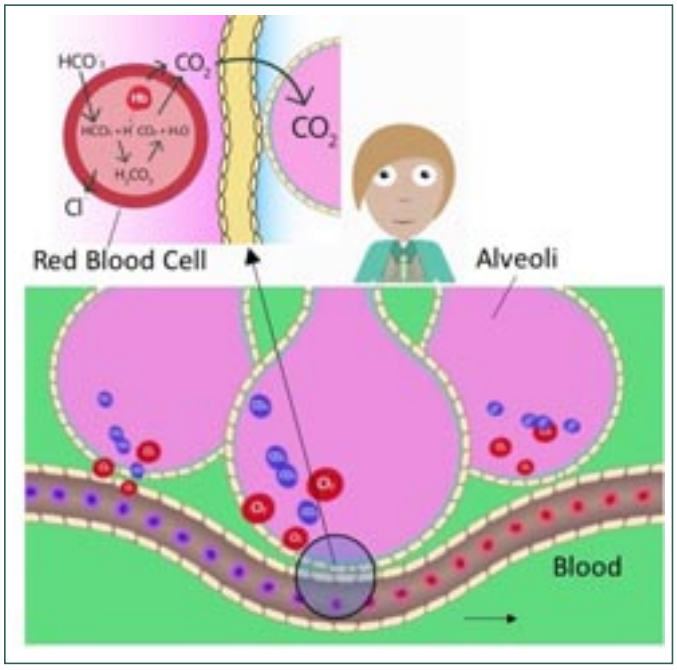


Figure 2: Example taken from a Tough Topics animation showing gas exchange at the lungs

the problem-based learning approach used by many medical schools may also have led to gaps in fundamental physiological knowledge.

More successful approaches developed at the University of Liverpool (UoL) and elsewhere, include the use of online digital resources to accompany traditional didactic teaching. Such approaches provide more directed and focused on-line learning material to facilitate learning of challenging concepts, using different learning approaches such as acquisition, investigation and practice[3]. They utilise technology by developing animations and visualisations with user interactive elements in short modules to facilitate understanding. Physiologists and clinicians at UoL have developed a series of resources using these approaches called 'Tough Topics in Physiology Made Easy' concentrating on explaining complex physiological concepts in simple terms (Figure 2). Increasingly, student evaluations provide evidence of enhanced student satisfaction with such teaching processes leading to a positive impact on understanding and assessment performance. During the recent pandemic where face to face teaching was abruptly halted, such alternative educational approaches became increasingly important. The accessibility of such resources also offers advantages to students on placements; for example, medical students training in a hospital setting are able to access resources on their mobile phones to quickly remind them of key physiology principles. Versatility across sectors has also been demonstrated, with elements of the Tough Topics series being made available to secondary schools. The resources can support A level students playing catch-up due to COVID disruption in their education and support students' preparation for physiology related university courses. Such collaborations should be encouraged to help bridge the gap between secondary school and university education. Other applications include top up education in the workplace such as healthcare settings as described below.

HOW PHYSIOLOGY WAS FUNDAMENTAL TO OVERCOMING THE CHALLENGES OF THE COVID PANDEMIC

In cases requiring hospitalisation, the

pathophysiology associated with the body's response to COVID-19 infection includes severe respiratory compromise. This encompasses effects on lung mechanics and oxygen and carbon dioxide exchange between the body and the atmosphere. At its peak, the scale of the pandemic required recruitment of healthcare professionals outside the area of respiratory expertise. It quickly became apparent that urgent training was required in not only the practical skills such as oxygen administration, but knowledge of physiology and understanding the pathophysiology that occurs as a result of COVID-19 infection required for important clinical decision making. As the pandemic took hold, one of the unusual features of COVID-19 was later referred to by clinicians as 'silent hypoxia'[4]. Unlike other acute respiratory diseases, oxygen levels can fall dangerously low without initially causing any respiratory distress. Patients were reported to have levels almost incompatible with life, but were seemingly in little discomfort and browsing their mobile phones. By the time symptoms manifest, patients will have become in need of urgent intervention. One of the pathophysiological mechanisms to explain this phenomenon includes a reduced response of the respiratory centres in the brain to changes in blood gas levels. Altered central and peripheral chemoreceptor responses may occur as a result of COVID-19 interaction with the ACE2 (angiotensin-converting enzyme 2) receptor disrupting signalling to the respiratory centre and ultimately dampening the respiratory response. Recognition of 'silent hypoxia' has emphasised the need for physiological measurement rather than observation alone, together with monitoring to inform decisions on treatment. Another example demonstrates how knowledge of the physiology of lung mechanics and gas exchange led to the use of the proning technique (patients lying on their stomach) which improves ventilation of patients in intensive care (Figure 1).

One of the ways to ensure healthcare professionals are equipped to deal with the above challenges, is to provide easily accessible, interactive educational resources such as the digital approaches described above, explaining physiological concepts in simple terms. Such educational material can be provided by collaborations between Universities and local hospitals as demonstrated by the production of a respiratory toolkit in collaboration with physiologists at UoL during the pandemic[5]. Healthcare professional users of the toolkit, showed appreciation for the flexible accessibility of the learning tool and reported having a clearer understanding of the physiology behind respiration.

CONTRIBUTIONS TO WORLDWIDE PHYSIOLOGY EDUCATION

Collaborations can be extended to worldwide initiatives to ensure physiology education and its benefits can be accessible globally. The continuous text book of women's medicine launched by the International Federation of Gynaecology and Obstetrics (FIGO)[6] is an example of world-wide collaboration of physiologists and clinicians. The purpose of the text book is to enhance the knowledge and skills of students and doctors in caring for women worldwide and includes contributions from over 500 international experts including physiologists from UoL. This is a major initiative, which has never been previously attempted to raise the standard of women's health globally through more effective continuous education of medical professionals. The text book features global assessment and study certification, including continuous professional development awards. The series is also freely available online, and a memory stick distribution initiative has provided access across the world to local hospitals in areas with no internet access.

In conclusion, knowledge of physiology plays an integral part in maintaining a healthy society. It is therefore essential to continue to provide courses in higher education with core physiology components. There is growing popularity of more general biomedical and biosciences undergraduate programmes, with fewer students opting to take the more traditional and focused physiology courses. In medicine programmes, physiology has to compete with an already packed curriculum, it is essential therefore to ensure that physiology remains a core element of these programmes. Without this knowledge, we are in danger of being ill equipped to face the challenges the next pandemic will bring and other inevitable medical challenges we face. It is imperative that as physiology educators we continue to develop innovative ways to support acquisition of physiology knowledge and continue to raise the profile of physiology within medical and biomedical sciences curricula.

References

1. The Physiological Society and Academy for Healthcare Science (2022). Contribution of physiology education and training to the UK economy. Download from https://www.physoc.org/policy/higher-education/physiology-education/
2. Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. New York: Longman. ISBN-10: 080131903X ISBN-13: 978-0801319037
3. Laurillard, D. (2012). Teaching as a Design Science: Building Pedagogical Patterns for Learning and Technology. London: Routledge.
4. Tobin, M. J., Laghi, F., and Jubran, A. (2020). Why COVID-19 Silent Hypoxemia Is Baffling to Physicians. Am. J. Respir. Crit. Care Med. 202, 356–360. doi: 10.1164/rccm.202006-2157cp
5. Wallace, H., and Angus, R. (2021). Supplemental Learning in Respiratory Physiology for Healthcare Professionals Towards Successful Treatment of COVID-19 Frontiers in Physiology Front Physiol. 2021 Apr 20;12:624528. doi: 10.3389/fphys.2021.624528.
6. The Global Library of Women's Medicine. https://www.glowm.com/about-CPD ■

GO CLEAN, GO FAST: NEW RESEARCH SHOWS CLEAR ECONOMICAL CASE FOR REACHING NET-ZERO AS SOON AS POSSIBLE

Dr Rupert Way

Professor Doyne Farmer
Credit: Carlotta Cardana

Author Dr Caroline Wood is a Communications Manager for Research and Innovation at Oxford University.

Latest research led by Oxford University debunks the popular idea that going green will be expensive and hinder economic growth; instead, decarbonising the global energy system by 2050 will likely save trillions.

Achieving net-zero global greenhouse gas emissions by 2050 is thought to be essential in order to limit global warming to 1.5°C above pre-industrial levels. Above 1.5°C, we risk breaching climatic tipping points such as the melting of arctic permafrost (which would release millennia of stored greenhouse gases) and causing catastrophic climate instability – with more frequent droughts and fires, greater food insecurity, and mass migration driven by rising sea levels.

To date, however, fears that a net-zero transition would be costly and harm economies have held back progress. Yet new research [1] led by Oxford University actually indicates the reverse: an ambitious, decisive transition to green energy technologies such as solar, wind, and batteries, is expected to save the world at least $12 trillion compared to continuing our current levels of fossil fuel use, while providing more energy to the global economy, and expanding energy access to more people around the world.

Lead author of the study Dr Rupert Way, a postdoctoral researcher at Oxford University's Smith School of Enterprise and the Environment, said, *'Past models predicting high costs for transitioning to zero carbon energy have deterred companies from investing, and made governments nervous about setting policies that will accelerate the energy transition and cut reliance on fossil fuels. But clean energy costs have fallen sharply over the last decade, much faster than those models expected.'*

Modelling energy transition costs in a new way, using a forecasting method that has been tested against historical data for 50 different technologies, Dr Way and colleagues have turned that narrative on its head. The probability of further cost reductions in key green energy technologies is now so high that a rapid clean energy transition is clearly the best bet for the economy as well as for the planet.

The rapid declines in the cost of clean energy technologies reflect increased experience gained in their design, manufacture, finance, installation, and maintenance. For example, average generation costs for solar PV have fallen by over 80% since 2010, with the International Energy Agency recently declaring it to be 'the cheapest source of electricity in history' for many regions [2]. In contrast, although the prices of oil, coal, and gas are extremely volatile (as demonstrated by the current inflation driven by

Russia's invasion of Ukraine), the long range trend is flat: after adjusting for inflation, prices now are close to what they were a century ago. The cost of nuclear electricity has also consistently increased over the last five decades, making it highly unlikely to be cost competitive with renewables in the future.

'*There is a pervasive misconception that switching to clean, green energy will be painful, costly, and mean sacrifices for us all – but that's just wrong*,' said Professor Doyne Farmer, who leads the team that conducted the study at the Institute for New Economic Thinking at the Oxford Martin School. '*Renewable costs are already cheaper than fossil fuels in many situations, and our research shows that they will become cheaper than fossil fuels across almost all applications in the years to come. And if we accelerate the transition, they will become cheaper faster, making this the best option not just for the climate but for energy costs too.*'

Up to now, however, this steep decline in the cost of renewables has not been reflected in standard energy models, which has deterred the investment and commitment needed by companies and governments to cut our reliance on fossil fuels. The research team analysed thousands of transition cost scenarios produced by major energy models including those used in the Fifth Assessment Report of the IPCC, and found that over 20 years all of these models vastly overestimated the future costs of key clean energy technologies versus reality. For instance, the real cost of solar energy dropped twice as fast as the most ambitious projections in these models.

In this latest study, the Oxford team used a different approach, developing a 'probabilistic model' to estimate the costs of possible future energy systems more accurately based on past data. Probabilistic models are used widely throughout industry and research to estimate the likelihood of future events. The betting industry, for example, uses probabilistic models to make forecasts that, while never perfect, on average get the odds right (enabling them to make £5.8 billion in UK profits in 2020 alone[3]). The analysis used 45 years of solar energy costs, 37 years of wind energy costs and 25 years for battery storage to generate probabilistic models for 'business-as-usual' and 'decisive transition to net-zero' scenarios. In the latter, fossil fuels are displaced from the energy sector within around 25 years, with all essential liquid and gas fuel use replaced by "green" hydrogen-based fuels, and most energy provided by solar and wind. Transport and heat are mostly electrified, and reliable electricity is maintained by using grid-scale batteries, chemical-based energy storage technologies (green fuels), and by boosting power grid capacity. Useful energy also grows at 2% per year, a rate much higher than in other decarbonisation scenarios.

The result from the modelling analysis was clear: a decisive global transition to net-zero could be trillions of dollars less expensive to engineer than continuing with the current system based on fossil fuels. This is even without factoring in the illnesses and deaths caused by fossil-fuel pollution, or the constant, long-term economic costs that would result from damaging hurricanes, floods, droughts, and wildfires brought on by higher levels of global warming.

Furthermore, unlike most other ambitious scenarios, this decisive transition does not rely on emerging technologies, such as carbon capture and storage (CCS) and Bioenergy with CCS (BECCS). This raises questions about whether investment should continue to be channelled towards these, particularly as it is unclear how they could be integrated with proven renewable technologies.

Dr Way said: '*Past models have overestimated key green technology costs again and again, leaving modellers to play catch-up as real world costs plunged over the last decade. Only a few years ago, net-zero by 2050 was believed to be so expensive that it was barely considered credible, yet now even the most pessimistic models concede that it's entirely within reach. Our research goes further and shows that scaling up key green technologies is likely to drive their costs down so far that overall they generate net cost savings, and the faster we go, the more we will save.*'

Professor Farmer added, '*The world is facing a simultaneous inflation crisis, national security crisis, and climate crisis, all caused by our dependence on high cost, insecure, polluting fossil fuels with volatile prices. This study shows that ambitious policies to dramatically accelerate the transition to a clean energy future as quickly as possible are not only urgently needed for climate reasons, but can save the world trillions in*

energy costs, giving us a cleaner, cheaper, more energy-secure future.' He suggests that, in the UK, such policies could include funding to support expanding and upgrading the electrical grid, feed-in tariffs or contracts-for-difference* for the production of green hydrogen-based fuels, land-use policies that encourage deployment of solar and wind energy, and halting construction of the Hinkley Point nuclear reactor.

The research is a collaboration between the Institute for New Economic Thinking at the Oxford Martin School, the Oxford Martin Programme on the Post-Carbon Transition and the Smith School of Enterprise & Environment at Oxford University, and SoDa Labs at Monash University.

*Contracts-for-difference (CfDs) are long-term contracts between electricity generators and the Low Carbon Contracts Company (LCCC). They are currently the main mechanism used by the UK Government to incentivise low carbon power generation, by enabling electricity generators to stabilise their revenues at a pre-agreed level (the Strike Price) for the duration of the contract. When the market price for electricity generated by a CfD Generator (the reference price) is below the Strike Price set out in the contract, payments are made by the LCCC to the CfD Generator to make up the difference. However, when the reference price is above the Strike Price, the CfD Generator pays the LCCC the difference.

References

1 Way R, Ives MC, Mealy P, Farmer JD, Empirically grounded technology forecasts and the energy transition, Joule (2022), doi: https://doi.org/10.1016/j.joule.2022.08.009.

2 IEA, 2020. World Energy Outlook 2020. Paris: IEA.

3 Statista, 2021. Gambling industry in the United Kingdom (UK) - statistics & facts. https://www.statista.com/topics/3400/gambling-industry-in-the-united-kingdom-uk/#dossierKeyfigures ■

QUANTUM TECHNOLOGIES: THE FUTURE FOR THE UK ECONOMY, SOCIETY AND SECURITY

Roger Mckinlay

A WAKE-UP CALL

On 4th May 2022 the Whitehouse issued National Security Memorandum/NSM 10, titled: "National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems". It sounds a mouthful, but it is a good piece of work. The memorandum identifies key actions in two areas. The first is to maintain the US national competitive advantage in quantum information systems; the second is to mitigate the risk quantum computers pose to the US cyber, economic, and national security.

The memorandum marks the start of a process to migrate vulnerable systems on to platforms protected by quantum-resistant cryptography. It also names the "evil": a *cryptanalytically relevant quantum computer (CRQC)* in the wrong hands.

QUANTUM IN THE UK

Although the UK has not made precisely the same statements, the thinking in the two countries is closely aligned. Countries aspire to be "quantum capable" both for their own benefits and to protect themselves from what other nations may have developed.

It would be overstating the case to say that one day we might talk of *Quantum States* in the same way we currently identify *Nuclear Weapon States* bit the profound capabilities of technology cannot be overstated.

THE UK NATIONAL QUANTUM TECHNOLOGIES PROGRAMME.

In the UK we believe that the risks – and the opportunities – lie not just in powerful computers but in a broader application of the technology.

The UK National Quantum Technologies Programme (NQTP) was launched in 2014 bringing together UK Research and Innovation (UKRI), BEIS, GCHQ, MOD and the National Physical Laboratory. This truly Cross-Whitehall programme started with the formation of four academic hubs: sensing (University of Birmingham), Imaging (University of Glasgow), Computing (University of Glasgow) and Communications (University of York). These hubs have grown many spokes and now form a network of over thirty universities and research organizations. By the time it reaches its tenth birthday, the NQTP will have transformed approximately £1B of public and private funding into a thriving industrial sector.

The model – now emulated by several other countries – has been successful for many reasons. Academics spend much of their time competing for

funding. A single, coordinated, national programme (Sir Peter Knight of Imperial College London was the visionary behind it) not only focuses the UK's efforts but also presents a formidable and united capability to the rest of the world. From the outset the goal of the programme has been the translation and commercialization of quantum technologies. This goal is being achieved.

With funding from the Industrial Strategy Challenge Fund (£173M since 2018), the Quantum Challenge (in UKRI) took these industry-facing activities to a higher level. The funding is now committed to 95 collaborative projects involving 128 companies and 38 Universities. This grant funding has proven to be highly catalytic, and the portfolio of companies funded has already raised more than the £200M. The figure at the end of the Quantum Challenge in 2025 is likely to exceed £500M.

ACCELERATING GROWTH

Both the Hubs and the ISCF programmes are accelerators. The Quantum Hubs have not only funded research but also companies, supporting the entrepreneurs translating research ideas into spinout and startup companies.

The Quantum Challenge has provided support from the other end, funding companies to work with universities. Individual companies benefit from the grant funding but we have found funding the "glue" of collaboration also has an impact. Not only are companies growing but supply chains are forming as well.

The intellectual property arising from the collaborations is shared; the team members have equal rights to exploitation. The government does not "own" anything at the end of the programme. The aim is not to take a stake in companies in order to recover the money invested but instead to unleash the many benefits arising from having created and grown a new sector.

NOT BRICKS AND MORTAR

A key tenet of the programme has been a wariness of spending money on bricks and mortar. Just as buying a new kitchen will not conjure up a group of exciting new friends to party with, an "innovation centre" will not instantly rally researchers or

ignite innovation. Instead, the focus has been on doing the work and letting the "task pull in the infrastructure". The NQTP has instigated two major facilities: the Quantum Metrology Institute at the National Physical Laboratories in Teddington, and the National Quantum Computing Centre under construction on the Harwell Campus.

FASTER THAN YOU WOULD THINK.

This mixture of science, collaboration, intellectual property, suppliers, customers, new applications and emerging markets is a volatile one, and success can come surprisingly quickly. One of the first projects funded by the Quantum Challenge has led to BT and Toshiba to create a quantum-key secured metro-network which was recently launched in London. EY is the lead customer.

Another example is the QLM gas sensor which offers a "true measurement of greenhouse gas emissions that is affordable, accurate and scalable". It is not just a slogan; you can buy one.

WHAT OTHERS THINK

In quantum technologies, other countries are seeing something we may have been slow to recognize in ourselves.

Our public spending to date places us around No 3 in the world. We do not muddle through on a shoestring budget and triumph against all odds. We have a coordinated national programme others envy. However, we need to continue as we started and fund the next phase.

We have outstanding science and scientists. We really do. It is not the next national delusion about to be washed away by a bout of realism. We no longer have an empire and we are not as good at cricket as we would like but we can do science and engineering.

We have an entrepreneurial culture. Nobody questions it. We are the envy of the world because our brightest scientist not only want to do science, but they also want to start companies. And they are good at it.

We are going to make quantum stuff, not just design it. We will do hardware as well as software. The UK already has strength in two key technologies related to quantum: cryogenics and photonics. We are not talking about more of the "silicon" and "digital" technology which we seem to take for granted has passed us by. We are in at the start of something which will become very big.

GAPS

There are gaps which will need working around. Firstly, there is no IT Major of Google size in the UK. We need to grow companies of sufficient stature to work with the incumbents and access global markets.

Secondly, we have no industrial giants such as Siemens. Quantum will bring opportunities to manufacture and fabricate complex new systems. We already have UK companies with ambitions – very realistic ones – and the government needs to be supportive. The "we do not do that sort of thing here" attitude still lurks in Westminster and Whitehall. We are not only supporting UK quantum companies but attracting global ones.

TALENT – THE CANARY IN THE CAGE

In summary, there is much the government can do. We must keep funding the science; help companies grow; encourage private investment including foreign direct Investment; and help create facilities and infrastructure.

How do we know if we are getting it right? The canary in the

cage is talent. If we are successfully creating, retaining and attracting talent, we must be doing a pretty good job at everything else.

The NQTP is very active in this field. We are creating demand by growing companies. We have been meeting that demand with centers for doctoral training, fellowships, apprenticeships and training schemes, and will continue to do so. This is not just about science skills but also about engineering, manufacturing and business skills too.

Put another way, we're not just looking for "Q" skills: Q for *quantum*. What we do need are "D" skills: D for *difficult*. Difficult microwave engineering, silicon fabrication, optics, photonics, cryogenics, analogue design, control systems, machine learning, architectures, systems, software, algorithms and – yes – quantum physics.

Of course, there is a 20-year pipeline to consider, as with any skills. However, from day to day we must simply keep what we have, grow what we need and steal the rest! We have to be ruthlessly competitive, not just clever. ■

ONE SMALL STEP: CAN WE MAKE A UK QUANTUM MOONSHOT?

Ian Walmsley, Provost, Imperial College London

It was a great pleasure to address the Parliamentary and Scientific Committee's meeting on quantum technologies earlier this year. I was delighted to be joined by Roger McKinlay of the UK Quantum Technologies Programme, and by Drs Carmen Palacios-Berraquero and Ilana Wisby, two business leaders from the UK's quantum technologies sector.

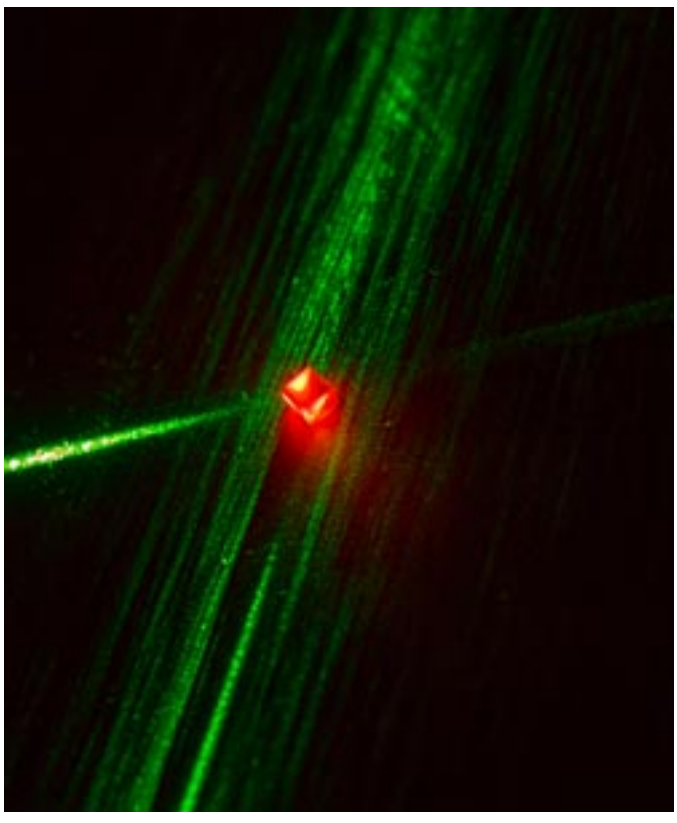
Together, we discussed the ways in which the UK had been an early adopter and a global leader in quantum science and the development of quantum technologies and services based on quantum science.

In the face of large investments and in quantum in the US, EU and China, it is essential that the UK retain our position as a key player in this emerging technology sector. We can only do this by ensuring we remain attractive place to undertake research and to start and scale a business.

THE STORY SO FAR

For those of you who were not able to join us and might not know much about quantum computing, here's what it means. Quantum physics – formulated in the early decades of the Twentieth Century to describe the behaviour of light and atoms - upturns the notions of classical physics by showing that individual identifiable particles are inadequate to describe the world.

What we have discovered over recent decades is that we can exploit these different rules to vastly increase the power of our

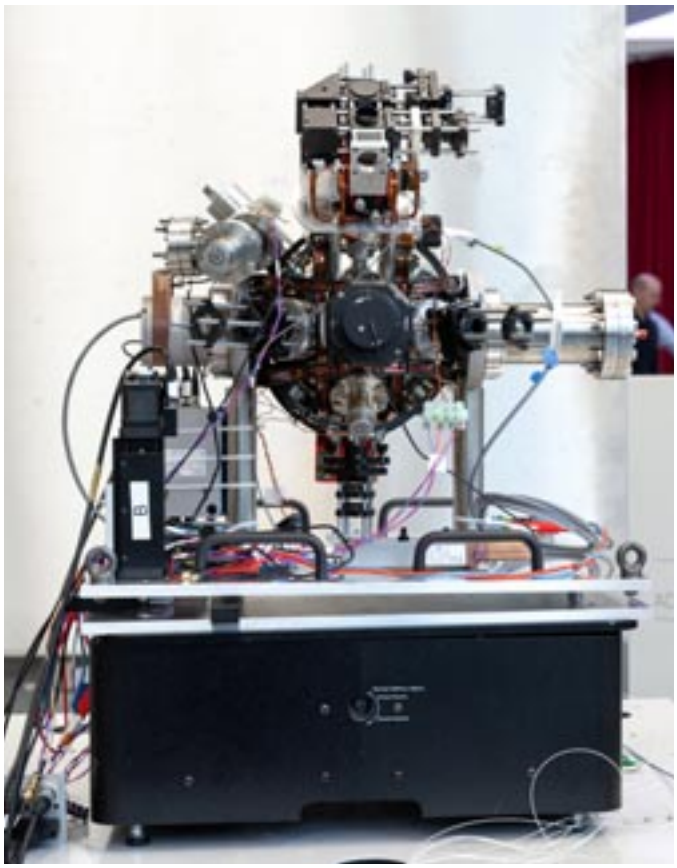


computers, to improve the precision of sensors and the security of communications, and the potential for impact in many other technologies.

A move from 'classical' computing to quantum computing opens up new areas of information processing, making it possible to solve problems that are insoluble for classical computers. It provides a platform for new classes of algorithms that pertain to the simulation and design of quantum structures, such as new molecules or materials, as well as to graph analysis, allowing us to solve important classes of equations and to code-breaking. These tasks are considered hard for classical computers since the time the take to find a solution scales rapidly with the size of the problem. For example, in the best case, doubling the size of computer input only requires doubling the size of the quantum computer, whereas it would require squaring the size of a classical computer. This represents huge increase processing power.

Developing our quantum computing capabilities will lead to huge advantages in areas of the economy that require advanced computing, such as data decryption, drug discovery, and logistics. Quantum sensors will be able to better detect certain underground resources, and to provide smaller and more precise brain and body images. New types of ultra-precise clocks will revolutionise what we know as 'Position, Navigation and Timing' (PNT), making our transport systems and military more efficient and more resilient. The advances that quantum tech will make possible in secure communications and payment systems will underpin improvements across the retail and service sectors, further enhancing the performance of many British businesses, from leading-edge research institutes, through complex multinational organisations and perhaps even all the way to the high street.

Quantum breakthroughs in these areas are already out of the laboratory and being translated into real products and services in both start-up and established companies, across industries from automobile and aircraft design to logistics and to major information technology providers.



A particularly important race is the global competition to develop the first quantum computers that can achieve a palpable computational advantage using quantum bits (qubits) as opposed to conventional bits. Already the first steps of this have been achieved in both industry and university laboratories, in several different physical platforms. Quantum processors have performed tasks that would either take many decades or even centuries for the best current supercomputers. While these are not yet useful machines, they do point the way to the opportunities opened up by quantum technologies.

The next critical step in our collective quantum journey is toward 'fault tolerance' – that is, the ability of a quantum device to continue operating despite the occurrence of minor imperfections and errors. This is the standard to which our everyday computers are built, and full fault-tolerance allowing scalability will be the defining feature of the world's first full quantum computer when it is first achieved.

THE UK QUANTUM 'MOONSHOT'

How can the UK stay competitive in this field? I'd suggest that a way to signal our ambition and commitment to reaping the benefits of quantum is to set ourselves a "moonshot" objective that capitalises on our existing scientific and technical leadership and inspires both the nation and the world as we push forward to achieve it. And I'd propose that moonshot **should be to develop a fully fault-tolerant quantum computer, and to achieve this in the next decade.**

Based on our existing expertise and industrial base, we have a viable roadmap to reach this technological milestone. We are not alone in this race, the scramble to develop and master quantum technologies is heating up across the world and the development of the world's first quantum computer will be a signal achievement for any country (or group of countries, such as the EU).

Whilst achieving this will be no mean feat, the UK has the scientific talent and industrial dynamism to achieve this goal and to be among the first to do so. We should aim to achieve the moonshot as a demonstration of our resolve to remain at the forefront of the quantum race, and then deploy the full range of our government, business and third sector efforts towards this singular breakthrough.

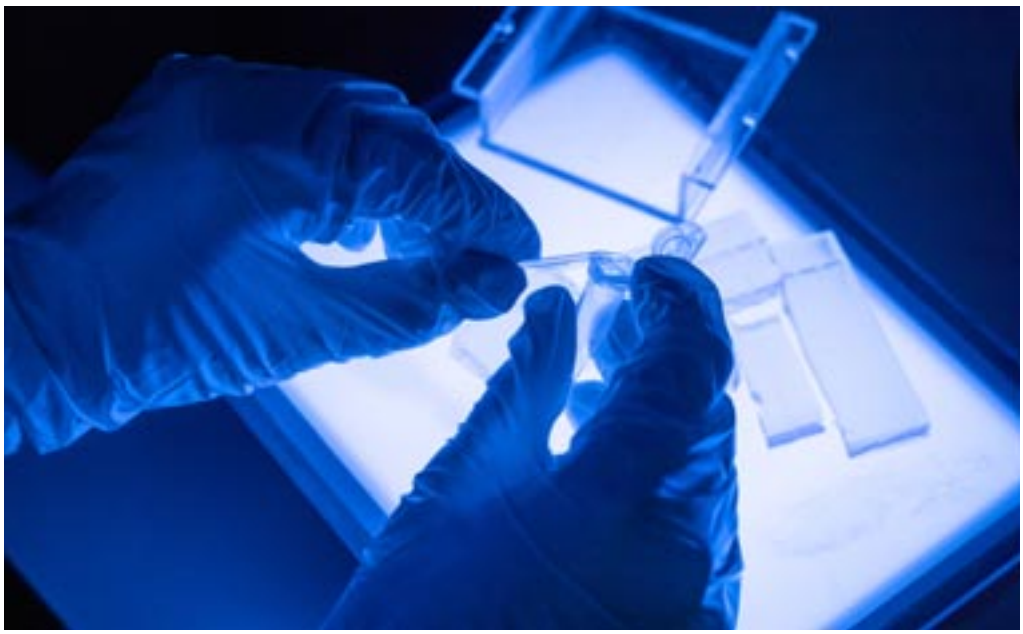
This moonshot could consist of:

- **Focus** – a UK Government, drawing on the UK National Quantum Technology Programme, setting out the goal, the timeline, and its importance, to be taken up

by Parliament, business, and the public and private sectors

- **Investment** – creating a specialist challenge fund for us to take the remaining steps towards viability, and the UK government underwriting investments to 'de-risk' commercial investments that contribute toward this national goal
- **Leadership** –empowering our existing national bodies, especially the National Centre for Quantum Computing, to focus on the goal and to identify the measures we need to take to achieve it
- **Industry collaboration** – listening to the innovators of today, asking British quantum businesses what they need to push ahead with their most ambitious plans without fear of failure and with confidence that the UK should be their home
- **Education** – delivering the skilled engineers and technicians needed to actually design and build quantum machines, as well as introducing children to quantum physics through our national challenge to create a quantum computer, an important first step towards building quantum awareness and transferrable skills into our future researchers and workforce

Government, Parliament, industry and civil society should come together over the next few months to create a full programme for the ways in which we can achieve our ambition. Higher Education Institutions like Imperial College London and groups of Parliamentarians such as the Parliamentary and Scientific Committee will be vital players in convening the wide and dynamic coalition that we will need to turn this exciting possibility into a firm reality.



As the UK Government develops its first national 'Quantum Strategy' and our world-leading National Quantum Technologies Programme moves into its third investment cycle, now is the perfect time for government and Parliament to use their extraordinary convening powers to build a fully national, inclusive and outcome-driven national moonshot programme in quantum computing.

OUR 'GIANT LEAP' AWAITS

The scale of our quantum ambition should be matched by the breadth of economic opportunities and security advantages that the development of a fully fault-tolerant quantum computing device will open for us when we achieve it.

While the rest of the world still thinks quantum computers are decades away, we can show the kind of visionary global and industrial leadership that made the UK the first great power of the industrial age.

Let us make the UK a beacon for talented and ambitious scientists, engineers, entrepreneurs and industrialists by a clear statement of our own national ambition to build the first truly quantum computer, right here.

My message to Government, Parliament, industry and wider society is that, when British science has the opportunity to lead the world again, we must be brave enough to take it. After all, the greatest breakthroughs in human history have all begun with 'one small step…'. ■

SPARKING INNOVATION THROUGH A CHALLENGE FUND APPROACH TO SOCIETAL PROBLEMS

Professor Rick Delbridge FAcSS FBAM FLSW, Professor of Organizational Analysis at Cardiff Business School and Co-convenor of the Centre for Innovation Policy Research, Cardiff University

INTRODUCTION

Science policy has increasingly made reference to the need for inter-disciplinarity in order to address complex or 'wicked' social problems. However, research practice has not always appeared to grasp the full implications of mobilising in a truly inter-disciplinary and cross-sectoral way when embracing calls for more ambitious 'mission approaches' to delivering impactful research and innovation. In this short article, I will introduce a series of coordinated steps that Cardiff University has taken to develop the capacity for inter-disciplinary work that addresses societal challenges. At the heart of this initiative is an understanding that to deliver on the possibilities of inter-disciplinarity requires the building of collaborative social relations of trust, mutual understanding and a sense of shared enterprise. For this reason, this decade-long initiative has incorporated the development of new bespoke physical space where researchers work alongside each other and in partnership with private, public and third sector organizations. The co-location of research centres and external partners is highly conducive to developing the social relations that underpin knowledge sharing and co-creation. Moreover, the development of an Innovation Campus in the heart of the city of Cardiff provides an anchor point for place-based innovation that is informed by, and in tune with, the needs of the city and the nation. Central to the initiative has been the creation of a social science research park.

THE SOCIAL SCIENCE PARK

Sbarc|spark opened its doors earlier this year and was developed over a lengthy period involving extensive consultation with innovation experts, particularly Nesta with whom the initial concept was developed,[1] other universities with experience of inter-disciplinary research and with the research centres for whom Spark would become home.

From the outset, these plans were centred on how best to realise the inter-disciplinary and grand challenge-focused science policy discourse noted above. The innovative nature of the initiative in itself makes clear the limitations to delivering on this agenda through variations on 'business-as-usual'. Both the initiative and building have drawn on evidence of how obstacles might be overcome. For example, a piece of work we consulted early in the development stage explored social labs as platforms for addressing complex social challenges. The findings identified three core characteristics of such ventures:[2]

1. *They are social* bringing together diverse participants drawn from different sectors of society.
2. *They are experimental*, taking an iterative approach to research challenges, prototyping interventions and evaluating various promising solutions.
3. *They are systemic*, seeking solutions that go beyond dealing with symptoms to address the root cause of why things are not working in the first place.

Some of my own research[3] on integrating and sustaining innovation had highlighted that particularistic and trust-based social relationships and a commitment to shared values are fundamental to collaborative innovative activity.

These insights shaped our thinking for both the physical space and the organizational model for Spark. The building is designed with collaboration and interaction at its heart. Research has reaffirmed the vital importance of the 'buzz' that face-to-face interaction provides in tackling particularly complex and ill-defined challenges where information is imperfect, rapidly changing and not readily codified. These are precisely the characteristics of some of society's more intractable problems. The pandemic has created unforeseen hurdles in this regard but the creation of an attractive space – with good coffee and catering from a local independent supplier – are helping to encourage people 'back to the workplace'.

Spark's oculus staircase *Credit: Will Scott*

The research ethos of Spark is informed by a social science sensibility and an emphasis on the civic and societal responsibilities of universities. These underscore the inter-linkages between economic and societal benefits, but also emphasize the wider cultural, environmental and public value of universities working with various partners. There are research centres in Spark working on health, social policy, security, the environment, the economy and so on, all mobilising inter-disciplinarity to address these issues.

A key aspect, one that is often overlooked or downplayed, is the initial framing of challenge-oriented research and innovation. Spark houses facilities that bring social scientists together with researchers from across the university and beyond to work jointly on defining, framing and then researching social problems. There are physical, medical and computer scientists, mathematicians and engineers who are members of these research centres. The facilities provide for the computational and technical requirements necessary to work securely with large datasets, the behavioural lab facilities needed to explore human behaviour, and also the visualization and multimedia facilities in order to engage, inform and educate audiences on the research and its implications. The building is also designed to engage local citizens with the ground floor, café and events space open to the public. Collaboration across disciplines and with citizens are key components of Spark and further collaboration with external partners from the private, public and third sectors

Spark café – the café is called Milk & Sugar *Credit Tim Corrigan*

is facilitated through co-location; Spark houses both research centre partners and some of the university's strategic external partners. One such partner is the Cardiff Capital Region (CCR), the city deal of 10 local authorities in south-east Wales[4], and a current project jointly developed and delivered with them gives an example of the work being undertaken in Spark.

THE CARDIFF CAPITAL REGION CHALLENGE FUND

The CCR Challenge Fund is a £10M, 3.5 year initiative that aims to build local wealth and stimulate economic growth

through challenge-driven innovation which tackles public service issues and addresses societal problems.[5] The fund has been established through a partnership between CCR and Cardiff University and has created a bespoke approach to the development of challenges that support innovation while also building a community of practice and the capability for innovation in the region. Each challenge is owned by a public or third sector organization operating in the region and the project is jointly developed to identify innovation opportunities that have the potential to produce novel solutions to societal problems. Our first challenge was focused on healthcare training and identified commercial opportunities for the use of simulation technologies. The challenge was led by Cardiff and Vale University Health Board and delivered in partnership with Welsh Government. It began as a rapid response to Covid-19 pandemic conditions. Its aim was to develop immersive simulation training solutions for NHS clinicians, benefiting from advances in virtual reality and associated technologies. Centring on tracheostomy training, the challenge used an approach derived from the Small Business Research Initiative to identify the most promising proposals and fund innovation activity in two firms. These two firms were supported to undertake prototyping and testing activity and have produced two potentially marketable solutions that are now being trialled in hospitals in Wales and England. Further challenges have been developed in partnership with the Innovate UK Knowledge Transfer Network. These four projects are all addressing challenges faced by local authorities as they seek to deliver on Net Zero targets.

Each of the challenges has involved collaboration which brings together a variety of organizations and sources of expertise to work on creating new ways to solve societal problems. The experiences to date have identified a number of difficulties in delivering on a challenge approach, particularly the lack of time and resources in the public sector to lead on challenge development while dealing with the 'day job', but have also supported the view that innovation can be achieved through mobilising around focused 'joint enterprises' or 'micro-missions' where individuals buy into the objectives and can see their role in delivering these.

In seeking to develop capability for such an approach in the region, the place-based convening role of the university has been important. Alongside partnering with challenge owners to develop and deliver specific challenges, the CCR and Cardiff University Challenge Fund team have developed a web-based portal and nurtured a community of practice which held its first face-to-face meeting in Spark in the summer. These are small positive steps toward creating the social relations that underpin knowledge sharing and co-creation.

The creation of knowledge is fundamentally a social process and Spark represents one example of how recognition of this can be incorporated into the design of research and innovation activity in order to deliver inter-disciplinary research to address societal challenges. What has been reinforced in Spark's first few months of operation is the enduring importance of face-to-face communication. While universities, and many other organizations besides, showed considerable agility in moving to virtual and hybrid arrangements during the pandemic, 'three-dimensional' and personal social interaction remains fundamentally significant to the creativity and knowledge co-creation that are at the heart of radical innovation.

VR simulation training solution being trialled

Image from the VR simulation for tracheostomy training

References

1 Price, A. and Delbridge, R. 2015. Social Science Parks: Society's New SuperLabs, Nesta: London. Available here: https://www.nesta.org.uk/report/social-science-parks-societys-new-super-labs/

2 Hassan, Z. 2014. The Social Labs Revolution. San Francisco: Berret-Koehler. Excerpt available here: http://ssir.org/articles/entry/the_social_labs_revolution_a_new_approach_to_solving_our_most_complex_chall

3 Biggart, N. and Delbridge, R. 2004. 'Systems of exchange', Academy of Management Review, 29, 1, 28-49; Delbridge, R. 2007. ESRC/EPSRC Advanced Institute of Management Research: Senior/Mid Career Fellowship: Integrating and Sustaining Innovation: End of Award Report, ESRC RES-331-25-0014. ESRC: Swindon.

4 Further information about the Cardiff Capital Region is available here: https://www.cardiffcapitalregion.wales

5 Further information about the Cardiff Capital Region Challenge Fund is available here: https://www.challengefund.wales

GOVERNMENT SCIENCE AMBITIONS REQUIRE GREATER FUNDING AND WIDER PUBLIC UNDERSTANDING

Professor Ian Taylor
Ian Taylor is an advisor to several companies in the UK, EU and USA mainly involved with technology and innovation and is a former Chair of P&SC.

This article was written before the change in Prime Minister in September 2022.

Following the outbreak of COVID-19 and facing the challenges and opportunities of a post-Brexit world, the UK government must deliver on the vision of its innovation strategy with increased funding for scientific research. The success of the life sciences sector will be key to the delivery of the government's scientific superpower ambitions. Boosting public funding will depend on continued political, and therefore public, support. With reference to his career in politics and industry, Ian Taylor shows how effective communication with the public, providing reassurance and dispelling myths, is central to the sector sustaining success in the long term.

The outbreak of the COVID-19 pandemic has meant that the importance and profile of UK science, both to policy makers and public, is at the highest it has ever been. This is particularly true about the life sciences sector and its success in rapidly developing effective and safe vaccines to combat COVID-19. The regular televised appearances of the prime minister standing shoulder to shoulder with the government's chief medical officer and the chief scientific adviser reinforced the linkage between scientific advice and our daily lives, even if sometimes the tension showed. Fame is, however, precarious, and so every effort needs to be made to enhance public understanding of science, of the risks involved in scientific enquiry and the requirement for increased long-term funding for research.

Life sciences has now become a key sector and a story of success. The industry employs more than 250,000 people in the UK and generated over £81 bn in 2019.[1] The report, Life Sciences Innovation: Building the Fourth Industrial Revolution (2021)[2], provides further detail that, in 2020, life sciences companies completed £20 bn of corporate investment, placing the UK fourth in global ranking, and predicted that by 2025 life sciences will add an extra £8.5 bn to the economy and over 31,000 jobs.

I have been fortunate to work directly around the interface between government and UK science. As a Member of Parliament, I was Parliamentary Private Secretary to William Waldegrave when he was science minister in the early 1990s. Later, I took over as science minister after the Office for Science and Technology moved to the then Department for Trade and Industry (the precursor to the current Department for Business, Energy and Industrial Strategy).

In 1993 the government published the 'Realising our Potential' white paper on the reorganization of the Research Councils that provide funding to academic institutions for scientific research. Amongst its recommendations was the creation of the Biotechnology and Biological Sciences Research Council (BBSRC), now the largest public funder of non-medical bioscience, through the incorporation of the former Agricultural and Food Research Council (AFRC) with the biotechnology and biological sciences programmes of the former Science and Engineering Research Council (SERC). Then, as now, ensuring the most effective structure of our public sector research base was a priority and key to delivery of objectives.

This was an interesting period for bioscience, with several important breakthroughs capturing the imagination – if not the understanding – of the public. As minister, I supported the funding of the Roslin Institute's research which led to Dolly the sheep, the first mammal cloned from an adult

somatic cell. The objective was to find ways to lessen the impact of debilitating diseases such as Parkinson's and Huntington's. This news garnered global attention and significant concern from many quarters on the implications. Prior to the announcement, I sought to help allay such concerns through the establishment of the Human Genetics Advisory Commission, reporting to ministers on new developments in human genetics which could have further wider social, ethical and/or economic consequences.

In addition, we confronted the bovine spongiform encephalopathy (BSE) crisis and with it the politically difficult public anxiety about food supply chain transmission to humans as variant CJD (vCJD) was likely to be caused by consuming meat from a cow that had BSE (or 'mad cow' disease), a similar prion disease to CJD. Huge publicity was given to the supposed risks of eating beef. In the face of that, we had to make high-stakes policy decisions which could not wait for any final scientific assessment. This happened in the face of uncertainty with the primary purpose of protecting the public rather than the economics of an industry, political alliances or other considerations.

There were also arguments over the deployment of genetically modified crops against fierce opposition, and the beginning of the Human Genome projects with a then unresolved debate about public or private ownership (settled in favour of the former eventually), all of which augured a new age and higher profile for bioscience. In theory these issues should have contributed to the development of a better understanding of risk and impacts, but sadly the public debate showed how controversy can over-rule calm scientific explanation. I was guided as minister by the calm analytical expertise of the then chief scientific advisor, the late (Lord) Bob May, who had a stellar academic background in ecosystem ecology, mathematical biology and epidemiology. He issued in 1997 a report on scientific advice in policy making, which argued that 'there should be a presumption of openness in explaining the interpretation of scientific advice'. He advocated engagement with opponents of GM crops or animal experimentation, rather than dismissing them as anti-rational. "Our values will indicate what questions we should be asking about the natural world and humanity's impact on it," he said. "Our science will ensure that the answers have a solid foundation."

That challenge persists today. Further transparency and public consultation are needed to downplay conspiracy theorists' non-factual disinformation on risks.

SEED INVESTMENT

In 2013 I became Chair, for 7 years, of the UK Innovation and Science Seed Fund (UKI2S), which provides seed funding, strategic mentoring and support for science companies in their early stages as they emerge from the public sector research base. Nurturing and growing startup technology ventures which have the potential to become leaders in their field generates skills, high-quality jobs and exports and contributes to the longer-term productivity improvement we need to stay competitive as a nation. The fund involves public sector research establishments as partners including BBSRC, STFC, NERC and DSTL. UKI2S also collaborates with Innovate UK and the Catapult Network, helping to catalyse and de-risk innovation by road-testing new technology applications that are at pre-return-on-investment. These types of partnerships can help cover the gap between R&D and industry, to provide 'translational infrastructure' that allows the most innovative ideas to be commercialised.

In 2013, as part of the then Science Minister David Willetts' 'Eight Great Technologies' initiative, the government gave UKI2S a specialist £10 mn Synthetic Biology Fund with the purpose of helping companies in the early stages of their journey towards sustainability, through investment, strategic support and leveraging private capital. Synthetic biology or engineering biology is the design and construction of entirely novel biological systems or the re-engineering of existing biological systems. Its applications can serve a wide variety of markets and it has the potential to solve many of the environmental and societal challenges of this century – major global issues with sustainability including environmental health, energy shortages, pollution, hunger and disease are all being addressed now by synthetic biology. UKI2S identified and invested in several ground-breaking companies in this space including Synthace (automating synthetic biology for speed and repeatability), Quethera (ocular gene therapy), Tropic Biosciences (improving tropical crops) and Nemesis Bioscience (combatting anti-microbial resistance).

With an overall portfolio of 57 companies, created with £15 mn of capital invested, UK2IS companies have attracted over £500 mn of later stage investment and have a combined market value of over £750 mn. For every £1 of UKI2S investment, portfolio businesses have received £3 of other public investment and £29 of private investment according to independent expert analysis by SQW. On the more human side, our seed investment has released the enthusiasm of scientists and enabled them to advance their research and deploy their efforts for the benefit of society.

PUBLIC ATTITUDES VERSUS POLITICAL, SCIENTIFIC REALITIES

All discoveries and developments raise questions, but synthetic biology is perhaps on the front line when it comes to tricky ethical dilemmas. There will always be some distance between public expectation and scientific, political realities and timing. As with Dolly the sheep, it is not unusual for generalists at first to over-estimate the speed (and risks) of impacts, which can then transmute into frustration with the slow and challenging applications of breakthroughs.

It is often difficult to explain scientific procedures and terminology for public debate, much though that it is necessary. One example is the distinction between genetic modification and gene editing. Here in the UK we have at least started to explore how to deploy the gene editing (CRISPR) technique a little more, but the consumer will be the decider as we look to post-Brexit opportunities. There will be research and export issues if UK practice is not aligned with the EU. At the time of writing this article, the government has announced legislation to better enable field trials in England on crops that are gene-edited (as opposed to genetically modified) for environmental and nutritional benefits.

Carefully monitored, synthetic biology has the potential to help solve some of our biggest global problems, but clearly there are

political factors which always impinge on scientific discovery. The science ex-minister, George Freeman MP, brought with him a life sciences and related venture capital background and appreciation. He had a leading role on the Taskforce on Innovation and Regulatory Reform (TIGGR) that identified and developed proposals across a range of areas that drove innovation, growth and competitiveness through regulatory reform, in connection with the UK's post-Brexit Regulatory Framework, and in which life sciences received favourable consideration.

With funding allocations, we also need to ensure support is available for wide-ranging potential impacts of applied science, especially around genetic modification. The power of today's science brings great responsibility. Other discoveries have had serious consequences recognized too late in the day, with microplastics providing a useful case study.

The contribution of biology, chemistry and synthetic biology to the understanding of effective multidisciplinary research is also worth recognizing. Researchers and practitioners from many fields can draw inspiration from work taking place elsewhere. This is especially the case with architecture, the built environment more generally, design and the biomanufacturing and biomarking fields. Dr Melissa Sterry, the transdisciplinary design scientist and complex systems theorist, makes the case that to answer challenges such as computer-aided biology requires more dialogue between scientists and those that are embracing biology as a creative and production agent.

CRITICAL MOMENT FOR DELIVERY OF UK SCIENTIFIC SUPERPOWER AMBITIONS

As the consequences, difficulties and opportunities of Brexit play out uncertainly, it is vital that industry and government make every effort to promote the UK as a place to do work and do business. Encouraging visiting scientists/technologists is not merely about economic growth, but an expression of the UK as an open, enquiring, culturally diverse society. Above all, we should be welcoming rather than hostile, inclusive not just by exception. We have leading scientific researchers punching above our comparative weight in terms of citations – but this cannot be taken for granted and we must always recognize that open access to research conducted elsewhere is vital.

The UK government has published its Innovation Strategy, and its associated strategies on place, people and culture either have been or are soon to be published. The coming years will have to be about delivery of these plans and ambitions. At the same time, the review of R&D innovation by Sir Paul Nurse, as well as a BEIS 'major review' of UKRI and its strategy should also be closely followed as they seek to further increase impact.

As all countries face an uncertain pandemic and economic outlook, it will be the level of British success with the skills and innovation agenda which will determine UK competitive advantage for critical growth sectors like life sciences. As William Hague recently put it, "Innovation will determine if we soar or stumble." This refrain is shared by successive science ministers, including my successor David Sainsbury, who has just published a stimulating book on the subject 'Windows of Opportunity'.

The government has committed to achieving 2.4% of GDP on R&D by 2027, contributing £22 bn towards that target by 2026/2027 (formerly 2024/2025). However, public contribution to R&D spending has determinedly hovered around 0.7% of GDP over the past three decades (as it was when I ceased to be minister in 1997). Hence the latest Spending Review's emphasis on the contribution of amended R&D tax credits to ensure that they better support cutting-edge research methods, supplementing this figure to 1.1% of GDP. As always, the key variable will be private sector investment, currently still the largest contributor to UK R&D intensity.

The UK government has placed a huge emphasis on innovation delivering productivity improvements necessary for economic readjustment post-pandemic and post-EU. That requires a commitment and delivery of ambitions – not least on increasing R&D contribution from UK businesses – which have proven elusive for a long period. While the current UK upward trajectory of government science funding is demanding, it is the least ambitious target of all the G7 countries. German expenditure in relation to its GDP is already 3.2%. The UK will be competing for globally mobile R&D investment, hence the recent announcement to give cash to international companies with 'strategically important' investment proposals, albeit after due diligence to ensure value for the taxpayer, to start, grow and invest in a business. The new fund includes £354 mn to support investment in life sciences manufacturing.

As Sir Paul Nurse said to the Commons' Science and Technology Committee last October: "We have been underfunded in science for decades… and we bump around at the bottom of the OECD figures at around 1.6% or 1.7%... The truth is that if we had money, we would be absolutely spectacular at science. Let me just say that again: spectacular at science."

References

1 Life Science Competitiveness Indicators 2020: Annual report on the UK life Science Sector – HM Government https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/977265/Life_Science_Competitiveness_Indicators_2020_report.pdf

2 Life Sciences Innovation Building the Fourth Industrial Revolution – Perkins&Will, Blackstock https://blackstock.co.uk/insights/life-sciences-innovation-building-the-fourth-industrial-revolution/

Further reading and listening

Windows of Opportunity: How Nations Create Wealth, Lord David Sainsbury

"Innovation will determine if we soar or stumble", Lord William Hague, The Times, 18 October 2021

Impact of Life Science Industry: https://www.sciencecampaign.org.uk/resource/the_economic_contribution_of_the_uk_life_sciences_industry-abpi.html

Dr Melissa Sterry on Computer-Aided Biology podcast hosted by Fane Mensah - https://anchor.fm/cabtalk/episodes/CABTalk-S2E5-The-Future-of-Research-with-Melissa-Sterry-e11ftpj/a-a5lp6m2

References to the late Lord May's views taken from https://www.theguardian.com/science/2020/apr/29/robert-may-bob-may-lord-may-obituary

UKI2S impact: https://ukinnovationscienceseedfund.co.uk/impact/economic-value/

UK scientific achievement in global context: https://www.elsevier.com/connect/report-compares-uks-research-performance-with-key-nations#

Comparative R&D Spend by country: http://uis.unesco.org/apps/visualisations/research-and-development-spending/

Comparative R&D Expenditure by country: https://en.wikipedia.org/wiki/List_of_countries_by_research_and_development_spending

UK Business Investment: https://on.ft.com/3dIlhtg ■

PARLIAMENTARY LINKS DAY 2022

Links Day, one of the biggest days in the parliamentary calendar for science, saw more than 100 people come together at Portcullis House to discuss the opportunities and benefits of collaboration in science.

The event was launched by Rt Hon Dame Eleanor Laing MP, Deputy Speaker of the House of Commons, followed by an introduction from Stephen Metcalfe MP, chair of the Parliamentary & Scientific Committee.

Stephen Metcalfe was then followed by Chi Onwurah MP, the Shadow Minister for Business, Energy and Industrial Strategy.

Chi Onwurah stressed the need to better support underfunded regions in the UK, and for universities to help drive regional growth: "I believe in science for science's sake, but it is also important to recognise the economic importance of science and the role it plays in rebuilding our economy."

Chi Onwurah's keynote was followed by a panel discussion, chaired by the RSB's associate director of public and parliamentary affairs, Susie Rabin MRSB.

The panel featured director of the John Innes Centre Professor Dale Sanders FRS FRSB, president of the Royal Society of Chemistry Professor Tom Welton

OBE, director of the British Antarctic Survey Professor Dame Jane Francis, and Dr Rosalind Coggon, co-editor of the International Ocean Discovery Program.

Professor Sanders discussed the need for collaboration to address the mounting pressure of food security: "We are facing a huge food crisis…which can only be solved through collaboration and interdisciplinary efforts.

"There will be two billion more people to feed in the next 30 years, with no additional land on which to farm." He also stressed the need to increase accessibility in STEM, a sentiment echoed by Professor Welton.

Professor Francis explained how essential collaboration is for research in the Antarctic, and how it is a continent completely governed through international efforts; 54 nations make up the Antarctic Treaty, including the UK.

The panel discussion was then followed by a keynote delivered by Minister for Science, Research and Innovation, George Freeman

MP, who shared that the Government had just announced an expansion on the support for Ukrainian researchers displaced by the war.

He returned to the topic of Horizon membership – as a driver behind the proposed Plan B alternative, George Freeman stated he was keen to move forward: "If the phone does not ring in the next few weeks, my working assumption will be that we are out [of Horizon Europe] and that we move forward with Plan B."

Government Chief Scientific Advisor, Sir Patrick Vallance, also stressed the importance of Horizon Europe: "For us to not associate to Horizon would be mutual self-harm for both the UK and Europe."

He then discussed how collaboration is vital for tackling climate change, describing the recent success of COP26 in bringing world leaders and scientists together to set global goals.

Rt Hon Greg Clark MP, chair of the House of Commons Science and Technology Select Committee, invited the audience to get more involved with setting their agenda, with the news that they plan to relaunch the My Science Inquiry process. This will allow anyone to present case studies on new research areas for the committee to explore.

The morning ended with closing remarks from Dr Stephen Benn FRSB, the Viscount Stansgate.

Parliamentary Links Day is organised by the Royal Society of Biology on behalf of the Anatomical Society, Biochemical Society, British Ecological Society, British Pharmacological Society, British Society for Immunology, Council for the Mathematical Sciences, Genetics Society, Geological Society, Institute of Physics, Nutrition Society, Royal Society of Chemistry, Society for Applied Microbiology, Society for Experimental Biology, and The Physiological Society.

Philippa Skett
Royal Society of Biology ■

ANNUAL LUNCHEON 2022

One of the key events in the P&SC calendar, our Annual Luncheon, returned to the Cholmondeley Room, House of Lords on Tuesday 5th July.

As members will recall this gathering was previously held in November. By switching to July, guests were able to enjoy pre-lunch drinks on the Terrace, and on a lovely Summer's day.

The Lunch was hosted by our President, Dr Stephen Benn, The Viscount Stansgate, and featured remarks by the Chairman, Stephen Metcalfe MP and guest speaker, Chi Onwurah MP, Shadow Minister for Science, Research and Digital.

The event also marked the retirement of Karen Smith, our excellent Administrator for the past five years, who with her partner John Slater has contributed so much to the work of P&SC.

As pictured on page 28, Karen was presented with a number of leaving gifts by Stephen Metcalfe MP and Viscount Stansgate. ■









All photos by Dr Isabel Spence

HOUSE OF COMMONS SELECT COMMITTEES

BUSINESS, ENERGY AND INDUSTRIAL STRATEGY COMMITTEE

The Business, Energy and Industrial Strategy Committee scrutinises the policy, spending and administration of the Department for Business, Energy and Industrial Strategy and its public bodies, including Ofgem, the Financial Reporting Council and the Committee on Climate Change.

The Committee regularly holds accountability evidence hearings with Government Ministers and with bodies such as the Financial Reporting Council, the Committee on Climate Change and Ofgem. The BEIS Committee also hears from a range of stakeholders in the course of its work, receiving evidence from academics, business groups, NGOs and charities to its inquiries.

Membership:

Darren Jones MP, Labour, Chair
Alan Brown MP, Scottish National Party
Judith Cummins MP, Labour
Richard Fuller MP, Conservative
Nusrat Ghani MP, Conservative
Paul Howell MP, Conservative
Mark Jenkinson MP, Conservative
Charlotte Nichols MP, Labour
Sarah Owen MP, Labour
Mark Pawsey MP, Conservative
Alexander Stafford MP, Conservative

Inquiries:

- Net zero and UN climate summits - Opened 6 March 2020. Government response published 17th May 2021.
- The impact of coronavirus on businesses and workers - Opened 13 March 2020. Government response published 19th May 2021.
- Delivering audit reform - Opened 18 March 2020.
- Work of the Department and Government Response to coronavirus - Opened 14 April 2020
- Post-pandemic economic growth - Opened 3 June 2020.
- Post-pandemic economic growth: Industrial Strategy – Opened 23rd July 2020.
- Post-pandemic economic growth: Levelling up local and regional structures and the delivery of economic growth – Opened 24th July 2020.
- ONE WEB – Opened 16th September 2020.
- Freed Labour in UK value chains – Opened 18th September 2020. Government response published 10th June 2021.
- Decarbonising heat in homes – Opened 2nd October. Accepting written evidence until 13th November 2020.
- Business and Brexit preparedness – Opened 17th November 2020.
- Mineworkers' Pension Scheme – Opened 18th March 2021. Deadline 12th April 2021.
- Findings of the Report of Climate Change Assembly UK – Opened 19th April 2021
- Liberty Steel and the Future of the UK Steel Industry – Opened 27th April 2021

For further details: Tel: 020 7219 5777
Email: beiscom@parliament.uk

ENVIRONMENTAL AUDIT COMMITTEE

The remit of the Environmental Audit Committee is to consider the extent to which the policies and programmes of government departments and non-departmental public bodies contribute to environmental protection and sustainable development, and to audit their performance against sustainable development and environmental protection targets.

Unlike most select committees, the Committee's remit cuts across government rather than focuses on the work of a particular department.

From its beginning in 1997, in carrying out its environmental 'audit' role the Committee has had extensive support from the National Audit Office, providing seconded staff and research and briefing papers.

Membership:

Rt Hon Philip Dunne MP, Conservative, Chair
Duncan Baker MP, Conservative
Dan Carden MP, Labour
Sir Christopher Chope MP, Conservative
Barry Gardiner MP, Labour
Rt Hon Robert Goodwill MP, Conservative
James Gray MP, Conservative
Helen Hayes MP, Labour
Ian Levy MP, Conservative
Caroline Lucas MP, Green Party
Cherilyn Mackrory, Conservative
Jerome Mayhew MP, Conservative
John McNally MP, Scottish National Party
Dr Matthew Offord MP, Conservative
Claudia Webbe MP, Independent
Nadia Whittome MP, Labour

Inquiries

- Preparation for COP26 – Opened 17 March 2020.
- Greening the post-Covid Recovery – Opened 13 May 2020. Government response published 22nd June 2021.
- Energy Efficiency of Existing Homes – Opened 18 May 2020. Government response published 13th May 2021.
- Biodiversity and Ecosystems – Opened 13th July 2020

- Fixing Fashion follow up – Opened 6th October 2020
- Technological Innovations and Climate Change: Tidal Power – Opened 9th November 2020
- Green Jobs – Opened 17th November 2020.
- Water Quality in Rivers – Opened 8th December 2020.
- Next steps for deposit return schemes – Opened 12th February 2021.
- Technological Innovations and Climate Change: Community Energy – Opened 19th February
- Sustainability of the built environment – Opened 25th March 2021
- Technological Innovations and Climate Change: Supply chain for Battery Electric Vehicles – opened 4th May 2021

For further details: Tel: 020 7219 5776
Email: eacom@parliament.uk

SCIENCE AND TECHNOLOGY COMMITTEE

The work of many Government departments makes use of — or has implications for — science, engineering, technology and research. The Science and Technology Committee exists to ensure that Government policies and decision-making are based on solid scientific evidence and advice. It is chaired by Greg Clark MP.

The Committee has a similarly broad remit and can examine the activities of government departments that make use of science, engineering, technology and research (otherwise known as science for policy). In addition, the Committee scrutinises policies that affect the science and technology sectors, such as research funding and skills (often referred to policy for science).

Membership:

Rt Hon Greg Clark MP, Conservative, Chair
Aaron Bell MP, Conservative
Dawn Butler MP, Labour
Chris Clarkson MP, Conservative
Katherine Fletcher MP, Conservative
Andrew Griffith MP, Conservative
Mark Logan MP, Conservative
Rebecca Long-Bailey MP, Labour
Carol Monaghan MP, Scottish National Party
Graham Stringer MP, Labour
Zarah Sultana MP, Labour

Inquiries

- UK Science, Research and Technology Capability and Influence in Global Disease Outbreaks. – Opened 20 March 2020. Deadline 31 July 2020. Government response published 8th January 2021.
- Commercial genomics – Opened 9 April 2020.
- UK telecommunications infrastructure and the UK's domestic capability – Opened 9 April 2020.
- A new research funding agency – Opened 9th April 2020.
- The role of technology, research and innovation in the COVID-19 recovery – Opened 24th July 2020.
- Coronavirus – Lessons Learnt – Opened 6th October 2020.
- The Role of Hydrogen in Achieving Zero – Opened 4th December 2020.
- UK space strategy and UK satellite infrastructure – Opened 24th June 2021.

For further details: Tel: 020 7219 2793
Email: scitechcom@parliament.uk

HEALTH AND SOCIAL CARE COMMITTEE

The Committee scrutinises government and in particular the work of the Department of Health and Social Care. It is chaired by Jeremy Hunt MP.

The Committee also scrutinises the work of public bodies in the health system in England, such as NHS England and Improvement, Public Health England and the Care Quality Commission, and professional regulators such as the General Medical Council and the Nursing and Midwifery Council. They do so by holding inquiries on specific topics and accountability hearings with the Secretary of State, and Chief Executives of relevant public bodies.

Membership:

Rt Hon Jeremy Hunt MP, Conservative, Chair
Paul Bristow MP, Conservative
Rosie Cooper MP, Labour
Dr James Davies MP, Conservative
Dr Luke Evans MP, Conservative
Barbara Keeley MP, Labour
Taiwo Owatemi MP, Labour
Sarah Owen MP, Labour
Anum Quaiser-Javed MP, Scottish National party
Dean Russell MP, Conservative
Laura Trott MP, Conservative

Inquiries

- Social care: funding and workforce – Opened 10 March 2020. Government response published 17th February 2021.
- Safety of maternity services in England – Opened 24th July 2020.
- Workforce burnout and resistance in the NHS and social care – Opened 30th July 2020. Published 8th June 2021.
- Coronavirus – Lessons Learnt – Opened 6th October 2020.
- Coronavirus – Recent developments – Opened 5th January 2021.
- Children and young people's mental health – Opened 29th January 2021.
- Treatment of autistic people and individuals with learning disabilities – Opened 3rd February 2021.
- Department's White Paper on health and social care – Opened 25th February 2021. Published 14th May 2021.
- Supporting those with dementia and their carers – Opened 12th May 2021.

For further details: Tel: 020 7219 6182 Email: hsccom@parliament.uk ■

HOUSE OF LORDS SELECT COMMITTEES

SCIENCE AND TECHNOLOGY COMMITTEE

The Science and Technology Committee has a broad remit "to consider science and technology". It is chaired by Baroness Brown of Cambridge.

The Committee scrutinises Government policy by undertaking cross-departmental inquiries into a range of different activities. These include:

- public policy areas which ought to be informed by scientific research (for example, health effects of air travel),
- technological challenges and opportunities (for example, genomic medicine) and
- public policy towards science itself (for example, setting priorities for publicly funded research).

In addition, the Committee undertakes from time to time shorter inquiries, either taking evidence from Ministers and officials on topical issues, or following up previous work.

Members:

The Baroness Brown of Cambridge DBE FREng FRS, Crossbench, Chair
The Baroness Blackwood of North Oxford, Conservative
Viscount Hanworth, Labour
The Lord Holmes of Richmond MBE
The Rt Hon. the Lord Kakkar, Crossbench
The Lord Krebs, Crossbench
The Baroness Manningham-Buller LG DCB, Crossbench
The Lord Mitchell, Labour
The Baroness Rock, Conservative
The Baroness Sheehan, Liberal Democrat
The Baroness Walmsley, Liberal Democrat
The Baroness Warwick of Undercliff, Labour
The Lord Wei, Conservative
The Lord Winston, Labour

Inquiries

- Ageing: Science, Technology and Healthy Living – Opened 25 July 2019 Government response published 15th March 2021.
- The science of COVID – 19 Opened 7 May 2020.
- The Contribution of Innovation Catapults to Delivering the R&D Roadmap – Opened 11th November 2020. Government response published 6th April 2021.
- Role of batteries and fuel in allowing Net Zero – Opened 3rd March 2021. Report published 27th July 2022. Government response, 27th September 2022.
- Nature-based solutions for climate change. Report published 27th January 2022. Government response, 21st April 2022.
- Delivering a UK science and technology strategy. Report published 4th August 2022. Government response due 18th October 2022.
- People and skills in UK science, technology, engineering and mathematics. Opened 10th February 2022.

For further details: Tel: 020 7219 5750
Email: hlscience@parliament.uk ■

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

POST is a bicameral body that bridges research and policy, providing reliable and up-to-date research evidence for the UK Parliament. It is overseen by a Board of MPs, Peers and external experts.

POST briefings are impartial, non-partisan, and peer-reviewed. Timely and forward-thinking, they are designed to make scientific research accessible to the UK Parliament. POSTnotes are four-page summaries of public policy issues based on reviews of the research literature and interviews with stakeholders from across academia, industry, government and the third sector. They are peer-reviewed by external experts. POSTnotes are often produced proactively so that parliamentarians have advance knowledge of key issues before they reach the top of the political agenda. Our research is published on our website.

POSTnotes produced since June 2022 were:

677: Energy Consumption of ICT
676: Energy Security
675: Palliative and end of life care
674: Prolonged Disorders of Consciousness

Ongoing and future projects approved by the POST Board:

BIOLOGY AND HEALTH

In production

Performance, Inclusion and Elite Sport - Athletes with Differences in Sex Development
Performance, Inclusion and Elite Sport – Transgender Athletes
Diet-related Inequalities

ENERGY AND ENVIRONMENT

In production

Climate security
Habitat restoration
Nature recovery, conservation and climate change adaptation
Low-carbon hydrogen use
GB Plant biosecurity

Nuclear energy in the UK
Biomass energy
Long duration energy storage
Urban Outdoor Air quality

DIGITAL AND PHYSICAL SCIENCES

In production

Automation in military operations
Hypersonic missiles
Cyber warfare
Digital Technology and the Future of Freight
Competition in Online Advertising

SOCIAL SCIENCES

In production
Assisted dying
Invisible disabilities
The impact of remote and hybrid work on workers and organisations
Reform of the Mental Health Act impacts on children and young people

The POST Board oversees POST's objectives, outputs and future work programme. It meets quarterly.

Officers

- Chair: Adam Afriyie MP
- Vice-Chair: Professor the Lord Winston, FMedSci, FRSA, FRCP, FRCOG, FREng
- Secretary: Claire Quigley

House of Commons

- Rt Hon Greg Clark MP
- Katherine Fletcher MP
- Stephen Metcalfe MP
- Maria Miller MP
- Carol Monaghan MP
- Dr Ben Spencer MP
- Alan Whitehead MP

House of Lords

- Baroness Brown of Cambridge
- Lord Haskel
- Lord Ravensdale

Non-parliamentary

- Professor Elizabeth Fisher, FMedSci
- Paul Martynenko, FBCS
- Professor Sir Bernard Silverman, FRS, FAcSS
- Professor Dame Sarah Whatmore, FBA

Ex-officio

- Oliver Bennett MBE, Head of the Parliamentary Office of Science and Technology
- Grant Hill-Cawthorne, House of Commons Librarian and Managing Director of Research & Information
- Farrah Bhatti, Principal Clerk, Committee Office, House of Commons
- Xameerah Malik, Head of Science and Environment Section, House of Commons Library
- Nicolas Besly, Clerk of Select Committees, House of Lords

Head of POST

- Oliver Bennett MBE

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY

Houses of Parliament
Westminster
London SW1A 0AA ■

HOUSE OF COMMONS LIBRARY

The House of Commons Library is an impartial research and information service for Members of Parliament of all parties and their staff.

The Library provides confidential, impartial and bespoke briefing to Members of the House of Commons and their offices supporting the full range of parliamentary work, from policy development to constituency issues.

The Library also publishes a range of products including topical research briefings, shorter insight articles and briefings for non-legislative debates, all of which are available online for MPs and the public. These briefings include analysis of all major pieces of legislation. You can find publications on the Commons Library website (https://commonslibrary.parliament.uk) where you can also sign up for alerts.

The Science and Environment Section (SES) is one of eight teams in the Research Service in the House of Commons Library. In recent months they have published and updated briefings on issues including:

Reference	Title	Date published
CDP-2022-0155	Debate on supporting local food infrastructure	6/9/2022
CDP 2022-0154	Debate on Covid-19 vaccines and the Vaccine Damage Payment Scheme	5/9/2022
CBP 8081	Energy bills and the price cap	1/9/2022
CBP 9332	Coronavirus: Covid-19 booster vaccines frequently asked questions	22/8/2022
CBP 9557	Genetic Technology (Precision Breeding) Bill 2022-23	10/8/2022
CBP 9461	Energy Bills Support Scheme: Government policy and FAQs	9/8/2022
CBP 9600	Air quality: policies, proposals and concerns	27/7/2022
CDP 2022-0149	The importance of agricultural and county shows to rural Britain	19/7/2022
CBP 8875	Coronavirus: the lockdown laws	14/7/2022
CDP 2022-0147	The effect of the war in Ukraine on UK farming and food production	18/7/2022
CDP 2022-0146	New pylons in East Anglia	18/7/2022 ■

SCIENCE DIRECTORY

UK Research and Innovation

Contact: Roxy Squire
Parliamentary Affairs Lead, UKRI
58 Victoria Embankment, 4th floor
EC4Y 0DS, London

Tel: 02073952280 | 07706000363
Email: externalaffairs@ukri.org

Website: www.ukri.org

Big challenges demand big thinkers - those who can unlock the answers and further our understanding of the important issues of our time. Our work encompasses everything from the physical, biological and social sciences, to innovation, engineering, medicine, the environment and the cultural impact of the arts and humanities. In all of these areas, our role is to bring together the people who can innovate and change the world for the better. We work with the government to invest over £7 billion a year in research and innovation by partnering with academia and industry to make the impossible, possible. Through the UK's nine leading academic and industrial funding councils, we create knowledge with impact.

Arts and Humanities Research Council

Website: www.ahrc.ukri.org

AHRC funds outstanding original research across the whole range of the arts and humanities. This research provides economic, social and cultural benefits to the UK, and contributes to the culture and welfare of societies around the globe.

Biotechnology and Biological Sciences Research Council

Website: www.bbsrc.ukri.org

BBSRC invests in world-class bioscience research and training. This research is helping society to meet major challenges, including food security, green energy and healthier, longer lives and underpinning important UK economic sectors, such as farming, food, industrial biotechnology and pharmaceuticals.

Economic and Social Research Council

Website: www.esrc.ukri.org

ESRC is the UK's largest funder of research on the social and economic questions facing us today. This research shapes public policy and contributes to making the economy more competitive, as well as giving people a better understanding of 21st century society.

Engineering and Physical Sciences Research Council

Website: www.epsrc.ukri.org

EPSRC invests in world-leading research and postgraduate training across the engineering and physical sciences. This research builds the knowledge and skills base needed to address scientific and technological challenges and provides a platform for future UK prosperity by contributing to a healthy, connected, resilient, productive nation.

Innovate UK

Website: www.gov.uk/government/organisations/innovate-uk

Innovate UK drives productivity and economic growth by supporting businesses to develop and realise the potential of new ideas, including those from the UK's world-class research base. They connect businesses to the partners, customers and investors that can help them turn these ideas into commercially successful products and services, and business growth.

Medical Research Council

Website: www.mrc.ukri.org

MRC is at the forefront of scientific discovery to improve human health. Its scientists tackle some of the greatest health problems facing humanity in the 21st century, from the rising tide of chronic diseases associated with ageing to the threats posed by rapidly mutating micro-organisms.

Natural Environment Research Council

Website: www.nerc.ukri.org

NERC is the driving force of investment in environmental science. Its leading research, skills and infrastructure help solve major issues and bring benefits to the UK, such as affordable clean energy, air pollution, and resilience of our infrastructure.

Research England

Website: www.re.ukri.org

Research England creates and sustains the conditions for a healthy and dynamic research and knowledge exchange system in English universities. Working to understand their strategies, capabilities and capacity; supporting and challenging universities to create new knowledge, strengthen the economy, and enrich society.

Science and Technology Facilities Council

Website: www.stfc.ukri.org

STFC is a world-leading multi-disciplinary science organisation. Its research seeks to understand the Universe from the largest astronomical scales to the tiniest constituents of matter, and creates impact on a very tangible, human scale.

SCIENCE DIRECTORY

Contact: Dr Jane Gate, Executive Director
AIRTO Ltd: Association of Innovation Research & Technology Organisations Ltd
c/o National Physical Laboratory
Hampton Road, Teddington
Middlesex TW11 0LW
Tel: 020 8943 6600
E-mail: enquiries@airto.co.uk
Twitter: @airtoinnovation
Website: www.airto.co.uk

AIRTO, the Association of Innovation, Research and Technology Organisations, comprises approximately sixty principal organisations operating in the UK's Innovation, Research and Technology (IRT) sector. The IRT sector has a combined turnover of £6.9Bn, employs over 57,000 people and contributes £34Bn to UK GVA. AIRTO's members work at the interface between academia and industry, for both private and public sector clients. Members include independent Research and Technology Organisations, Catapult Centres, Public Sector Research Establishments, National Laboratories, some university Technology Transfer Offices and some privately held innovation companies.

Contact:
Tony Harding
07895 162 896 for all queries whether for membership or assistance.
Branch Office Address:
Merchant Quay,
Salford Quays, Salford
M50 3SG.

Website: www.amps-tradeunion.com

We are a Trades Union for Management and Professional Staff working in the pharmaceutical, chemical and allied industries.

We have produced a training programme funded by the EU on diversity and helping women managers remain in the workplace after a career break. This training programme is aimed at both men and women and is intended to address the shortfall in qualified personnel in the chemical and allied industries.

We are experts in performance based and field related issues and are affiliated to our counterparts in EU Professional Management Unions.

Contact:
Colin Danson
Distinguished Scientist & Head of Profession for Physics and Mathematics
AWE
Aldermaston, Reading RG7 4PR
Email: Colin.Danson@awe.co.uk
www.awe.co.uk
Tel: 0118 98 56901

AWE plays a crucial role in our nation's defence by providing and maintaining warheads for the UK's nuclear deterrent and delivers advice and guidance on a 24/7 basis to UK government in the area of national security.

We are a centre of scientific, engineering and technological excellence, with some of the most advanced research, design and production facilities in the world. AWE is contracted to the Ministry of Defence (MOD) through a Government-owned-contractor-operated (GOCO) arrangement. While our sites and facilities remain in government ownership, their management, day-to-day operations and maintenance of Britain's nuclear stockpile is contracted to a private company: AWE Management Limited (AWE ML). AWE ML is a consortium comprising three partners: Jacobs Engineering Group, the Lockheed Martin Corporation and Serco Group plc.

Policy Team
Biochemical Society
1 Naoroji Street
London
WC1X 0GB

Tel: +44 (0)20 3880 2793
Email: policy@biochemistry.org
Website: www.biochemistry.org

The Biochemical Society works to promote the molecular biosciences; facilitating the sharing of expertise, supporting the advancement of biochemistry and molecular biology and raising awareness of their importance in addressing societal grand challenges. We achieve our mission by :

- bringing together molecular bioscientists;
- supporting the next generation of biochemists;
- promoting and sharing knowledge and
- promoting the importance of our discipline.

Contact:
Ben Connor, Policy Manager
British Ecological Society
42 Wharf Rd, Hoxton,
London N1 7GS
Email: ben@britishecologicalsociety.org
Tel: 020 3994 8282
Website: www.BritishEcologicalSociety.org
Twitter: @BESPolicy

The British Ecological Society is an independent, authoritative learned society, and the voice of the UK's ecological community. Working with our members we gather and communicate the best available ecological evidence to inform decision making. We offer a source of unbiased, objective ecological knowledge, and promote an evidence-informed approach to finding the right solutions to environmental questions.

British In Vitro Diagnostics Association (BIVDA)

Contact: Doris-Ann Williams MBE
Chief Executive
British In Vitro Diagnostics Association
299 Oxford Street, London W1C 2DZ

Tel: 0845 6188224
Email: doris-ann@bivda.co.uk
www.bivda.org.uk

BIVDA is the UK industry association representing companies who manufacture and/or distribute the diagnostics tests and equipment to diagnose, monitor and manage disease largely through the NHS pathology services. Increasingly diagnostics are used outside the laboratory in community settings and also to identify those patients who would benefit from specific drug treatment particularly for cancer.

Contact: Policy Officer
British Pharmacological Society
The Schild Plot, 16 Angel Gate,
City Road, London EC1V 2PT
Tel: 020 7239 0171
Email: policy@bps.ac.uk
Website: www.bps.ac.uk

The British Pharmacological Society is a charity with a mission to promote and advance the whole spectrum of pharmacology. It is the primary UK learned society concerned with drugs and the way they work, and leads the way in the research and application of pharmacology around the world.

Founded in 1931, the Society champions pharmacology in all its forms, across academia, industry, regulatory agencies and the health service. With over 3,500 members from over 60 countries worldwide, the Society is a friendly and collaborative community. Enquiries about the discovery, development and application of drugs are welcome.

Tracey Guise, Chief Executive Officer
British Society for Antimicrobial Chemotherapy (BSAC)
53 Regent Place, Birmingham B1 3NJ
+44 (0)121 236 1988
tguise@bsac.org.uk
www.bsac.org.uk

BSAC is a learned society whose members are among the world's leading infectious disease physicians, pharmacists, microbiologists, and nurses.

With more than 45 years of leadership in antibiotic research and education, BSAC is dedicated to saving lives by fighting infection. It does this by supporting a global network of experts via workshops, conferences, evidence-based guidelines, e-learning courses, and its own high-impact international journal.

BSAC also provides national surveillance and susceptibility testing programmes, an outpatient parenteral antimicrobial therapy (OPAT) initiative, research and development grants, and the secretariat for the All-Party Parliamentary Group on Antibiotics.

BSAC has members in 40 nations and active learners in more than 135 countries.

Contact Dr Doug Brown, CEO
British Society for Immunology
Devonshire House,
60 Goswell Road,
London EC1M 7AD.
Tel: 020 3019 5901
E-mail: bsi@immunology.org
Website: www.immunology.org

The British Society for Immunology's mission is to promote excellence in immunological research, scholarship and clinical practice in order to improve human and animal health. We are the leading UK membership organisation working with scientists and clinicians from academia and industry to forward immunology research and application around the world. Our friendly, accessible community of over 3,500 immunologists gives us a powerful voice to advocate for immunological science and health for the benefit of society.

SCIENCE DIRECTORY

BRITISH SOCIETY OF SOIL SCIENCE

Contact: Sarah Garry
Building 42a Cranfield University
Cranfield, MK43 0AL
Email: exec@soils.org.uk
Website: www.soils.org.uk

The British Society of Soil Science (BSSS) was founded in 1947 and is an established international membership organisation and charity committed to the study of soil in its widest aspects. The society brings together those working within academia, practitioners implementing soil science in industry and all those working with, or with an interest in soils.

We promote research and education, both academically and in practice, and build collaborative partnerships to help safeguard our soil for the future. This includes hosting the World Congress of Soil Science 2022 in Glasgow, where those with an interest in soil science can meet to discuss the critical global issues relating to soil.

Brunel University London

Contact: Geoff Rodgers
Brunel University London
Kingston Lane
Uxbridge UB8 3PH
Tel: 01895 265609
Fax: 01895 269740
E-mail: g.j.rodgers@brunel.ac.uk
Website: www.brunel.ac.uk

Brunel University London is an international research active university with 3 leading research institutes:

Institute of Energy Futures: Led by Professor Savvas Tassou, the main themes of the Institute are *Advanced Engines and Biofuels, Energy Efficient and Sustainable Technologies, Smart Power Networks*, and *Resource Efficient Future Cities*.

Institute of Materials and Manufacturing: The main themes of research are *Design for Sustainable Manufacturing, Liquid Metal Engineering, Materials Characterisation and Processing, Micro-Nano Manufacturing*, and *Structural Integrity*. The Institute is led by Professor Luiz Wrobel.

Institute of Environment, Health and Societies: Professor Susan Jobling leads this pioneering research institute whose themes are *Health and Environment, Healthy Ageing, Health Economics Synthetic Biology, Biomedical Engineering and Healthcare Technologies*, and *Social Sciences and Health*.

Brunel University London offers a wide range of expertise and knowledge, and prides itself on having academic excellence at the core of its offer, and was ranked in the recent REF as 33rd in the UK for Research Power (average quality rating by number of submissions) and described by The Times Higher Education as one of the real winners of the REF 2014.

Cavendish Laboratory

UNIVERSITY OF CAMBRIDGE

Contact: Departmental Administrator,
The Cavendish Laboratory,
J J Thomson Avenue, Cambridge CB3 0HE, UK.
E-mail: glw33@cam.ac.uk
http://www.phy.cam.ac.uk

The Cavendish Laboratory houses the Department of Physics of the University of Cambridge.

The research programme covers the breadth of contemporary physics

Extreme Universe: Astrophysics, cosmology and high energy physics

Quantum Universe: Cold atoms, condensed matter theory, scientific computing, quantum matter and semiconductor physics

Materials Universe: Optoelectronics, nanophotonics, detector physics, thin film magnetism, surface physics and the Winton programme for the physics of sustainability

Biological Universe: Physics of medicine, biological systems and soft matter

The Laboratory has world-wide collaborations with other universities and industry

Chartered Institute of Ergonomics & Human Factors

Contact: Dr Noorzaman Rashid
Chief Executive
noorzaman.rashid@ergonomics.org.uk
+4407966335309
www.ergonomics.org.uk

Our vision is integrated design to improve life, wellbeing and performance through science, engineering, technology and psychology. The Institute is one of the largest in the world representing the discipline and profession of Human Factors and Ergonomics. We have sector groups in most industries from defence to aviation and pharmaceuticals that provide expert advice to industry and government. We accredit university courses and consultancy practices and work closely with allied learned societies.

The Cosmetic Toiletry & Perfumery Association | ctpa

Contact: Dr Emma Meredith
Sackville House
40 Piccadilly
London W1J 0DR
Tel: 020 7491 8891
E-mail: info@ctpa.org.uk
Website: www.ctpa.org.uk &
www.thefactsabout.co.uk

CTPA is the UK trade association representing manufacturers of cosmetic products and suppliers to the cosmetic products industry. 'Cosmetic products' are legally defined and subject to stringent EU safety laws. CTPA is the authoritative public voice of a vibrant and responsible UK industry trusted to act for the consumer; ensuring the science behind cosmetics is fully understood.

CLIFTON SCIENTIFIC Trust

Contact: Dr Eric Albone MBE, Director,
Clifton Scientific Trust
49 Northumberland Road, Bristol BS6 7BA
Tel: 0117 924 7664 Mob:07721 683528
E-mail: eric@clifton-scientific.org
Website: www.clifton-scientific.org

We bring school students and their teachers

- to work closely with scientists and engineers
- to experience science as a creative, questioning, team exploration
- to add real-life meaning and motivation, from primary to post-16
- internationally to build global awareness and experience science as a cultural bridge
- to build transferable skills for employability and citizenship

Two powerful Exemplars

- Post-16; our **unique UK-Japan Young Scientist Workshop Programme** hosted in universities in England and Japan since 2001
- Primary; our local **Meet-a-Medic Programme** since 2005

Clifton Scientific Trust Ltd is registered charity in England and Wales 1086933

The Council for the Mathematical Sciences

Contact: Lindsay Walsh
De Morgan House
57-58 Russell Square
London WC1B 4HS
Tel: 020 7637 3686
Fax: 020 7323 3655
Email: cms@lms.ac.uk
Website: www.cms.ac.uk

The Council for the Mathematical Sciences is an authoritative and objective body that works to develop, influence and respond to UK policy issues affecting mathematical sciences in higher education and research, and therefore the UK economy and society by:

- providing expert advice;
- engaging with government, funding agencies and other decision makers;
- raising public awareness; and
- facilitating communication between the mathematical sciences community and other stakeholders

THE FRANCIS CRICK INSTITUTE

Emily Teller
Head of External Affairs
The Francis Crick Institute
Midland Road, London NW1 1AT
M: 07817958541
Press office: 020 3796 5252
E: emily.teller@crick.ac.uk
W: www.crick.ac.uk

The Francis Crick Institute is a biomedical research institute carrying out world-class discovery research to understand how living things work and to drive benefits for human health. Our discoveries will enhance our understanding of the fundamental processes of life, and have the potential to transform the prevention, diagnosis and treatment of human disease.

The Crick was formed in 2015, commencing full operations in 2017 in a brand new state-of-the-art building in central London which brings together more than 2,000 scientists, staff and students working collaboratively across disciplines.

Daphne Jackson Trust

Contact: Dr Katie Perry
Chief Executive
The Daphne Jackson Trust
Department of Physics
University of Surrey, Guildford GU2 7XH
Tel: 01483 689166
Email: Katie.perry@surrey.ac.uk
Website: www.daphnejackson.org

Founded in 1992 in memory of the UK's first female Professor of Physics, the Trust is the UK's leading charity dedicated to realising the potential of scientists and engineers returning to research after career breaks for family, caring and health reasons. Recently, we have expanded our remit to incorporate the social sciences and arts & humanities. Our Fellowship programme, working in partnership with universities, UKRI, charities, learned societies and industry, enables individuals to undertake part-time research in universities and research institutes. Fellowships comprise a research project alongside an individually tailored retraining programme, with additional mentoring and support, enabling recipients to re-establish their research credentials, update skills and redevelop confidence, in a suitably supportive environment.

SCIENCE DIRECTORY

Contact: Louise Kingham OBE FEI
Chief Executive
61 New Cavendish Street
London W1G 7AR
Tel: 020 7467 7100
Email: info@energyinst.org
Website: www.energyinst.org

The Energy Institute (EI) is the chartered professional membership body bringing together expertise for urgent global challenges. Our ambition is that energy, and its critical role in our world, is better understood, managed and valued. We're a unique network with insight spanning the world of energy, from conventional oil and gas to the most innovative renewable and energy efficient technologies. We gather and share essential knowledge about energy, the skills that are helping us all use it more wisely, and the good practice needed to keep it safe and secure. We articulate the voice of energy experts, taking the know-how of around 20,000 members and 200 companies from 120 countries to the heart of the public debate. And we're an independent, not-for-profit, safe space for evidence-based collaboration, an honest broker between industry, academia and policy makers.

Suzanne King
Policy and Voice Manager
EngineeringUK
Northern & Shell Building, 5th floor
10 Lower Thames Street
London, EC3 6EN
Email: sking@engineeringuk.com

EngineeringUK is an independent organisation that promotes the vital role of engineers, engineering and technology in our society. EngineeringUK partners business and industry, Government and the wider science and technology community: producing evidence on the state of engineering; sharing knowledge within engineering, and inspiring young people to choose a career in engineering, matching employers' demand for skills.

Contact: Director of Science
Fera Science Ltd. (Fera)
Sand Hutton, York, YO41 1LZ
Tel: 01904 462000
E-mail: chiefscientistoffice@fera.co.uk
Website: www.fera.co.uk

Fera provides expert analytical and professional services to governments, agrichemical companies, food retailers, manufacturers and farmers to facilitate safety, productivity and quality across the agrifood supply chain in a sustainable and environmentally compatible way.

Fera uses its world leading scientific expertise to provide robust evidence, rigorous analysis and professional advice to governments, international bodies and companies worldwide. Our food integrity, plant health, agri-tech and agri-informatics services ensure that our customers have access to leading edge science, technology and expertise.

Contact: Steven Brambley
Rotherwick House
3 Thomas More Street
London, E1W 1YZ
Tel: 020 7642 8080
E-mail: info@gambica.org.uk
Website : www.gambica.org.uk

GAMBICA is the voice of the laboratory technology, instrumentation, control and automation industries, providing influence, knowledge and community. We offer members a common platform for voicing their opinions and representing their common interests to a range of stakeholders. GAMBICA seeks to spread best-practice and be thought leaders in our sectors.

Contact: Florence Bullough
Head of Policy and Engagement
Burlington House
Piccadilly
London W1J 0BG
Tel: 020 7434 9944
Fax: 020 7439 8975
E-mail: florence.bullough@geolsoc.org.uk
Website: www.geolsoc.org.uk

The Geological Society is the national learned and professional body for Earth sciences, with 12,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government, with a wide range of perspectives and views on policy-relevant science, and the Society is a leading communicator of this science to government bodies and other non-technical audiences.

Contact: Lynda Rigby, Executive Head of Marketing and Membership
Institute of Biomedical Science,
12 Coldbath Square, London, EC1R 5HL
Tel: 020 7713 0214
Email: mc@ibms.org
Twitter: @IBMScience
Website: www.ibms.org

Advancing knowledge and setting standards in biomedical science

With over 20,000 members in 61 countries, the Institute of Biomedical Science (IBMS) is the leading professional body for scientists, support staff and students in the field of biomedical science.

Since 1912 we have been dedicated to the promotion, development and delivery of excellence in biomedical science within all aspects of healthcare, and to providing the highest standards of service to patients and the public.

By supporting our members in their practice, we set quality standards for the profession through training, education, assessments, examinations and continuous professional development.

Contact: Delia Mertoiu
5 Cambridge Court
210 Shepherds Bush Road
London W6 7NJ
Tel: 020 7603 6316
E-mail: info@ifst.org
Website: www.ifst.org

We are the UK's leading professional body for those involved in all aspects of food science and technology. We are an internationally respected independent membership body, supporting food professionals through knowledge sharing and professional recognition.

Our core aim is the advancement of food science and technology based on impartial science and knowledge sharing.

Our membership comprises individuals from a wide range of backgrounds, from students to experts, working across a wide range of disciplines within the sector.

Contact: Michelle Medhat
Institute of Innovation & Knowledge Exchange
Rex House
4 – 12 Regent Street
London SW1Y 4PE
www. InnovationInstitute.org.uk

IKE is the UK's professional body for innovators. It accredits and certificates innovation practices. We influence the inter-relationship between education, business, and government through research and collaborative networks. Our Innovation Manifesto highlights our commitment to support the development of innovative people and organisations. IKE runs think-tanks, conducts research, develops new business models and tools and supports organisations to benchmark their innovation capabilities.

Institute of Marine Engineering, Science and Technology (IMarEST)

Contact: Bev Mackenzie
Institute of Marine Engineering, Science and Technology (IMarEST), Aldgate House, 33 Aldgate High Street, London, EC3N 1EN
Tel: +44(0) 20 7382 2600
Fax: +44(0) 20 7382 2667
E-mail: technical@imarest.org
Website: www.imarest.org

Established in London in 1889, the IMarEST is a leading international membership body and learned society for marine professionals, with over 15,000 members worldwide. The IMarEST has an extensive marine network of 50 international branches, affiliations with major marine societies around the world, representation on the key marine technical committees and non-governmental status at the International Maritime Organization (IMO) as well as other intergovernmental organisations.

SCIENCE DIRECTORY

Institute of Measurement and Control

Contact: Steff Smith
Chief Executive
The Institute of Measurement and Control
297 Euston Road
London NW1 3AD
Tel: +44 (0) 20 73874949
E-mail: steff.smith@instmc.org
Website: www.instmc.org
Registration Charity number: 269815

The Institute of Measurement and Control is a professional engineering institution and learned society dedicated to the science and application of measurement and control technology for the public benefit. The InstMC has a comprehensive range of membership grades for individuals engaged in both technical and non-technical occupations. Also, it is licensed by the Engineering Council to assess and register individuals as Chartered Engineers (CEng), Incorporated Engineers (IEng) and Engineering Technicians (EngTech).

The InstMC works to develop the knowledge and skills of individual engineers, fostering communication and advancing the science and practices within the industry.

IOP Institute of Physics

Contact: Elizabeth Chamberlain
Head of Policy
Institute of Physics, 37 Caledonian Road, London N1 9BU
Tel: 020 7470 4824
E-mail: Elizabeth.Chamberlain@iop.org
Website: www.iop.org

The Institute of Physics (IOP) is the professional body and learned society for physics in the UK and Ireland. The IOP's mission is to raise public awareness and understanding of physics, inspire people to develop their knowledge, understanding and enjoyment of physics and support the development of a diverse and inclusive physics community. As a charity, the IOP seeks to ensure that physics delivers on its exceptional potential to benefit society.

IPEM

Contact: Philip Morgan (CEO)
Fairmount House,
230 Tadcaster Road,
York, YO24 1ES
Tel: 01904 610821
E-mail: phil@ipem.ac.uk
Website: www.ipem.ac.uk

IPEM is a registered, incorporated charity committed to our Mission of Improving Health through Physics and Engineering in Medicine. Our vision is one in which professionalism drives improvements in diagnosis, treatment and care, transforming the lives of patients. Our members, the professional community of medical physicists, biomedical engineers and clinical technologists working in hospitals, academia and industry around the world are the people who deliver our mission and vision. We work to support them through professional development, community and leadership initiatives, including training and CPD, events, campaigns, publications and scientific meetings. IPEM is licensed by the Science Council to award CSci, RSci and RSciTech, and by the Engineering Council to award CEng, IEng and EngTech.

IChemE

The Institution of Chemical Engineers

The Institution of Chemical Engineers (IChemE) advances chemical engineering's contribution worldwide for the benefit of society. We support the development of chemical engineering professionals and provide connections to a powerful network of around 35,000 members in 100 countries.

We support our members in applying their expertise and experience to make an influential contribution to solving major global challenges, and are the only organisation to award Chartered Chemical Engineer status and Professional Process Safety Engineer registration.

Alana Collis, Technical policy manager
+44 (0) 1788 534459
acollis@icheme.org
www.icheme.org

Kuala Lumpur | London | Melbourne | Rugby | Singapore | Wellington

IET The Institution of Engineering and Technology

Contact: Joanna Cox
IET
Michael Faraday House
Six Hills Way
Stevenage
SG1 2AY
Tel: +44(0)1438 765690
Email: policy@theiet.org
Web: www.theiet.org

The IET is a world leading professional organisation, sharing and advancing knowledge to promote science, engineering and technology across the world. Dating back to 1871, the IET has over 163,000 members in 127 countries with offices in Europe, North America, and Asia-Pacific.

LGC

Contact: Dr Julian Braybrook
Queens Road, Teddington
Middlesex, TW11 0LY
Tel: +44 (0)20 8943 7000
E-mail: info@lgcgroup.com
Website: www.lgcgroup.com

LGC is a global leader in the life sciences tools sector, including human healthcare and applied markets (food, agbio and the environment). LGC provides a comprehensive range of measurement tools, proficiency testing schemes, supply chain assurance standards and specialty genomics tools (oligos, PCR tools, NGS reagents), underpinned by leading analytical and measurement science capabilities. Under the Government Chemist function, LGC fulfils specific statutory duties as the referee analyst and provides advice for Government and the wider analytical community on the implications of analytical measurement for matters of policy, standards and regulation. LGC is also the UK's National Measurement Laboratory for chemical and bio-measurement.

With headquarters in Teddington, South West London, LGC has laboratories and sites across Europe, the US, China, Brazil, India, and South Africa.

L'ORÉAL UK AND IRELAND

Contact: Jagdeep Rai
Director of Scientific and Regulatory
Tel: +44(0)20-8762-4752
Email: jagdeep.rai@loreal.co.uk
Website: www.loreal.co.uk

L'Oréal employs more than 3,800 researchers world-wide and dedicates over €877 million each year to research and innovation in the field of healthy skin and hair. The company supports women in science research through the L'Oréal UNESCO For Women In Science Programme and engages young people with science through the L'Oréal Young Scientist Centre at the Royal Institution. L'Oréal also collaborates with a vast number of institutions in the UK and globally.

The LINNEAN SOCIETY of London

Contact: Professor Gail Cardew
Chief Executive Officer
The Linnean Society of London
Burlington House, Piccadilly,
London W1J 0BF
Tel: +44 (0)20 7434 4479 EXT 212
E-mail: gail@linnean.org
Website: www.linnean.org

As the world's oldest active biological society, the Linnean Society is an essential forum and meeting point for those interested in the natural world. The Society holds regular public lectures and events, publishes three peer-reviewed journals, and promotes the study of the natural world with several educational initiatives. The Society is home to a world famous library and collection of natural history specimens. The Society's Fellows have a considerable range of biological expertise that can be harnessed to inform and advise on scientific and public policy issues.

A Forum for Natural History

Marine Biological Association

Contact: Dr Matthew Frost
Marine Biological Association,
The Laboratory, Citadel Hill, Plymouth, PL1 2PB
Tel: 07848028388
Fax: 01752 633102
E-mail: matfr@mba.ac.uk
Website: mba.ac.uk

Since 1884 the Marine Biological Association has been delivering its mission *'to promote scientific research into all aspects of life in the sea, including the environment on which it depends, and to disseminate to the public the knowledge gained.'* The MBA represents its members in providing a clear independent voice to government on behalf of the marine biological community. It also has an extensive research programme and a long history as an expert provider of advice for the benefit of policy makers and wider society.

SCIENCE DIRECTORY

Institution of MECHANICAL ENGINEERS

Contact: Paul Haines
Head of Content & Communications
1 Birdcage Walk
London SW1H 9JJ
Tel: +44 (0)20 7304 6833
E-mail: P_haines@imeche.org
Website: www.imeche.org

The Institution provides politicians and civil servants with information, expertise and advice on a diverse range of subjects, focusing on manufacturing, energy, environment, transport and education policy. We regularly publish policy statements and host political briefings and policy events to establish a working relationship between the engineering profession and parliament.

Met Office

Contact: Kirsty McBeath
Met Office,
Fitzroy Road,
Exeter,
EX1 3PB
Email: kirsty.mcbeath@metoffice.gov.uk
Website: www.metoffice.gov.uk

The Met Office doesn't just forecast the weather on television. Our forecasts and warnings protect UK communities and infrastructure from severe weather and environmental hazards every day – they save lives and money. Our Climate Programme delivers evidence to underpin Government policy through the Met Office Hadley Centre. Our Mobile Meteorological Unit supports the Armed Forces around the world. We build capacity overseas in support of international development. All of this built on world-class environmental science.

MICROBIOLOGY SOCIETY

Contact: Policy Officer
Microbiology Society
14–16 Meredith Street
London EC1R 0AB
Tel: 020 3034 4870
E-mail: policy@microbiologysociety.org
Website: www.microbiologysociety.org

The Microbiology Society is a membership charity for scientists interested in microbes, their effects and their practical uses. It is one of the largest microbiology societies in Europe with a worldwide membership based in universities, industry, hospitals, research institutes and schools.

Our principal goal is to develop, expand and strengthen the networks available to our members so that they can generate new knowledge about microbes and ensure that it is shared with other communities. The impacts from this will drive us towards a world in which the science of microbiology provides maximum benefit to society.

NPL National Physical Laboratory

Contact: Dr James Claverly
National Physical Laboratory
Hampton Road, Teddington
Middlesex TW11 0LW
Tel: 020 8977 3222
Email: james.claverley@npl.co.uk
Website: www.npl.co.uk/contact-us

The National Physical Laboratory (NPL) is the United Kingdom's national measurement institute, an internationally respected and independent centre of excellence in research, development and knowledge transfer in measurement and materials science. For more than a century, NPL has developed and maintained the nation's primary measurement standards - the heart of an infrastructure designed to ensure accuracy, consistency and innovation in physical measurement.

NATURAL HISTORY MUSEUM
Advancing the science of nature

Contact: John Jackson
Head of Science Policy and Communication
Natural History Museum
Cromwell Road, London SW7 5BD
Tel: +44 (0)20 7942 5257
E-mail: j.jackson@nhm.ac.uk
Website: www.nhm.ac.uk

We challenge the way people think about the natural world – its past, present and future

We use our unique collection and unrivalled expertise to tackle the biggest challenges facing the world today.

We are leaders in the scientific understanding of the origin of our planet, life on it and can predict the impact of future change.

We study the diversity of life and the delicate balance of ecosystems to ensure the survival of our planet.

We help enable food security, eradicate disease and manage resource scarcity.

We inspire people to engage with science to solve major societal challenges.

University of Northampton

Contact: Nick Allen
Executive Officer, Office of the Vice Chancellor
University Drive, Northampton, NN1 5PH
Tel: 01604 735500
E-mail: nick.allen@northampton.ac.uk
Website: www.northampton.ac.uk

The University of Northampton is an institution committed to science education through initial teacher training, a STEM Ambassador network which works within the community and teaching and research to doctoral level. We are an Ashoka U 'Changemaker Campus' status university recognising our commitment to social innovation and entrepreneurship.

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Contact: Alex Miles
Deputy Director, External Relations
(Public Affairs)
University Park, Nottingham, NG7 2RD
E-mail: alex.miles@nottingham.ac.uk
Mobile: 07917115197
Twitter: @AlextoMiles
www.nottingham.ac.uk

With 43,000 students and campuses in Nottingham, China and Malaysia, The University of Nottingham is 'the nearest Britain has to a truly global university'. With more than 97 per cent of research at the University recognised internationally according to the Research Excellence Framework 2014, the University is ranked in the top 1% of the world's universities by the QS World University Rankings.

THE NUTRITION SOCIETY
Advancing Nutritional Science

Contact: Mark Hollingsworth
Chief Executive Officer
The Nutrition Society
10 Cambridge Court, 210 Shepherds Bush Road, London, W6 7NJ, UK
Email: office@nutritionsociety.org
Tel: +44 (0)20 7602 0228
www.nutritionsociety.org

The Nutrition Society is a not for profit, membership organisation which is dedicated to delivering its mission of advancing the scientific study of nutrition and its application to the maintenance of human and animal health. Highly regarded by the scientific community, the Society is one of the largest learned societies for nutrition in the world and anyone with a genuine interest in the science of human or animal nutrition can become a member.

The Physiological Society

Andrew Mackenzie
Head of Policy and Communications
Hodgkin Huxley House
30 Farringdon Lane
London EC1R 3AW
Tel: +44 (0) 20 7269 5728
E-mail: amackenzie@physoc.org
Website: www.physoc.org

As the largest network of physiologists in Europe, with academic journals of global reach, we continue our 140-year tradition of being at the forefront of the life sciences.

We bring together scientists from over 60 countries, and our Members have included numerous Nobel Prize winners from Ivan Pavlov to John O'Keefe.

SCIENCE DIRECTORY

Contact: Garry Graham,
Deputy General Secretary,
Senior Management Team
New Prospect House
8 Leake St, London SE1 7NN
Tel: 020 7902 6678
E-mail: Garry.Graham@prospect.org.uk
www.prospect.org.uk

Prospect is an independent, thriving and forward-looking trade union with over 120,000 members across the private and public sectors and a diverse range of occupations. We represent scientists, technologists and other professions in the civil service, research councils and private sector.

Prospect's collective voice champions the interests of the engineering and scientific community to key opinion-formers and policy makers. With negotiating rights with over 300 employers, we seek to secure a better life at work by putting members' pay, conditions and careers first.

QUADRAM INSTITUTE

Contact: Andrew Stronach
Head of External Relations
Quadram Institute, Rosalind Franklin Road.
Norwich, NR4 7UQ
Tel: 01603 255000
Email: andrew.stronach@quadram.ac.uk
Website: www.quadram.ac.uk

The £75m Quadram Institute opened in 2019 and is focused on fundamental and translational research into the interfaces between the gut microbiome, food, and human health. The Quadram Institute combines leading-edge bioscience capabilities with NHS endoscopy, clinical trials and biobank facilities. The Quadram Institute is a partnership between the Norfolk and Norwich University Hospital, University of East Anglia, Quadram Institute Bioscience and BBSRC.

Contact: Tom Exall
External Relations Manager
Royal Academy of Engineering
3 Carlton House Terrace
London SW1Y 5DG
Tel: 020 7766 0600
E-mail: tom.exall@raeng.org.uk
Website: www.raeng.org.uk

As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering. We have four strategic challenges: drive faster and more balanced economic growth; foster better education and skills; lead the profession; and promote engineering at the heart of society.

Contact: Office of the Science Directorate
Royal Botanic Gardens, Kew
Richmond, Surrey, TW9 3AB
Tel: 020 8332 5050/5248
Email: scienceadmin@kew.org
Website: www.kew.org

RBG Kew is a centre of global scientific expertise in plant and fungal diversity, conservation, and sustainable use, housed in two world-class gardens. Our scientific vision is to document and understand global plant and fungal diversity and its uses, bringing authoritative expertise to bear on the critical challenges facing humanity today.

Kew's strategic priorities for science are:

1. To document and conduct research into global plant and fungal diversity and its uses for humanity.
2. To curate and provide data-rich evidence from Kew's unrivalled collections as a global asset for scientific research.
3. To disseminate our scientific knowledge of plants and fungi, maximising its impact in science, education, conservation policy and management.

These priorities enable us to curate, use, enhance, explore and share Kew's global resource, providing robust data and a strong evidence base for our UK and global stakeholders. Kew is a non-departmental government body with exempt charitable status, partially funded by Defra.

Contact: Daniel Callaghan
Head of Public Affairs
The Royal Society, 6-9 Carlton House Terrace
London SW1Y 5AG.
Tel: 020 7451 2500
Email: daniel.callaghan@royalsociety.org
Website: www.royalsociety.org

The Royal Society is the academy of science in the UK and the Commonwealth comprising 1400 outstanding individuals representing the sciences, engineering and medicine. The Society has played a part in some of the most fundamental, significant and life-changing discoveries in scientific history and Royal Society scientists continue to make outstanding contributions to science across the wide breadth of research areas. Through its Fellowship and permanent staff, it seeks to ensure that its contribution to shaping the future of science in the UK and beyond has a deep and enduring impact, supporting excellence in science and encouraging the development and use of science for the benefit of humanity.

Contact: Dr Stephen Benn
Director of Parliamentary Affairs
Royal Society of Biology
1 Naoroji Street
London WC1X 0GB
Tel: 020 3925 3440
E-mail: stephen.benn@rsb.org.uk
Website: www.rsb.org.uk

The Royal Society of Biology is a single unified voice, representing a diverse membership of individuals, learned societies and other organisations. We are committed to ensuring that we provide Government and other policy makers – including funders of biological education and research – with a distinct point of access to authoritative, independent, and evidence-based opinion, representative of the widest range of bioscience disciplines. Our vision is of a world that understands the true value of biology and how it can contribute to improving life for all.

Contact: Matt Davies
Public Affairs Manager
Royal Society of Chemistry,
Thomas Graham House (290),
Science Park, Milton Road,
Cambridge, CB4 0WF
Tel 01223 438 322
Email daviesm@rsc.org
Website: www.rsc.org

The Royal Society of Chemistry is the world's leading chemistry community, advancing excellence in the chemical sciences. With over 50,000 members and a knowledge business that spans the globe, we are the UK's professional body for chemical scientists; a not-for-profit organisation with 170 years of history and an international vision of the future. We promote, support and celebrate chemistry. We work to shape the future of the chemical sciences – for the benefit of science and humanity.

Contact: Lucky Cullen
Policy, Public Affairs, and Diversity Manager
Salisbury House, Station Road, Cambridge
CB1 2LA
Lucky@sfam.org.uk
+44 (0)20 3880 2881

*Sf*AM utilises the expertise of its international membership to advance, for the benefit of the public, the application of microbiology to the environment, human and animal health, agriculture, and industry. Our values include equality, diversity and inclusivity; collaboration to amplify impact; scientific integrity; evidence-based decision-making and political neutrality. With Wiley-Blackwell, *Sf*AM publishes five internationally acclaimed journals.

Society for Underwater Technology

Society for Underwater Technology
Contact: Dr Cheryl Burgess
Chief Executive
HQS Wellington
Victoria Embankment, London WC2R 2PN
(correspondence address only)
T: +44 (0)7947 911992
www.sut.org
E Mail: jane.hinton@sut.org

The SUT is a multidisciplinary learned society that brings together individuals and organisations with a common interest in underwater technology, ocean science, and offshore/subsea engineering. The society was founded in 1966 and has members from over 40 countries, including engineers, scientists, other professionals and students working in these areas.

SCIENCE DIRECTORY

Society of Chemical Industry

SCI: where science meets business

Contact: Sharon Todd
SCI
14-15 Belgrave Square
London SW1X 8PS
Tel: 020 7598 1500
E-mail: sharon.todd@soci.org
Website www.soci.org

Established by Royal Charter in 1881, SCI is a unique multi-disciplinary community. Set up by a prominent group of forward thinking scientists, inventors and entrepreneurs, SCI continues to be a multi-science and industry network based around chemistry and related sciences. Our charitable objective is to promote links between science and industry for the benefit of society. Our passion is invention and creation.

We deliver our charitable objective by:

- Supporting the commercial application of science into industry
- Tackling global challenges across Agrifood, Energy, Environment, Health and Materials

Society of Cosmetic Scientists

Contact: Gem Bektas,
Secretary General
Society of Cosmetic Scientists
Suite 109 Christchurch House
40 Upper George Street
Luton Bedfordshire LU1 2RS
Tel: 01582 726661
Fax: 01582 405217
E-mail: secretariat@scs.org.uk
Website: www.scs.org.uk

Advancing the science of cosmetics is the primary objective of the SCS. Cosmetic science covers a wide range of disciplines from organic and physical chemistry to biology and photo-biology, dermatology, microbiology, physical sciences and psychology.

Members are scientists and the SCS helps them progress their careers and the science of cosmetics ethically and responsibly. Services include publications, educational courses and scientific meetings.

SMI
Society of Maritime Industries · UK

Contact: Tom Chant
Society of Maritime Industries
28-29 Threadneedle Street
London
EC2R 8AY
020 7628 2555
info@maritimeindustries.org
www.maritimeindustries.org

The Society of Maritime Industries (SMI) is the voice and champion of the UK maritime engineering, marine science & technology and business service sectors.

THE SOCIETY FOR RADIOLOGICAL PROTECTION

Contact: Tessa Harris
SRP, DS009 Dartington Hall
Dartington, Devon TQ9 6EN
Tel: 01803 866743
Email: admin@srp-uk.org
Website: www.srp-uk.org

The Society for Radiological Protection is the principal independent professional body for radiation protection in the UK. Its members operate in the fields of medicine, the nuclear power cycle and other industries, research, and teaching. We offer a profession-wide view to regulators and are involved in training and educational outreach. We ensure that professional standards are maintained at the highest levels.

UK INNOVATION & SCIENCE SEED FUND

Contact: Dr Andrew Muir
c/o STFC Innovations Ltd
Harwell Campus Oxford OX11 0QX
Tel: 0121 710 1990
E-mail: Andrew.muir@midven.co.uk
Website: https://ukinnovationscience seedfund.co.uk/

The **UK Innovation & Science Seed Fund** is a leading patient capital investor with more than £330 million private investment leveraged to date. The Fund works to build technology companies from the earliest stage by working closely with its partners led by STFC, BBSRC, NERC and Dstl, with the National Research and Innovation Campuses they support, and with entrepreneurial science-led teams. UK Innovation & Science Seed Fund is also closely aligned with the Catapults and InnovateUK, helping to commercialise key technological advances in industrial biotech, agricultural technology, healthcare, medicine, clean energy, materials, artificial intelligence, software and space.

Understanding ANIMAL RESEARCH

Contact: Chris Magee
Head of Policy and Media
Understanding Animal Research
Hodgkin Huxley House
30 Farringdon Lane, London EC1R 3AW
direct tel: 020 3675 1234
email: cmagee@UAR.ORG.UK
http://www.understandinganimalresearch.org.uk/

Understanding Animal Research is a not-for-profit organisation that explains why animals are used in medical, veterinary, environmental and other scientific research. We aim to achieve a broad understanding of the humane use of animals in medical, veterinary, scientific and environmental research in the UK. We work closely with policymakers to ensure regulation is effective and are a trusted source of information for the national and international media. We are funded by our members who include universities, professional societies, trade unions, industry and charities.

University of Essex

Contact: Dr Rob Singh
Deputy Director, Enterprise
Wivenhoe Park
Colchester CO4 3SQ
T 01206 874278
E rjsingh@essex.ac.uk
W www.essex.ac.uk/business

Established in 1964, the University of Essex is ranked as one of the Top 20 universities in the Research Excellence Framework and is awarded Gold in the Teaching Excellence Framework. It is home to world-leading expertise in analytics and data science, with research peaks spanning the social sciences, sciences, and humanities. Pioneers of quantitative methods and artificial intelligence techniques, Essex is also in the UK top 10 for Knowledge Transfer Partnerships, and works with businesses to embed innovation into operations, through KTPs, knowledge exchange and contract research.

Universities Federation for Animal Welfare

UFAW

Contact: Dr Robert Hubrecht OBE
Chief Executive and Scientific Director
The Old School, Brewhouse Hill
Wheathampstead, Herts. AL4 8AN.
Tel: 01582 831818. Fax: 01582 831414.
Email: ufaw@ufaw.org.uk
Website: www.ufaw.org.uk
Registered in England Charity No: 207996

UFAW, the international animal welfare science society, is an independent scientific and educational charity. It works to improve animal lives by:

- supporting animal welfare research
- educating and raising awareness of welfare issues in the UK and overseas
- producing the quarterly scientific journal Animal Welfare and other high-quality publications on animal care and welfare
- providing advice to government departments and other concerned bodies.

The Welding Institute

Contact: Chris Eady
The Welding Institute, Granta Park, Great Abington, Cambridge, CB21 6AL

Tel: 01223 899614
Fax:01223 894219
E-mail: chris.eady@twi.co.uk
Website: www.twi-global.com

The Welding Institute is the leading institution providing engineering solutions and knowledge transfer in all aspects of manufacturing, fabrication and whole-life integrity management.

Industrial membership provides access to innovative problem-solving from one of the world's foremost independent research and technology organisations.

Non-Corporate services include membership and registration, education, training and certification for internationally recognised professional development and personnel competence assurance.

TWI provides Members and stakeholders with authoritative and impartial expert advice, knowhow and safety assurance through engineering, materials and joining technologies.

SCIENCE DIARY

PARLIAMENTARY AND SCIENTIFIC COMMITTEE – ALL-PARTY PARLIAMENTARY GROUP

Email: office@scienceinparliament.org.uk
www.scienceinparliament.org.uk
follow us on Twitter @ParlSciCom

FORTHCOMING DISCUSSION AND OTHER MEETINGS

Monday 31st October
Discussion Meeting on
Net Zero and the role of engineering
In partnership with the Institution of Mechanical Engineers
5.30pm to 7.00pm, Palace of Westminster

Monday 28th November
Discussion Meeting on
COP27: Physiology, health and the fight against climate change
In partnership with The Physiological Society
5.30pm to 7.00pm, Palace of Westminster

Wednesday 14th December
Christmas Parliamentary Reception
Attlee Suite, Portcullis House
6.00pm to 8.00pm

Monday 16th January 2023
Discussion Meeting topic and details to be advised
In partnership with UKRI
5.30pm to 7.00pm, Palace of Westminster

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

Tuesday 1st November 2022
Leadership in Tomorrow's World
Foundation Future Leaders Conference 2022
9:00am – 4:00pm Glaziers Hall,
9 Montague Close, London SE1 9DD
For full details of upcoming events:
www.foundation.org.uk/events/upcoming
office@foundation.org.uk

THE PHYSIOLOGICAL SOCIETY

Wednesday 2nd November
Report Launch:
How can we develop a National Ageing Workforce Strategy?
2.00pm to 5.00pm, Churchill Room, Palace of Westminster
For further details, please contact:
spande@physoc.org

ROYAL SOCIETY OF BIOLOGY

For further details please contact
Karen Patel: events@rsb.org

ROYAL SOCIETY OF CHEMISTRY

For further details please contact
events@rsc.org

ROYAL SOCIETY

Details of all events can be found on the events calendar at events@royalsociety.org
For scientific meetings queries:
scientificmeetings@royalsociety.org

SCIENCE IN PARLIAMENT sip
2nd Floor,
201 Great Portland Street,
London W1W 5AB
Correspondence to:
office@scienceinparliament.org.uk

www.scienceinparliament.org.uk
Editor: Leigh Jeffes
Design Consultant: Mrs Val Warby
Printed by Premier Print Group Ltd

Published by Parliamentary and Scientific Committee – All-Party Parliamentary Group, 2nd Floor, 201 Great Portland Street, London W1W 5AB. Correspondence address: 1 Lych Gate Walk, Hayes, UB3 2NN. Published four times a year.
The 2021 subscripton rate is £80. Single numbers £20. ISSN 0263-6271

The Parliamentary & Scientific Committee's STEM for BRITAIN 2023 takes place on Monday 6th March, in the Attlee Suite, Portcullis House, House of Commons, during British Science Week

Applications are invited from from early-career research scientists, engineers, technologists and mathematicians who wish to exhibit posters in one of the following areas:

- Biological and Biomedical Sciences
- Chemistry
- Engineering
- Mathematics
- Physics

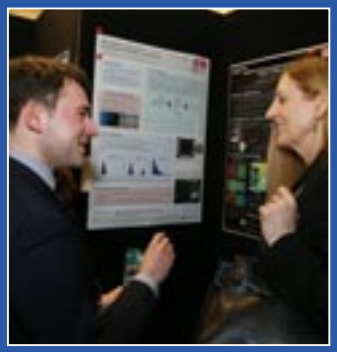
The closing date for applications is Monday 28th November 2022.

A wide range of important scientific, engineering and mathematics institutions and organisations are lending their support to this event, including the Institute of Physics, The Physiological Society, the Nutrition Society, the Royal Society of Chemistry, the Royal Academy of Engineering, the Council for the Mathematical Sciences, the Royal Society of Biology, Dyson Ltd, Warwick Manufacturing Group, the Institute of Biomedical Science, the Clay Mathematics Institute, British In Vitro Diagnostics Association, the Heilbronn Institute, United Kingdom Research and Innovation, the Biochemical Society, and the Society of Chemical Industry.

This reflects the importance we all attach to the encouragement of researchers at this stage in their careers.

Prizes will be awarded for the posters presented in each discipline which best communicates high level science, engineering or mathematics to a lay audience.

The Westminster Medal, will be awarded in memory of the late Dr Eric Wharton, who did so much to establish SET for Britain as a regular event in the Parliamentary calendar.



For further information, please go to www.stemforbritain.org.uk