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

SCIENCE IN PARLIAMENT
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AUTUMN 2020

The Parliamentary & Scientific Committee's STEM for BRITAIN 2021 is scheduled to take place ONLINE on Monday 8th March, during British Science Week

Applications are invited from Monday 19th October 2020 from early-career research scientists, engineers, technologists and mathematicians who wish to exhibit posters in one of the following five areas:

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

The closing date for applications is Monday 14th December.

A wide range of important scientific, engineering and mathematics institutions and organisations are lending their support to this event, including the Royal Society of Biology, the Institute of Physics, The Physiological Society, the Royal Society of Chemistry, the Royal Academy of Engineering, the Council for the Mathematical Sciences, the Institute of Biomedical Science, the Clay Mathematics Institute, the Nutrition Society, the Heilbronn Institute, Warwick Manufacturing Group, United Kingdom Research and Innovation, IEEE Communications Society, 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 communicate high level science, engineering or mathematics to a lay audience.

The Westminster Medal for the overall winner 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.

In addition to the online series of results events during the course of the 8th March, we hope to host, under our Chair, Stephen Metcalfe MP, an in-person ceremony in the Palace of Westminster in the latter half of next year, to which winners, supporters and Parliamentarians will be invited.

From Monday 19th October full details of the competition and exhibition including the application form can be found on the STEM for Britain website at: www.stemforbritain.org.uk.

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

Welcome to Autumn 2020 edition of Science in Parliament

A very warm welcome to the Autumn 2020 edition of our journal.

In this, larger than usual, 52-page issue we have, in addition to our usual features a great range of articles predominantly covering aspects of COVID-19, but also dealing with the increasing of the Government's public research budget for 2024/25; science education; non-tumour cancers and genomics; and the low carbon energy transition.

I thank each of our first class contributors, and particularly want to welcome to these pages, Dame Ottoline Leyser, who was appointed as Chief Executive of UKRI at the end of June.

Dr Stephen Benn has included a report on the annual Parliamentary Links Day in July, for which I was very pleased to chair a distinguished panel of speakers.

Our online discussions, which began in June, have proceeded apace with the P&SC Autumn/early Winter programme, and between September and early December there will have been seven of these events.

Since the publication of our last *Science in Parliament,* I have been very pleased to chair two excellent discussions. Firstly, on the 14th September, when the topic was 'Non-Cancer Tumours, Precision Medicine and Genomic Mapping'.

Our speakers were: Sarah McDonald, Director of Research and Patient Advocacy, Myeloma UK; Dr Karthik Ramasamy, Associate Professor of Haematology and Consultant Haematologist, Churchill Hospital, Oxford University and Oxford University Hospitals NHS Trust; Dr Inês Cebola, Group Leader, Regulatory Genomics and Metabolic Disease, Department of Metabolism, Digestion and Reproduction, Imperial College London; and Dr Ian Frayling, Honorary Senior Clinical Research Fellow, Institute of Medical Genetics, University Hospital of Wales. We are grateful to each for their talks and for penning an article for this edition.

My thanks also to Myeloma UK, the Royal College of Pathologists and Imperial College for their assistance with setting up the discussion.

On the 28th September, Baroness Brown of Cambridge, President of STEM Learning UK; Allie Denholm, Headteacher, Heworth Grange School, Gateshead; and Donald Morrison, Senior Vice-President & General Manager for People, Places and Solutions, Europe, Middle East and Africa, Jacobs Engineering UK Ltd, addressed us on the subject of 'Science education: supporting the UK as a science superpower'.

We are grateful to STEM Learning UK, for facilitating this discussion and to our speakers from the last two discussions, including those who have contributed to this issue.

For members who have missed these events, I am pleased to say that they have been recorded on YouTube and this will be the case for future meetings.

We will continue with our programme of virtual discussions at least until the State Opening of Parliament at the end of May 2021.

During the Summer, Leigh Jeffes embarked upon a targeted membership campaign and I am delighted to say that at the time of going to press 20 organisations have accepted an invitation to join P&SC.

It is therefore my pleasure to welcome the following who have completed the membership application process:

Scientific and Technical Organisations: British Computer Society; Chartered Society of Forensic Science; Knowledge Transfer Network (KTN); The Learned Society of Wales/Cymdeithas Ddysgedig Cymru; National Numeracy; National Institute of Economic and Social Research (NIESR) and STEM Learning UK.

Universities: Edinburgh Napier University; Glasgow Caledonian University; Teeside University; Ulster University; and the University of West London.

I am also delighted to welcome, as an individual member to P&SC, Professor Chris Rapley CBE, Professor of Climate Science at University College London, and former Director of the Science Museum and the British Antarctic Survey.

With best wishes.

SCIENCE IN PARLIAMENT
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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.

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THE IMPORTANCE OF THE MEASUREMENT INFRASTRUCTURE IN ECONOMIC RECOVERY FROM COVID-19

Dr Richard Brown
Head of Metrology, National Physical Laboratory

Richard Brown has worked at the National Physical Laboratory, the UK's National Metrology Institute, for 20 years having joined following his PhD at Imperial College London. He is currently NPL's Head of Metrology, with accountability for ensuring the quality of NPL's scientific output and for overseeing the accuracy of the UK's national standards of measurement, ensuring their comparability internationally, and enabling their dissemination through the UK's measurement quality infrastructure.

MEASUREMENT TODAY

Measurement is a fundamental activity which is invisible day-to-day, but supports the economy by underpinning science, technology, medicine, trade and industry. We actively use the products and services which are enabled by measurement science every day, because we have trust in their standards. This confidence does not happen by accident but is a result of a well-established infra-technology – our measurement infrastructure, which is based on a globally agreed system and implemented locally. It is an invisible glue that binds together science and technology and enables all progress. Metrology, the science of measurement, oversees the maintenance and improvement of the measurement infrastructure, continually responding to evolving societal needs.

The National Physical Laboratory (NPL) is the UK's National Metrology Institute (NMI). It holds the UK's measurement standards and is one of the six laboratories who make up the National Measurement System (NMS). This system provides the underpinning measurement infrastructure and technologies that are essential for enabling science, innovation, research and development, as well as facilitating trade. The measurement infrastructure is vital to the UK economy, for example due to its role in maintaining standards which enable trade, as well as by supporting industry to innovate. As a result, measurement science has a key role to play in accelerating the economic recovery from COVID-19, including in emerging sectors such as the digital economy.

MEASUREMENT SCIENCE CREATES THE FOLLOWING BENEFITS:

Measurement improves the effectiveness of science and R&D	The efficiency with which generic knowledge is converted into proprietary knowledge depends on access to research tools, techniques, and standards (Tassey, 2004). These core tools are public goods, known as infra-technologies, and determine the productivity of private R&D. NPL economists make the case that for the UK to achieve its target of investing 2.4% GDP into R&D, designed to boost productivity, businesses need to invest more in R&D (King & Renedo, 2020). It proposes that, to encourage this investment from industry, policy makers should invest in the infra-technologies which support R&D. Investment into measurement infrastructure technologies can support innovation and productivity by reducing the risks for businesses investing in R&D and optimising the process [1].
Measurement creates trust in the outcomes of R&D and innovation	Accessing reputable measurement services provides businesses and academics with greater confidence in their R&D. This confidence is then extended to others, who have greater assurance that the research or product is reliable, by virtue of its inventor's association with the reputation of the NMS labs. These factors enable private sector organisations to continue their innovation drive, and academics to continue research with confidence and trust from others. *"… by pinning NMS's reputation to our measurements, we are able to back up the claims we are making."* – NMS lab user

NPL National Physical Laboratory

Measurement improves efficiency of businesses by reducing waste, increasing productivity and value for money	Around 75% of all errors that occur in production are pre-determined in the earliest phases of manufacturing (Kunzmann et al., 2005). However, 80% of these failures are not detected until either the manufacturing process or after sale. Advanced metrology allows manufacturers to reduce their scrap-rates, by creating tighter production processes with better control of parameters that influence the quality of a final product (Orji et al., 2009). Secondly, between 2009 and 2017, there was a 5.5% increase in employment among businesses receiving regular support from the NMS (Belmana, 2020). Around 80% of this growth was additional, not seen in a matched control group, and employees moving to these NMS supported businesses received an annual wage premium of £2,600. This indicates measurement creates significant productivity benefits for industry.
Measurement accelerates innovation, getting products to market faster	To maximise productivity, the products of R&D need to be commercialised and brought to market as quickly as possible (Hawkins, 2017). A key driver in accelerating this process is giving potential customers or regulators confidence that a new technology works as well as its owner claims it does. Standards and accreditation are delivered through established methods for testing the performance of a product or process, which are rooted in measurement certainty. A survey of NMS users between 2014 and 2017 displayed the role of measurement in accelerating products to market. 80% of the NMS labs' business customers made a change to their products or processes, with 1 in 5 saying the change would not have happened without the support they received from the NMS labs. Similarly, the previous Measurement for Innovators programme, run by the NMS labs to provide free support to innovative businesses, found that businesses who completed the programme were around 11% more likely to file for a patent compared to comparative similar firms (Nwaigbo & King 2020).
Enables change to happen quickly, adding value	The efficiency or speed with which one type of knowledge is converted into another type of knowledge depends on having good access to appropriate research tools, techniques, and standards (King et al., 2017). These elements form the infra-technology needed for the reproducibility of experiments. Where supporting infra-technologies are not available, industry has a low success rate for knowledge transfer and commercialisation, as seen by biotech firms across the 1980s and 1990s (Tassey, 2004). For example, in 2005, only 12 of the 50 largest biotech companies were profitable and the industry was losing money, 25 years after the formation of the first company, Genetech.
Essential for the development and assessment of evidence-based policy	Measurement science provides vital evidence which underpins many policies. In 2015, a team aimed to fingerprint emissions from six municipal waste incinerators, and test for traces of these in ambient air samples. The analysis used metrology to detect of this, and found no evidence of incinerator emissions in ambient metal concentrations around four UK waste incinerators (Font et al., 2015). The conclusions of this paper were used in Parliamentary briefing notes on waste incineration facilities, as well as for the incineration of industrial and commercial waste.

MEASUREMENT FOR RECOVERY (M4R)

Increasing the adoption of better measurement will provide significant competitive advantage for the UK, as all nations now begin their recovery from COVID-19. It can help to accelerate the UK's recovery, making up for lost time and ensure resiliency for any future or further disruption. Running until the end of 2020, the BEIS funded Measurement for Recovery (M4R) programme [1] delivered by NPL and NMS partners [2] will provide 300 – 400 businesses with access to world-leading experts in testing and measurement, providing them with advice or short consultancies to support their response and recovery activities, free of charge. Within the first two months of the programme there have been nearly 150 applications from businesses across the UK with representation in England, Scotland and Wales.

MEASUREMENT FOR THE FUTURE

Whilst the measurement infrastructure supports all aspects of the physical world, there are several emerging sectors which go beyond the physical and have unique infra-technology needs. These topics include big data and the digital world, clean growth and achieving net zero carbon emissions by 2050, artificial intelligence, industry 4.0 and future communications, personal medicine and the ageing population.

As a result of their data intensive nature, these topics are not covered by the traditional measurement infrastructure, whose history evolved from the physical world of weights and measures. However, they require the stability and control that the application of measurement science brings, in order to advance rapidly. As a result, NPL has identified the need for the implementation of a new measurement infrastructure to unleash the potential of these emerging technologies and sectors which will revolutionise the society and economy. This new framework would build on the traditional measurement infrastructure to create a novel approach, not involving physical measurement standards.

THE INFRASTRUCTURE FOR THE FUTURE WILL CREATE THE FOLLOWING BENEFITS:

- Provide the focus for national and **global leadership in the development, validation and agreed standardisation of measurement methods**, making the UK a world leading superpower in these areas with a competitive advantage over other economies.
- The underpinning and flexible nature of this new measurement infrastructure

would be agile and universal, able to apply its principles to support, at short notice, new demands on the economy and UK government, providing **resilience to cope with any future national requirements or crises**. This would future proof the UK to flexibly develop and support yet-to-be-conceived technologies.

- The system will enable faster, more productive and efficient transfer of science into innovation to disseminate best practice for data assessment, interpretation, curation and reuse. It will form a new national infra-technology that supports technologies and challenges equally.
- It will place innovation at the heart of economic recovery and future growth and accelerate progress towards the government's 2.4 % R&D target.
- Lastly, a digital infrastructure will provide equal support across the regions and nations of the UK, supporting the levelling up agenda, as well as a progressive approach that ensures the UK attracts and retains a highly skilled, diverse workforce.

This proposed world leading measurement infrastructure is essential to the rapid, harmonious and widespread adoption of the digital economy, made even more crucial now as the UK seeks to recover from COVID-19. Read further evidence in Richard Brown's 2020 paper.

Footnotes

1 https://www.npl.co.uk/measurement-for-recovery

2 https://www.npl.co.uk/measurement-for-recovery/partners

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COVID-19: LESSONS TO BE LEARNED FROM PARLIAMENTARY SCRUTINY

The Right Honourable Greg Clark MP

Chair of the House of Commons Science and Technology Committee

Throughout the course of civilisation, great changes—societal shifts, wars, revolutions—have engendered great innovation in medicine, technology and automation. It is a privilege to Chair the House of Commons' Science and Technology Committee. Our country has a rich tradition of scientific discovery and is recognised around the globe as a world leader in scientific advancement. Perhaps now more than ever, the world appreciates the true importance of science and technology in our society, be it the video platforms connecting us with our loved ones, the software allowing some of us to continue to work from the safety of our homes, or the tireless work of medical researchers around the world racing to develop vaccines to help in our fight against COVID-19.

The times we are living through are unprecedented in our lifetimes. During the last six months the whole country witnessed the tireless work of NHS staff, civil servants, researchers and indeed all key workers. I speak not only for myself but for all of my colleagues when I say that their work is truly recognised by the Committee.

Yet much as crises spark innovation, they also deliver valuable lessons. In early March,

my Committee and I spoke privately with eminent scientists, epidemiologists and vaccinologists to assess the seriousness of what we could already begin to see was a rapidly escalating global health emergency. From there, it was clear that we would need to embark on an inquiry that would scrutinise the Government's response to our own COVID-19 outbreak.

I should make clear that the purpose of our inquiry has never been to cast a finger of blame. Rather, as a Committee which is able to scrutinise many Government departments, we are in the privileged position of being able to survey the spectrum of Government policy and assess the scientific evidence base on which decisions are made. Our place within Parliament has allowed us to take evidence from education, health and technology bodies, experts advising the Government and independent thinkers. It was clear to me that we needed to collect all of this information even as the pandemic took its course around us. Whilst it may be easy to lament missed opportunities or find reasoning for decisions taken in hindsight, the contemporary nature of Parliamentary scrutiny is one of its greatest strengths — forcing policymakers to consider the outcomes of their decisions before they are taken.

The inquiry has always sought to assess the UK's place within the global science community. Perhaps uniquely, the pandemic has both brought the world's scientists together and highlighted national differences. My Committee cast around the globe for answers and opinions, speaking with great interest to world-leaders in epidemiology, economic theory, biostatistics and public health. While clearly many factors — geography, culture, leadership style and policy decisions — have affected various countries' outcomes to date, hearing from scientists in Germany, South Korea and Sweden brought to light various ideas, strategies and actions from which the UK might learn. The international community's differing approaches to and reflections on controlling the outbreak were invaluable in informing my Committee's own views.

In May, my Committee and I wrote to the Prime Minister. It is common practice to wait until the end of an inquiry to present findings and recommendations to Government, but these were not normal times. There were specific lessons already to be learned that were imperative to implement without delay. Notably, and still pertinently as we head into the winter, it was apparent that testing and contact tracing capacity and capability needed to be urgently scaled up. Clearly, this is something that the Government has been necessarily prioritising, as national lockdown has lifted and restrictions eased somewhat, enabling the economy to re-open and a semblance of a normal life to resume.

We were also pleased to see that the Government accepted our recommendation to increase the transparency around its decision-making. The publication of SAGE papers, along with the names of most of those attending SAGE meetings, is of great importance in building public trust that decisions that are being taken are well informed.

Our other recommendations are issues which remain to date. While we still struggle to provide the required magnitude of testing, I would urge the Government to make full use of available public and private sector laboratories. This will, I believe, also be crucial in the situation where effective vaccines are developed, and the UK must be prepared for such an eventuality.

The power of Select Committees is largely through their collaborative nature, and my colleagues from my own and other parties have been instrumental in raising their own questions and concerns during our evidence sessions. In our next report, which we will publish this autumn, we will present our findings and recommendations to Government.

I hope that my Committee's findings will be useful in informing policy as we continue to live with COVID-19. The effect of the pandemic has important implications for our other inquiries. We are considering the Government's proposal for a new funding agency for UK research inspired by the US Advanced Research Projects Agency (ARPA). One of our eminent witnesses has recommended that it should take as its mission and focus a response to the global pandemic we are living through. Equally, our inquiry into 5G, and how the UK might build up domestic telecommunications infrastructure capability, will be in the context of the increasing reliance on communications that the crisis has brought about. Our newest inquiry will explore to what extent our renowned research and innovation sector can help to bolster economic recovery, and how to achieve that end.

However, I am mindful that the pandemic is far from over, and that Parliamentary scrutiny will still be required as the Government continues to navigate its way through COVID-19. Along with the Health and Social Care Select Committee, the Science and Technology Committee will continue to investigate policy decisions and hold evidence sessions. The new joint inquiry will bring together the skillsets and interest areas of colleagues across the House, and will ensure that the Government is held to account as the situation evolves. □

HOW THE UK'S SYNCHROTRON HAS BEEN HELPING SHED LIGHT ON COVID-19

Isabelle Boscaro-Clarke
Diamond Light Source

Over the past few months, scientific research on the SARS-CoV-2 virus which causes the disease COVID-19, has been a global priority. During this time, Diamond Light Source, the UK's national synchrotron, has collaborated tirelessly with the international and national scientific community to understand more about the virus and how we can combat it. Diamond are looking at the fundamental interactions of the virus, from which it is hoped new therapies can be developed. But it is also studying how existing drugs, that have already been tested and approved for other diseases, can be repurposed and used to treat patients. The array of specialised facilities at Diamond allow for many different techniques to be used, from looking at the structure of the virus and fitting drugs into it, like a tiny jigsaw puzzle, to taking direct images of the virus without its infectious component, so we can see how it interacts with drugs.

During the entire lockdown period it was not 'business as usual', as the synchrotron was solely devoted to COVID-19 research. However, as lockdown has eased services have now been expanded and include other Life Sciences research and programmes on other infectious diseases and illnesses that research teams need access to the facility to progress with a view to ramp-up operations in the physical sciences from Summer 2020 onwards.

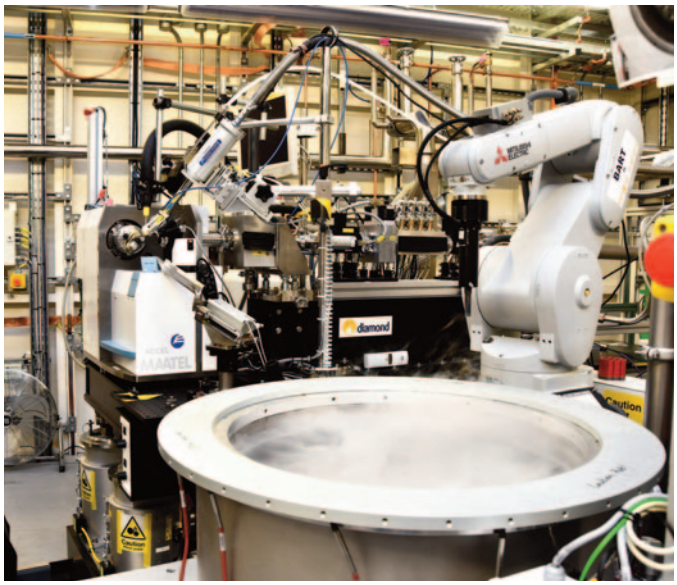
In addition to this, to facilitate the fastest dissemination of research at this critical time, it has not followed the usual research pathway of waiting for the publication of papers about research in peer-reviewed journals before releasing data. Through scientific collaboration, Diamond and its users have made (and are continuing to make,) data and results available in real time. Their goal is to share information as rapidly as possible to help inform the scientific community and wider public.

This article summarises the work and achievements to date of Diamond and its various international collaborators in the global challenge to find solutions to the worldwide pandemic:

WHY IS DIAMOND SO VALUABLE TO THE GLOBAL EFFORTS?

Diamond is one of the most advanced scientific facilities in the world. Funded by the UK Government through the Science and Technology Facilities Council (STFC) and by the Wellcome Trust, it provides the industrial and academic user communities with access to state-of-the-art analytical tools to enable world-changing science.

Shaped like a huge ring, the synchrotron works like a super-sized microscope. It accelerates electrons to near light speeds, to produce a light 10 billion times brighter than the Sun. This is then directed off into 33 laboratories known as 'beamlines'. This very intense light, predominantly in the X-ray region, (10 billion times brighter than the sun) can then be used to study minute matter such as atoms and molecules.



Beamline I04-1 Experimental Hutch - Sample changer and sample environment 2 – *Copyright of Diamond Light Source Ltd.*

SO WHAT HAS THE UK'S SYNCHROTRON BEEN DOING TO ADVANCE COVID-19 RESEARCH?

Diamond's research is centred on drug targets for COVID-19. The focus is mainly on the virus spikes, the receptor binding and the main protease. One specific part of its work, in conjunction with the University of Oxford, has been to look at these spikes on the outside of the virus.

Together, with a group at a hospital in Taiwan, they identified antibodies from a convalescent patient that could create a real potential for a drug target. This finding was valuable because it came from real patients who have the virus. Research about llamas' antibodies and SARS antibody CR3022 provided insights too. More on this to follow.

Further, the level of research automation offered by Diamond's synchrotron facility opened up ultra-high throughput screening methods. For example, the XChem platform's fragment screening capabilities enabled the interaction of many chemical fragments with potential drug targets within the virus to be analysed in great detail in a short amount of time.

To put fragment screening into context, it is one of the newest and most exciting techniques that offers scientists, who design new medicines, something unique: a glimpse into the future. With fragment screening, scientists can get away with testing only a few hundred tiny chemicals, what they call 'fragment compounds', to see if any of them might be the foundation for what could eventually become a new drug.

Fragment research is a recent and burgeoning field and can help produce drugs quicker, cheaper and smarter than before – critical at a time like this when finding new therapies is the focus of the scientific community. Diamond allows structural biologists to screen up to 500 structures daily. This is transforming the use of information for drug development, as information can be produced at a rate that can feed directly into chemical synthesis.

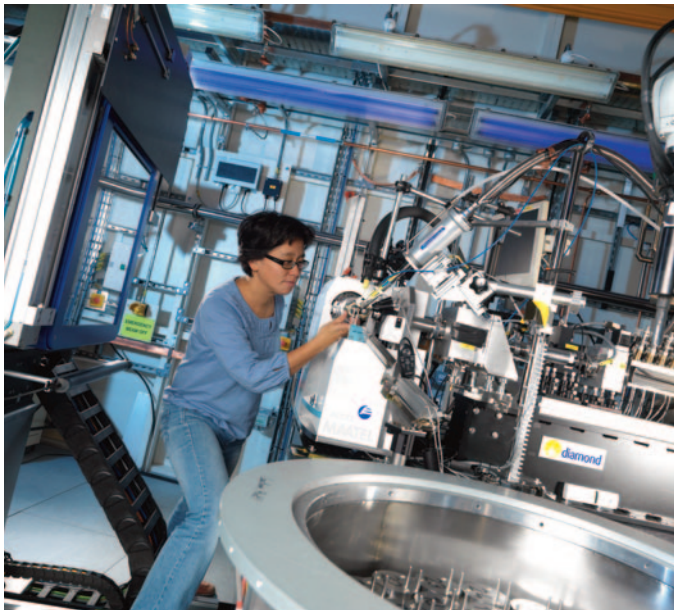
GLOBAL COMMITMENT, COLLABORATION, RESEARCH & RESULTS

As part of this acceleration, Diamond mobilised a concerted effort to collaborate on a global scale. This has involved seven researchers at Diamond (Walsh and von Delft groups), researchers from the Weizmann (London group) and Exscientia Ltd, among many others. It also established links with Public Health England (Carroll group), Shanghai (Rao group), Beijing (Wang group) and the University of Oxford (Owens group).

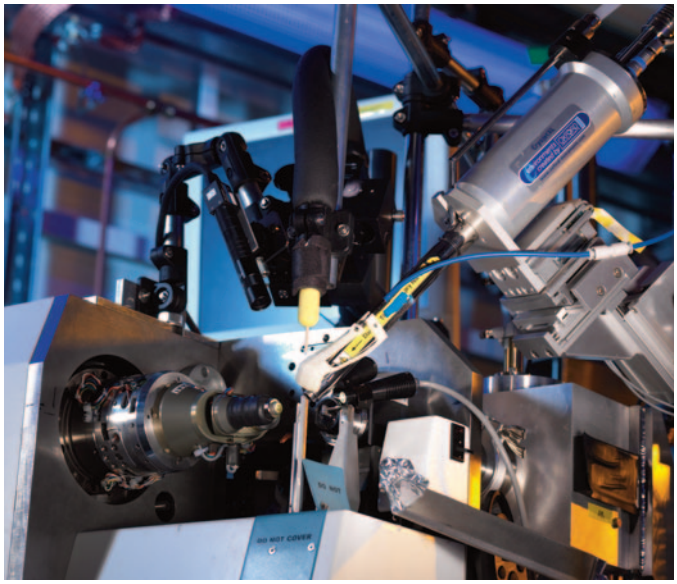
Many of the scientists on the seven beamlines kept them running all through lockdown, often with little sleep, as part of a genuine commitment to form part of global efforts to find solutions.

EXSCIENTIA, CALIBR AND OXFORD UNIVERSITY

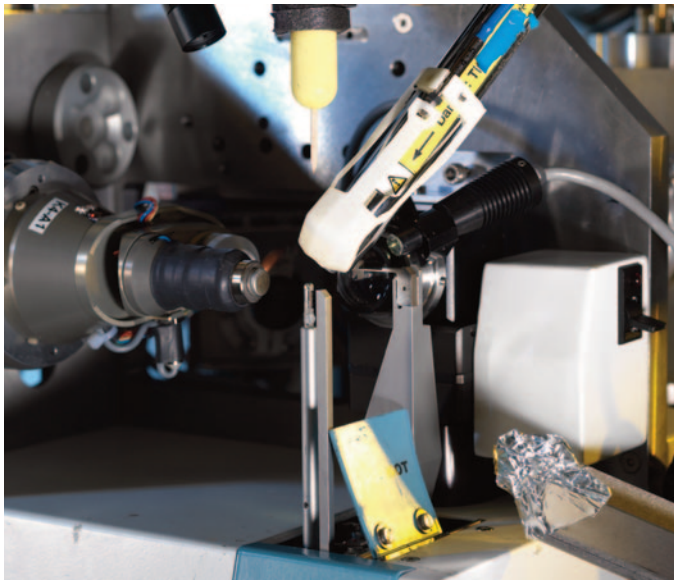
Starting in March, Diamond minimised the travel and number of people on site and suspended other user operations so that only COVID-19 research took place at the facility during the UK lockdown period. Importantly, Diamond also announced a joint initiative with Exscientia, the leading artificial intelligence (AI) driven drug discovery company and Calibr, the drug development division of Scripps Research, to search



Alice Douangamath, Senior Beamline Scientist I04-1 – *Copyright of Diamond Light Source Ltd.*



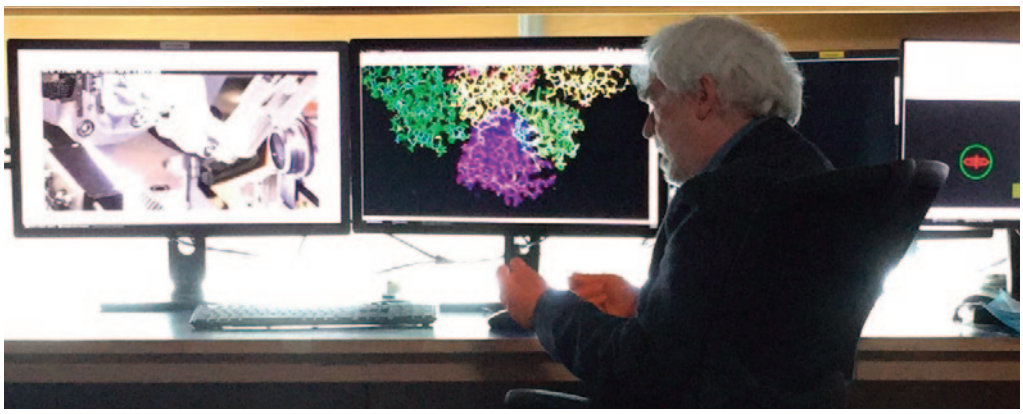
Beamline I04-1 Sample Environment – *Copyright of Diamond Light Source Ltd*



Beamline I04-1 Sample Environment 2 – *Copyright of Diamond Light Source Ltd.*

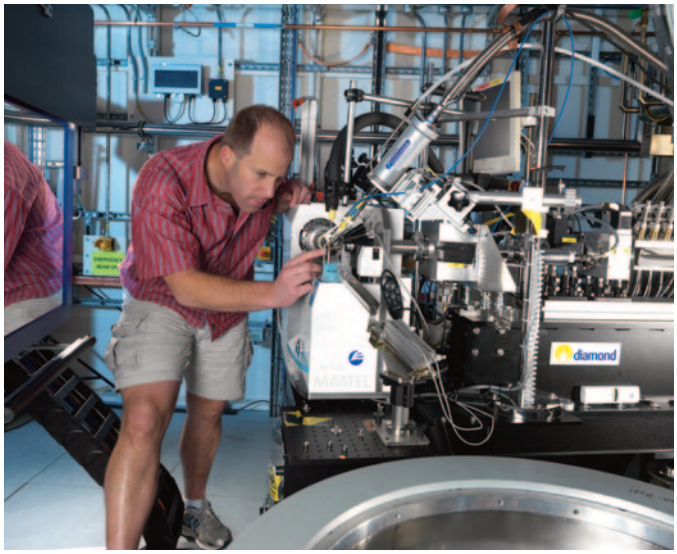
for clinically approved drugs that could be viable clinical drug candidates for the rapid treatment of COVID-19.

Through using Diamond's research on COVID-19 at its facilities, Exscientia screened nearly every known approved and investigational drug - 15,000 clinical drug molecules - against COVID-19 drug targets to search for rapid treatments. Additionally, Diamond and Oxford University have worked together since January to develop methods to produce the viral proteins for drug screening and structural analysis. This is providing atomic levels of detail in understanding how anti-viral drugs can work against the virus. Dr Martin Redhead, Head of Quantitative Pharmacology at Exscientia, carried out the analysis and commented at the time: *"Given the ever-expanding scale and rapid speed at which COVID-19 is spreading, one of the most urgent needs right now is to find ways to discover an existing drug we can repurpose to treat the virus, at speed and at scale. The Scripps Research collection allows us to screen nearly every drug that has been tested in human clinical trials, against a number of virus drug targets."*



Professor David Stuart & I03 Beamline - Director of Life Sciences at Diamond Light Source – *Copyright of Diamond Light Source Ltd.*

Prof. Dave Stuart FRS is Director of Life Sciences at Diamond Light Source and Joint Head of Structural Biology at the Department of Clinical Medicine at the University of Oxford. He is co-ordinating the efforts between Diamond Light Source and Oxford University along with colleagues, Dr Martin Walsh and Dr Jonathan Grimes. He added: *"The drugs we are testing have either been approved by the FDA for other diseases or have been extensively tested for human safety. By being able to repurpose existing molecules, we can save a lot of time in the drug discovery process, meaning a faster route to clinical trials, and potentially to treatment for patients."*



Frank von Delft, Principal Beamline Scientist I04-1 *Copyright of Diamond Light Source Ltd.*

THE COVID MOONSHOT INITIATIVE: DRIVING PROGRESS COLLABORATION

In April, Diamond Light Source, PostEra Inc. and an international group of scientists from academia and industry teamed up to form a new, ground-breaking non-profit initiative – the COVID Moonshot. The name is derived from its unprecedented aim to develop a clinically effective antiviral more rapidly than ever before; by crowdsourcing designs of new inhibitors from chemists around the world, mining the rich "fragment" data measured at Diamond in record time during March and April. All this data will be released in real time and in the open to enable worldwide collaboration and rapid progress.

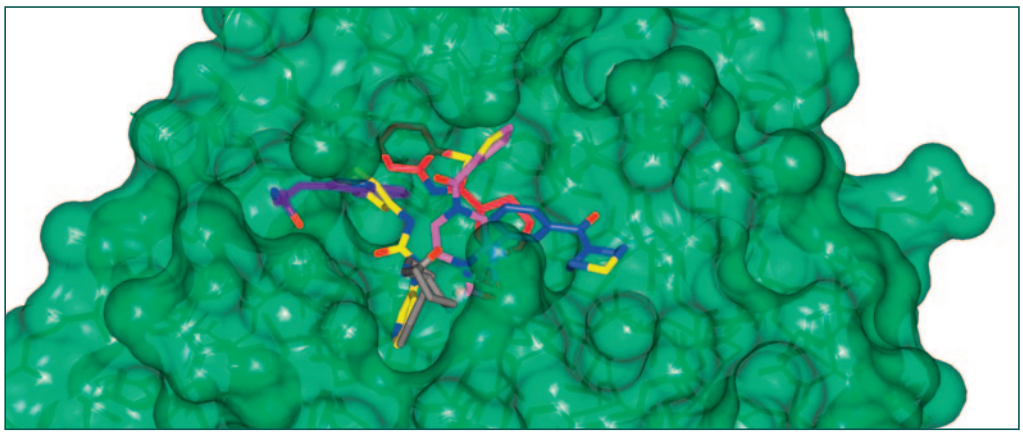
This collaboration of international scientists is working together to find new ways of tackling the COVID-19 challenge and have created a clear design-to-clinic strategy and timeline. Chemists were called on to come up with new molecules and to have practical input towards the global efforts to combat COVID-19. Researchers could submit their designs to PostEra, who were running machine learning algorithms in the background to triage suggestions and generate synthesis plans to enable a rapid turnaround. Promising compounds were then synthesized and tested for antiviral activity and toxicity.

Prof Frank von Delft, Science Leader of the XChem laboratory at Diamond commented: *"A key part of the strategy is to pursue only molecules that are easy to produce – because if we do find something, large quantities of it will be needed very quickly. If a safe, easy-to-make, effective antiviral compound exists, then we need to know, and fast. We have been humbled by the readiness of so many organisations and companies to contribute effectively pro bono, particularly Enamine in the Ukraine; and then of course, by the huge intellectual contribution from the scientific community."*

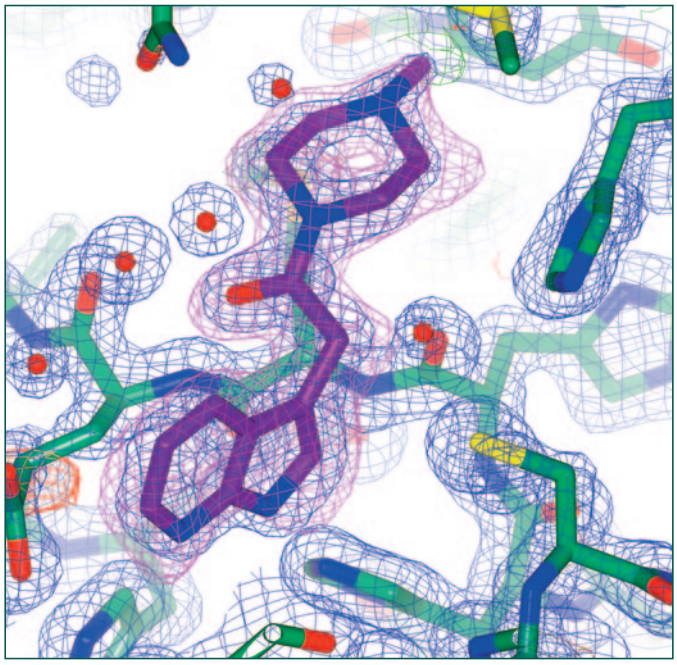
This new approach has already paid dividends. Following just two rounds of designs, the team received over 3500 molecular design contributions and the first compounds have been tested. A paper is close to submission and they have already identified at least one serious therapeutic possibility at Oxford.

THE ROLE OF OPEN SCIENCE AND NEW RESEARCH PORTALS

Aside from COVID Moonshot, Diamond reaffirmed its commitment to COVID-19 research by agreeing to act as a collaborator in an Open Science initiative, led by Wellcome and UKRI, when a consortium of scientists launched the COVID-19 Protein Portal in May. Crucially, the portal enables UK scientists to access protein reagents for critical research relating to SARS-CoV-2. Protein reagents are provided free of charge by a consortium of leading protein production laboratories.



Surface representation of SARS CoV-2 Mpro protein with fragment hits from XChem platform bound in active site (Green) – *Copyright of Diamond Light Source Ltd.*



Modelling of fragment hits into electron density maps obtained from X-ray diffraction CoV-2 Mpro protein crystals 1 – *Copyright of Diamond Light Source Ltd.*

ENGINEERED LLAMA ANTIBODIES NEUTRALISE COVID-19 VIRUS

In July scientists discovered that antibodies derived from llamas neutralise the SARS-CoV-2 virus in lab tests. Researchers included Diamond Light Source, the Rosalind Franklin Institute, Oxford University and Public Health England. They hoped the antibodies – known as nanobodies due to their small size – could eventually be developed as a treatment for patients with severe COVID-19. The peer reviewed findings were published in Nature Structural & Molecular Biology.

Professor James Naismith, Director of The Rosalind Franklin Institute and Professor of Structural Biology at Oxford University said: *"These nanobodies have the potential to be used in a similar way to convalescent serum, effectively stopping progression of the virus in patients who are ill. We were able to combine one of the nanobodies with a human antibody and show the combination was even more powerful than either alone. Combinations are particularly useful since the virus must change multiple things at the same time to escape; this is very hard for the virus to do. The nanobodies also have potential as a powerful diagnostic."*

Dave Stuart added: *"The electron microscopy structures showed us that three nanobodies can bind to the virus spike, essentially covering up the portions that the virus uses to enter human cells."*

SARS ANTIBODY CR3022 ALSO NEUTRALISES SARS-COV-2

New research points out that targeting spike proteins could provide an effective treatment for SARS-Cov-2. This will provide further insights to teams trying to develop vaccines. The research indicates that the SARS antibody CR3022 can neutralise SARS-CoV-2 by destroying prominent spike proteins. Conducted by a Diamond team, the research discovered that the CR3022 antibody may have therapeutic potential alone or in combination with other antibodies.

Dave Stuart explained: *"This new research demonstrates that CR3022 works in an entirely different way. Using the high-resolution Cryo-electron microscopes at Diamond's Electron Bio-Imaging Centre, the team were able to watch the antibodies in action against the virus and to determine their method of attack. It destabilises the spike protein entirely, neutralising the virus. CR3022,,therefore, could work on its own, or in tandem with receptor blocking antibodies."*

"This finding is particularly important in this antibody jigsaw puzzle because the most common way to screen antibodies for effectiveness against SARS-CoV-2 doesn't check for this alternative method of attack. Further screening could identify more useful antibodies that had previously been classed as ineffective. These results could lead to antibodies that can be used to treat SARS-CoV-2. As human antibodies arise within the body, they are relatively safe. Drug companies can replicate antibodies quickly in the quantities that would be needed."

As the search for drug targets continue, great strides have been made at Diamond Light Source in researching, testing and the analysis required to facilitate progress that will benefit the world. Diamond Light Source has played a critical role in working on a wide range of COVID-19 related projects that teach us more about the virus and how we can combat it - and will continue to do so in the future. □

ROSALIND FRANKLIN, LLAMAS AND DISRUPTIVE TECHNOLOGY

Professor James Naismith is the Director of the Rosalind Franklin Institute and a world-leading expert in structural biology. He became Interim Academic lead at the Franklin in 2017, leading the design and specification of the building, and theme leader for Structural Biology at the Institute. In June 2019, Professor Naismith became the first full Director of the Rosalind Franklin Institute.

July 2020 marked the centenary of the birth of Rosalind Franklin, the pioneering chemist and crystallographer, our namesake.

July also saw the peer reviewed publication of our work on nanobodies directed against COVID-19. This paper is amongst the 0.1 % of most impactful paper this year and 0.02 % ever.

The Rosalind Franklin Institute has a clear mission: to develop technology that will transform the life sciences and lead to better medicines and diagnostics. A mission that is directly inspired by Rosalind Franklin's famous discovery: her 'Photo 51' of DNA fibre.

This breakthrough in the life sciences was made possible because Franklin's expertise in the physical sciences had led her to do a novel experiment. It is predominantly technology that advances the life sciences, and this was a perfect example. As Sidney Brenner, the Nobel Prize-winning biologist, put it: "Progress in science depends on new techniques, new discoveries and new ideas, probably in that order."

In 1952, biologists knew that DNA was central to heredity and physicists understood diffraction could disclose the arrangement of atoms in crystalline material. Crystalline DNA fibres diffract X-rays, so scientists knew it should be possible to determine the structure of DNA, but it still seemed an impossible task. Franklin improved on previous X-ray diffraction experiments by controlling the hydration of the fibre throughout the process. This was crucial: it meant she was able to collect X-ray patterns from separate A and B form of DNA (photo 51 is the B-form). All previous efforts had been a variable mix of both and therefore impossible to interpret.

Image courtesy of Jenifer Glynn

The rest is well-known. Jim Watson saw photo 51 and with Crick made the leap to double stranded DNA. The story is a stunning example of the transformative impact that the physical sciences, if properly directed, can have on biology. What is less well known but really deserves more recognition, is that Rosalind Franklin moved on from her work in DNA and pioneered the use of X-rays to study viruses, making a transformational impact and for which was highly praised by scientists at the time. It remains a tragedy that cancer robbed the world of her talents at such a young age.

MAKING THE BREAKTHROUGH

Yet this sort of disruptive change in science is very hard to achieve. It's not just about talented people: it relies on luck, circumstances and timing.

Think, for example, of the biologist and biophysicist, Richard Henderson. Using his knowledge of fundamental physics, Henderson spent years advocating the use of electrons for imaging biological molecules. Vindication and his Nobel prize came much later when direct electron detectors finally appeared, something Richard had long called for, triggering a 'resolution revolution' in the detail and precision of the structures that could be obtained. In two years, the entire field of structural biology had been transformed.

The Franklin was set up to increase the chances of making this kind of breakthrough: to accomplish major changes in life science by means of interdisciplinary research and technology development.

We are funded through UK Research and Innovation's Engineering and Physical Sciences Research Council, and sit at the heart of the UK's national lab in the Harwell Science and Innovation Complex, home to some of the country's leading physicists, engineers and chemists. We

draw in expertise from our ten partner UK Universities, working with them as a team and enabling them to collaborate further afield.

Our neighbours at Harwell include the synchrotron Diamond Light Source - also one of our partners- the Central Laser Facility, ISIS (neutron source) and the Research Complex.

All of this means is that we can bring people from different disciplines and organisations together with top-level technology, embedded in a campus with extraordinary depth of physics and engineering.

A NATIONAL EFFORT

In the present pandemic situation, we've been able to act as a neutral focus that can lead a national effort for our partners to get engaged in. The Franklin has been at the forefront of efforts to bring the public and private sectors together to find a way through this - something we're very proud of.

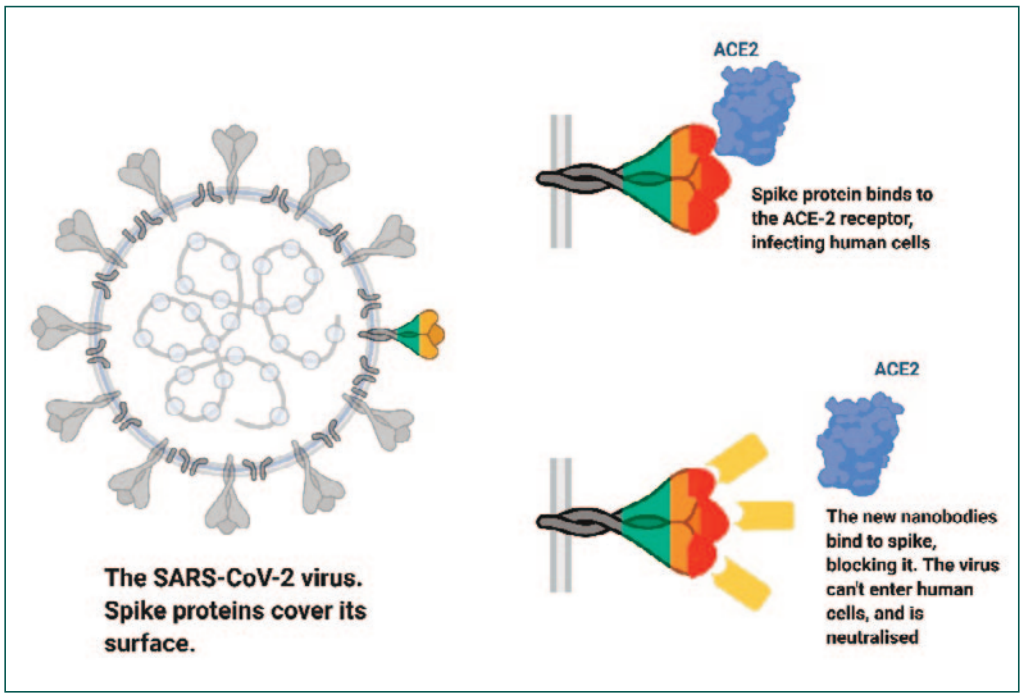
One of our most exciting areas of work relates to antibodies naturally produced by llamas and alpacas, known as nanobodies. These can be engineered in a laboratory to create nanobodies that can be used therapeutically, and also as a research tool to improve imaging of proteins. We are leading the UK's work in this field.

Working with Diamond Light Source, Oxford University and Public Health England, we have shown that these nanobodies can neutralise the SARS-CoV-2 virus in the lab. They do this by binding tightly to the 'spike' protein of the virus, working like a cap on a pen, the nanobodies stop the virus from working.

Using advanced imaging with X-rays, we've also found that the nanobodies bind to the spike protein in a new and different way to other antibodies already discovered. We have also able to combine one of the nanobodies with a human antibody and show the combination was even more powerful than either alone.

But these kinds of discoveries don't happen by chance. Some time ago, The Franklin identified nanobodies as an important technology asset for the country and started to work on them, bringing industry and academia together. One year ago, we had begun to build our nanobody lab. And when the pandemic hit, we were able to switch all that work completely over to focus on the new virus.

As Professor Ray Owens from Oxford University, who leads this nanobody work for The Franklin puts it: "This research is a great example of team work in science. We have created, analysed and tested the nanobodies in 12 weeks; and the team has carried out experiments in just a few days, that would typically take months to complete."



AN ANTIBODY COCKTAIL

There is currently no cure or vaccine for COVID-19. However, the clinical outcomes of critically ill patients have been improved by giving them with a transfusion of serum from convalesced individuals. This serum contains human antibodies against the virus - this process is known as passive immunisation and has been used for more than 100 years. However, it is difficult to identify the right individuals with the right antibodies and then to give such a blood product safely.

This is where nanobodies come in. A completely lab-based COVID-19 specific antibody 'cocktail', which can be made on demand, would have considerable advantages and could be used earlier in the stages of the disease where it is likely to be more effective.

DESIGNED AROUND SCIENCE

Our brand-new home at the Harwell campus, due to complete next year, is key to fostering that ability to collaborate. It will create a place where we can bring people together from different disciplines and those in industry,

Artists impression of the Rosalind Franklin Institute. Courtesy of IBI.

to work on areas where a factor of ten shift in technology is needed.

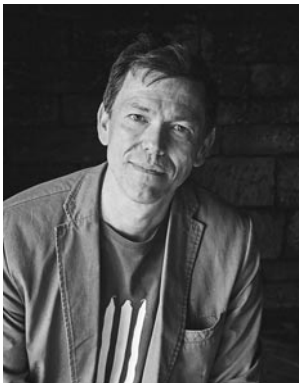
The building itself has been designed around science, providing an environment that mixes biologists and physical scientists to create something special. We have a unique electron microscopy facility, extensive tissue culture, a next generation chemistry lab and a dedicated mass spectrometry workshop. From the start we have designed features in the building to encourage collaboration and technology development. We are welcoming engineers, physicists, chemists, biologists and medics from our university partners and from industry. You could say we are increasing collisions to get a reaction.

FUNDING FOR DIVERSE PROGRAMMES

There are no 'silver linings' of COVID-19, but one outcome seems to be a recognition of how important it is to have a high-capability science base. This needs to include funding for what might seem to be esoteric programmes, such as antibodies from llamas, that subsequently turn out to be crucially important. We welcome the Government's recent R&D Roadmap announcement as a step towards this, along with the increase in public investment in research and development to £22 billion in the next five years. For the UK to become a 'science superpower' however, the kinds of disruptive discoveries we aim to foster will be more important than ever.

There's a vital role for experimenting in innovative ways with new technology. We believe that's a view Rosalind Franklin would support. □

THE SCIENCE OF COVID: LESSONS TO BE LEARNED FROM THE FRONTLINE



Professor Hugh Montgomery MB.BS BSc FRCP MD FFICM FRI
Professor of Intensive Care Medicine, UCL and Director, UCL Institute for Human Health and Performance

The Covid pandemic is a witches' brew. The recipe starts with environmental destruction, changes in animal husbandry and 'wet meat' markets abroad, mixing different species in high density and in close proximity to humans. We then add the virus itself.

Until recently, only four coronaviruses infected humans, causing generally mild upper respiratory tract disease. But in only 17 years, three more have jumped from animals to infect humans: SARS-CoV-1 (from bats/civets) in 2003, MERS (from camels) only 10 years later, and SARS-CoV-2 (which causes COVID-19 disease) seven years after that. Whilst SARS-CoV-1 and MERS were highly dangerous (killing 14% and 34% respectively of those infected), they were not hugely infectious. SARS-CoV-2 is different. It still kills 1-2% of those infected (compared to 0.1% for seasonal flu), and one in 5 of those over 80 years of age. But it is highly contagious through droplet spread (over 2m or so distance), by hand through contact with surfaces on which those droplets (and then contact with the mouth or eyes) but also (perhaps to a lesser extent) through distant aerosol carriage.

Add an incantation of 'we must all now meet again, on hols and boardroom and on plane'. Fifty-nine years ago, not a single commercial airline passenger had ever flown in a jet. By the end of 2004, two million jet passengers flew each year. In 2019, 144 flew every second.

Don't forget the inequality and poverty. The poor tend to live in close proximity. And when you do lock down, they have to go to work, often in public facing roles (care workers, shops, public transport). They are far more likely to have the sorts of diseases which make severe COVID more likely (obesity, diabetes, high blood pressure and more).

Delay lock downs, and watch as each person infects 3 more. Who each infect three. By the 10th cycle, nearly 90,000 people have been infected. Over 1770 will die. On 11th January, there were 41 cases worldwide. Eleven weeks later, there were over 4 million. By late September, there had been over 31 million.

On the frontline in Intensive Care Units (ICUs), we heard the roar of the approaching tsunami, but could not truly be prepared. This was unlike any other disease we had ever seen- affecting the lungs, yes, but also (we learned as we went along) the brain, nerves, muscle, heart,

kidneys, liver, immune and blood clotting systems. 'Intensive Care' was practiced on general wards, by nurses without ICU experience. The sickest went to ICU, cared for by trained staff- but also by dental receptionist volunteers. Drugs ran short. Many patients stayed for weeks or months. Upwards of one in three ICU patients would die.

However, much good appeared from the crisis. The red wax of bureaucracy melted away, and research trials received ethics clearance in days rather than months. Approvals to work happened in hours. New ways of working appeared overnight: telemedicine consultations became an immediate norm. While lives were lost when the sick failed to seek help, or when screening stalled, emergency departments were empty of those who, by and large, had minor self-terminating illnesses. With bars shut, trauma units were empty: nobody was getting drunk outside, fighting or falling or crashing cars. With few cars on the roads, pedestrians and cyclists were not run over. The air was clean of particulates and nitrogen oxides, meaning that cases of asthma and other lung diseases fell.

Britain had invested in Universities, which leapt into action as staff provided clinical and research leadership. We had a vibrant tech development and manufacturing capability. Partnerships with academia appeared, and new ventilatory support devices were created and cleared for medical use in days. We had invested in a National Institute for Health Research (NIHR) which was able to work with them to establish massive trials- which yielded the most effective treatments (steroids) yet found in the world. We had invested in 'Big Pharma' (such as Astra Zeneca) who could work with those academics (such as those in Oxford) to develop a vaccine.

There were gaps, though: we *still* don't have an integrated collated set of all NHS data. Had that existed, we would have been able to rapidly work out what management worked best- why one centre was doing better than another- and run trials with even greater efficiency.

We also know a lot more about the disease too. Perhaps half of those infected have minor symptoms, or none at all. Infectivity is greatest in the two days *before* symptoms appear. And we know who is at risk: men (more than women), BAME groups, the obese and, most of all, those who are older. Mortality rates in those under 20 are close to zero. Even in those under 65, mortality is probably only a little over 1%, and most of that in high risk individuals. This raises the question of the preventative approach to be taken: could we let the disease run wild in otherwise healthy the young and middle aged, whilst maintaining an economy and a functioning health service and shielding the at risk groups? Certainly, we are all seeing a large number of patients presenting with advanced or terminal disease who might otherwise have been treated or cured if seen earlier. And no health service or social care system can function well if our nation descends into debt.

But there are other lessons. We face a climate crisis in just one generation, the impact of which will utterly dwarf the impacts of COVID. Only in January, Australia was ablaze. Now, so too are Indonesia, Borneo, Congo, the Amazon, and at least three US states. The Greenland ice sheet alone is losing >1million tonnes of ice a second. Sea levels are rising by nearly 1cm every two years already. Crops are failing- our own wheat crop being drastically impacted by extreme weather this year. Just as for Covid, the lessons have been noted. But will they be learned?

- Invest in 'Public Health', recognising that most such activity occurs outwith the traditional 'health' space- in agriculture, transport, urban planning, taxation and more. We need to curtail the use of antibiotics in agriculture, a major driver of the emergence of antimicrobial resistance. We must create an agricultural system which promotes production and provision of cheap healthy food with low air miles, and which makes obesogenic foods more expensive: less disease spread, fewer greenhouse gases, less obesity (and thus Covid deaths). We should build on the fall in flying, not rush back to promote it, any more than we should a return to 'boozing Britain' as a way to drive our economy. Economic stimulus packages should not deliver more runways and roads, but walking and cycle paths, tree planting and parks, and clean secure energy generation. Again, less obesity and less pollution. An estimated 1m smokers have quit during the Covid crisis: capitalise on this, increasing tobacco taxation and 'quit' messaging.
- Actively reduce inequality and poverty, which drive non-communicable disease and susceptibility to infectious agents, and value those who do those jobs upon which we all depend.
- Connect all NHS health data
- Create a new vision of Great Britain and what it is for- not an economy that simply recycles money in service, but which creates and contributes to green tech design and manufacture.
- Invest in the UK pharmaceutical industry and in university research facilities, and facilitate partnerships between them both
- Burn the red tape of trials: establish a small expert group of frontline researchers and pharma to determine the most efficient route.
- Bolster international collaboration: as healthcare professionals, we shared knowledge with Israel, Iran and Qatar, and with China, Korea, Italy, Germany, Australia, America and more. Collaboration is good for health, politics and peace.

Insanity is doing the same thing and expecting a different result. Now is the time to learn the lessons and act upon them. We must change – but not by any small increment. Now is the time for disease-stimulated and science-led imagination and transformation of our society.

Who will have the vision and who will carry the torch? □

WHY IS THE NHS STILL HARMING PATIENTS?

Taking a Professional Approach to Patient Safety for COVID-19 and beyond

Sue Hignett, Ph.D. C.ErgHF is Professor of Healthcare Ergonomics & Patient Safety at Loughborough University. She worked in the NHS as a medical scientist, Physiotherapist and Chartered Ergonomist for over 20 years. Her research applies Human Factors/Ergonomics to improve hospital and ambulance design, medical device evaluation, staff wellbeing and patient safety (e.g. mobility and falls).

Paul Bowie, Ph.D. C.ErgHF is Programme Director (Safety & Improvement), NHS Education for Scotland and Honorary Professor at the Institute of Health and Wellbeing, University of Glasgow. He has worked in the NHS for over 25 years in a range of quality, safety and educational leadership roles. His research interests are in applying Human Factors thinking and methods to patient safety and quality improvement education and practice.

PATIENT SAFETY RECOGNISED IN 2000

Patient safety hit the headlines in 2000 with the publication of '*An Organisation with a Memory*' in response to the Bristol heart scandal in which it was estimated that 170 children died between 1986–1995 who would have survived in other NHS hospitals. In 2000, around £400 million was being paid each year for clinical negligence claims; 400 people died or were seriously injured by medical devices; nearly 10,000 people had adverse reactions to drugs and there were around 1,150 suicides after recent contact with mental health services.

HAS THIS CHANGED OVER THE LAST 20 YEARS? NO, IT HASN'T!

In 2020, Shrewsbury and Telford Hospital Trust is being investigated for at least 1,200 alleged cases involving the deaths of babies and mothers. The National Confidential Inquiry into Suicide and Safety in Mental Health reported over 1,500 suicides by people under mental health care with families affected by the lack of safety commenting that *"the NHS is not an organisation with a memory. The same problems in care keep happening".* Patient Safety has been described as a *'movement becalmed … [or] ... dead as a reform effort'* (Wears and Sutcliffe, 2020) and that the *'patient safety movement itself has gotten things wrong. Its understandings … of concepts such as safety, harm, risks and hazards are incomplete and simplistic and, as a result, its work has been grounded in assumptions and generalisations that are either wrong or lacking in context'.* The recent national response to COVID-19 has resulted in many avoidable patient deaths and harms.

The National Patient Safety Agency (2001-2012; now part of NHS England/Improvement) led many excellent projects but failed to embed safety science expertise at Trust level. There is a new opportunity with the 2019 NHS Patient Safety Strategy stating that *'NHS does not yet know enough about how the interplay of normal human behaviour and systems determines patient safety. The mistaken belief persists that patient safety is about individual effort … Getting this right could save almost 1,000 extra lives and £100 million in care costs each year from 2023/24. The potential exists to reduce claims provision by around £750 million per year by 2025.'*

This includes:

- creating the first system-wide and consistent patient safety syllabus, training, and education framework for the NHS
- establishing patient safety specialists to lead safety improvement across the system; which is the first step in professionalising this key role.

In this short paper, we propose taking a much-needed professional approach to patient safety through an accredited learning pathway to integrate safety into clinical systems and develop healthcare safety specialists and experts.

PROFESSIONAL SAFETY SCIENTISTS: CHARTERED HUMAN FACTORS/ ERGONOMICS SPECIALISTS

At the Chartered Institute of Ergonomics & Human Factors (CIEHF) our members have been leading and supporting safety in many other industrial sectors (aviation, defence, oil & gas, nuclear, rail etc.) for decades. We feel that the NHS has not yet taken safety seriously; it has been estimated that there are fewer than 5 professionally qualified Human Factors Specialists across 223 NHS Trusts - one for every 300,000 NHS England staff in contrast to the National Air Traffic Services (NATS), an ultra-safe organisation which has one Human Factors specialist for every 100 staff. Policy recognition of the need to close this gap would illustrate a strong commitment professionalising patient safety.

Our profession focuses on integrating humans and systems and brings knowledge and experience of a range of concepts, principles, standards, and methods to understand and resolve problems and issues routinely experienced in highly complex, dynamic systems. It

was established in the 1950s and received royal chartership in 2015. It is *'one of the first truly multi-, inter-, and cross-disciplinary subjects'* (Wilson, 2000), drawing knowledge from design, engineering, psychology, organisational management and human sciences (anatomy, physiology, biomechanics, kinesiology and anthropometry) and applying this to the safe and efficient design of systems, products and services.

We propose that a **Professional Approach** (Figure 1) should be taken to healthcare safety and this starts with targeted education and training for patient safety specialists, investigators (local and national) and other key personnel.

knowledge relevant to their professional and role by taking one-day courses. This will provide an understanding of all the topics in the patient safety syllabus and develop professional competencies which can be taken forward in Level 3.

Achieving **Level 3** will create professional patient safety (technical) specialists (local advisors) who have undertaken 600 hours of learning (taught, experiential and self-study), with mentorship from a Chartered Human Factors Specialist (C.Erg.HF). They will have a recognised accredited title: Technical Specialists (HFE in Healthcare) and postnominal of TechCIEHF.

Experience Person (SQEP) in **'JSP 912 Human Factors Integration for Defence Systems'** from the Ministry of Defence (2014); *'equipment and systems have to be operated in a demanding and diverse military context in circumstances of fatigue, hunger, stress and even fear. Ultimately their usability in these demanding environments will determine our operational success'.* This informs all procurement, whereas in contrast the NHS has poorly designed systems, devices and products as procurement has been based on purchase cost alone. This has resulted in usability problems as well as problems of maintenance, both

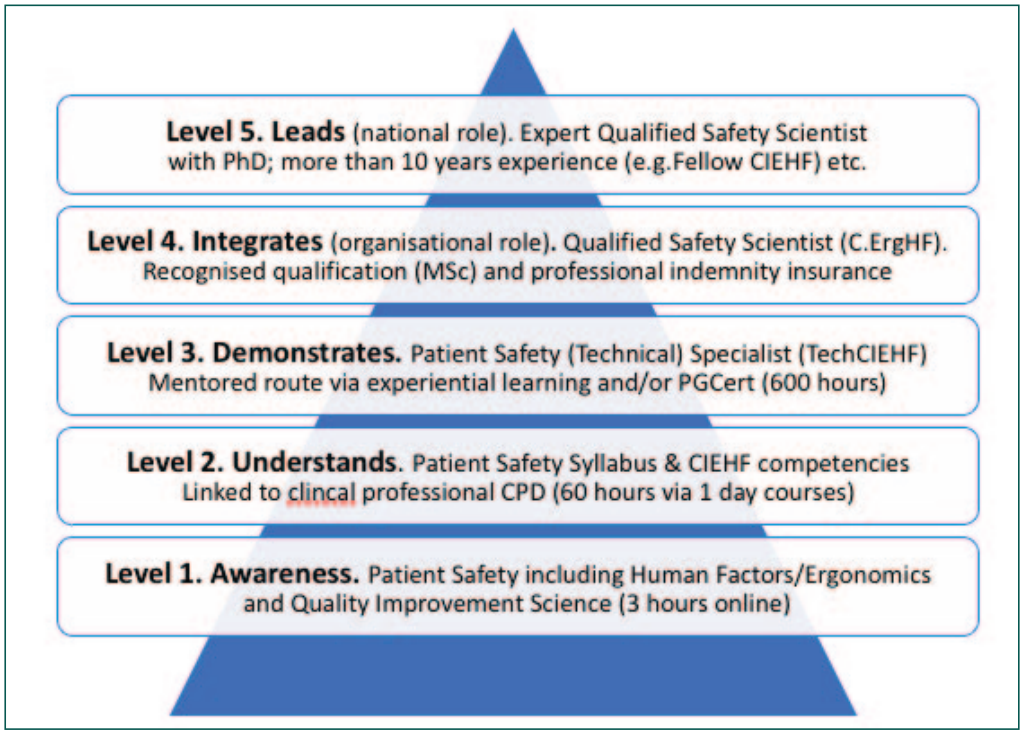


Figure 1. Taking a Professional Approach to Patient Safety

At **Level 1**, we are offering an online course, based on our 2015-2020 workshops with Health Education England and NHS Education for Scotland, to provide an awareness of safety science and Human Factors for all staff.

At **Level 2**, healthcare staff (clinician and non-clinical) will build their patient safety

Levels 4 (organisational lead) and **5** (national lead) offer opportunities to change career and become a professionally qualified safety scientist (Chartered Human Factors Specialist; C.Erg.HF).

Level 3 is equivalent to the minimum Human Factors knowledge required for a Suitably Qualified and

of which, directly or indirectly, can compromise patient safety.

COVID-19

The rapid response by the CIEHF to COVID-19 was to set up a Gold-Silver-Bronze command structure to respond to the multitude of requests for patient safety support.

The lack of ventilators offered the first opportunity to support the NHS. Our members volunteered from many sectors (e.g. rail, oil and gas, nuclear sectors) to work with the Medicines and Healthcare products Regulatory Agency (MHRA), Faculty of Intensive Care Medicine (FCIM), Intensive Care Society (ICS), Academic Health science Network (AHSN) and Nightingale Hospital London, Healthcare Safety Investigation Branch (HSIB), Clinical Human Factors Group (CHFG), Royal College of Speech & Language Therapy (RCSLT). We rapidly produced guides on:

- COVID Ventilators - the methods and approaches needed to capture the full range of user requirements: https://bit.ly/HFand Ventilators
- Usability Testing for Rapidly Manufactured Ventilator Systems: https://bit.ly/Ventilator UsabilityV2
- Bedside Action Cards for the care of ventilated patients: https://bit.ly/3axoNpd
- Routine Care for Tracheostomy Guide https://bit.ly/HFBedside TracheostomyGuidance
- Design of Work Procedures https://bit.ly/Work ProceduresDesignGuidance
- Covid-19 Risk Assessment for General Practice Remobilisation: https://bit.ly/31Xdi6l
- Capturing Organisational Learning and Achieving Sustainable Change: https://bit.ly/312JSEx

THE NEXT STEPS IN PATIENT SAFETY

Most Human Factors healthcare input has been funded through research, with

much of it based at universities rather than hospitals. There are examples for acute care, primary care, emergency care, home care, medical device design, health IT, health systems design, architecture, simulation, education, and reliability. Studies have analysed systems of work, teamwork, decision making, displays, device interactions, risks, threats, performance shaping factors, environmental and organizational approaches, and regulatory influences.

One consequence of the lack of a professional approach to patient safety is that few opportunities exist in clinical settings for embedding qualified Human Factors professionals. Given that return-on-investment can be difficult to calculate, and effect on outcomes is difficult to measure in a non-linear system, a direct business case is still hard to make although the fact that Human Factors Specialists are integrated in the safety operations of all high-risk industries except healthcare should arguably be reason enough.

This has created a chicken-and-egg problem, where Human Factors professionals have not been employed in healthcare organizations, because there has been a limited understanding of what they can do, no clear and immediate application, no business case, and no clear evidence base. However, without embedded experience within healthcare organisations the application, evidence and business case will not be developed. Healthcare organizations need to know how they can employ Human Factors specialists and upskill key parts of the workforce who lack safety science knowledge and skills (e.g. patient safety advisors and quality improvement specialists) through accredited safety routes at comparative low cost.

The CIEHF have been working with Health Education England (HEE), Healthcare Safety Investigation Branch (HSIB), NHS England/Improvement, NHS Education for Scotland (NES), Academic Health Science Network (AHSN), Academy of Royal Medical Colleges, Royal College of Nursing (RCN) and others to create this innovative Learning Pathway. As we enter our first COVID winter, taking a professional approach to patient safety should be one of the highest priorities in the NHS to send strong reassurance to patients, families, staff and the public of the continuing importance of this issue. □

MYELOMA, PRECISION MEDICINE AND GENOMIC MAPPING

Sarah McDonald - Director of Research, Myeloma UK

Myeloma UK is a patient focused charity, the only UK charity that deals exclusively with, the blood cancer, myeloma. We were established in 1997 and we have four central aims:

- Patients get a timely diagnosis
- They have the right treatment the right time
- They are supported, informed and empowered
- We fund research towards a cure.

On average 16 people in the UK are diagnosed with myeloma every day and we estimate that 24 thousand people are currently living with myeloma.

In the cancer world, myeloma is 18% of blood cancers and 2% of all cancers. This means myeloma is considered a less common cancer.

THE CHALLENGES OF MYELOMA

Myeloma is a blood cancer arising from plasma cells, a type of cell found in the bone marrow. It's a remitting and relapsing cancer and at the moment, it's incurable.

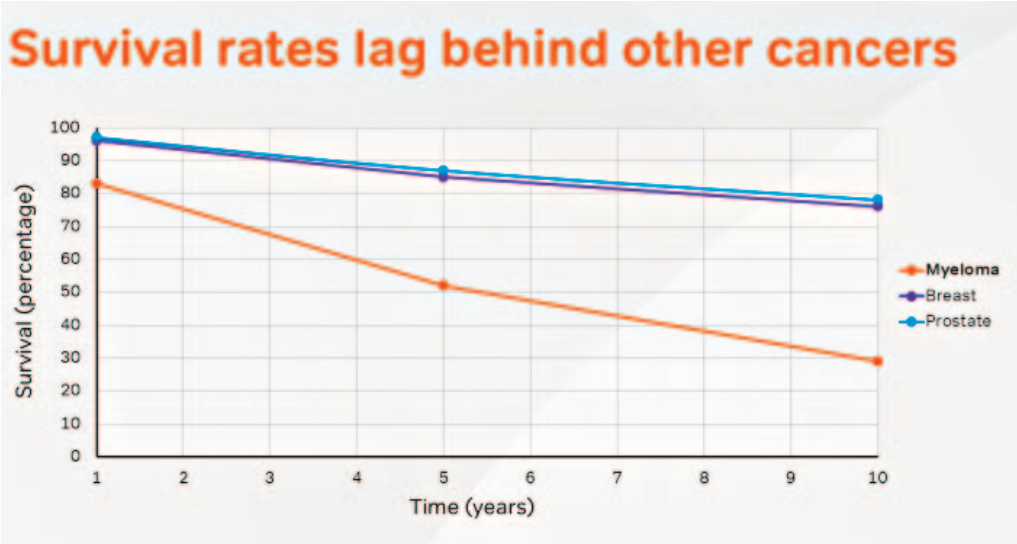
From a patient point of view, the biggest challenge about myeloma and usually the first thing patients experience is around diagnosis, and specifically late diagnosis. As a blood cancer myeloma isn't easy to detect, there isn't "a lump" and patients experience non-specific and vague symptoms like fatigue, a stiff back, or bone pain. At diagnosis, half of myeloma patients will have visited their GP three or more times. Around a third of patients are diagnosed via an emergency route presenting with serious complications caused by their myeloma such as kidney failure, bone fractures, spinal cord compression or severe infection. There is currently no screening programme for blood cancer and as a healthcare culture, the UK doesn't habitually take the blood tests which would pick up blood cancers earlier.

Myeloma is treatable but, sadly incurable. For patients finishing a course of chemotherapy, they don't worry if it will come back, they worry when it's coming back. Over the course of the disease, the time between remissions reduces and treatment side effects increase until the myeloma eventually becomes resistant to treatment.

Myeloma is heterogenous, every patient will have their own cell biology meaning patients may have different symptoms, respond differently to treatments and their myeloma grows at a different rate.

These challenges to diagnosis and treatment result in poor long-term survival rates.

The one-year survival for myeloma is 80% which is broadly in line with other cancers. However, the longer-term picture is bleak. with half of patients surviving for five years or more and only 30% surviving for at least ten years. This is where we get to the crux of the issue about rare disease, blood cancer in general and specifically myeloma, when compared to other cancers, we lag behind. We haven't had the long-term research investment leading to breakthroughs across the disease, we don't have effective awareness raising or a screening programme.



GENOMIC MAPPING AND MYELOMA

Genomic mapping is incredibly important in understanding disease and treatment. It compares DNA in the cancer cell to DNA in the patient's normal cell; giving specific information about the genomic changes for that patient. By linking this genomic data to a patient's medical records, we can begin to tease apart the complex relationship between disease and genes. We have seen step changes in recent years in the field of genomic medicine, and we have the potential to identify the drug that would be most effective for a particular person or identify potential druggable targets for new treatments. This includes the launch of programmes like the 100,000 genome project which provided a huge amount of data, and the genomic medicine hub and spoke model, which aims to identify new treatments and consider appropriate trials for patients. In 2019, NHS England launched the National Genomic Test Directory commissioning several genomic tests as standard of care. Sadly, myeloma doesn't feature on the directory list, of the 978 approved tests for cancer, only 41 are for Blood Cancer and only one test linked to a precursor condition to myeloma. We know this is something patents want, they ask us how they can help, how can their sample be used for research?

There are some challenges with genomic medicine; firstly, there's critical mass, you need to collect lots of data so you have a statistically large enough sample. With 5,800 myeloma patients diagnosed annually, there would need to be a concerted effort or a global initiative to get the numbers.

Patients will also need to be reassured about what happens with their data and how their samples are stored. Whilst every cancer patient wants their sample to go into a study, it would need to be clear what that might mean. Media stories about data harvesting, what the information could be used for, will it affect their access to treatment and ultimately who will benefit, financially as well as scientifically need to be transparent.

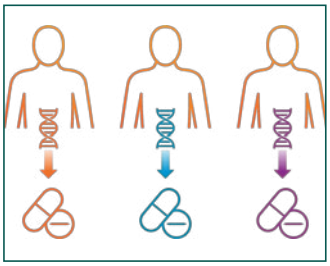
There are many organisations, such as Genomics England who have this infrastructure in place and there is a huge benefit to be part of the bigger picture. Patients, in fact anybody, could get a genetic screen themselves, we've all heard about 23 and me or similar programmes, where you send off saliva, or a cheek swab and get a report on your own genetic make-up have been available for some time. The challenge here is that testing done outside the healthcare system where an unprepared patient gets some information that they may not know what to do with it, or how it will affect them. There is a wider conversation about consent for tests, the associated counselling and how the results will be actioned and how patients are supported through any results from a standalone test, outside the healthcare system.

PRECISION MEDICINE AND MYELOMA

Precision medicine for myeloma would be truly groundbreaking. Currently, myeloma patients and their clinicians have a defined and restricted choice of approved treatments, some of which are only available at certain points after patients have relapsed. Treatment decisions are based on; clinical data, patient preference and the overall health of the patient. For some patients, they will receive treatment, experience the side effects and have no real benefit.

If we routinely tested patients as a standard of care, where clinicians can select the treatments which are most likely to help patients based on the genetic profile of their disease, with an increased likelihood the treatment would work; this would benefit so many patients. They would live longer, have a better quality of life and both patients and clinicians would be more informed about treatment choices.

This would take us a step closer to a functional cure; being able to give a patient the right treatment in the right order could add years to their life, and reduce anxiety about "what next".



However, there are risks involved; some patients tested

may not have a specific tailored treatment option, there would need to be thought into how these patients are cared for, what treatment can be offered. A treatment may be profiled to work and it just doesn't, or the side effects are more severe than anticipated and this may be more devastating to the patient.

We must also consider that not all patients want to engage with their treatment or discuss their prognosis. Some patients want to know everything to help them feel in control, others only want to know things if and when they really need to. When implementing precision medicine, we must not forget the patient voice and their wishes and preferences. For some patients, the right treatment and care is not the most effective but the one that lets them live the life they want.

Myeloma patients are losing out twice as science progresses. Lower patient numbers mean myeloma patients aren't a priority in developing precision medicine or for inclusion in larger research driven clinical initiatives. This double blow means that not only is myeloma patient data not being routinely collected to provide more knowledge to drive drug discovery or diagnostic screening tests; they are also not included on programmes which might offer them more options, like the genomic medicine hubs. Issues around data use needs to be transparent and we simply need more research into leveraging the potential of genomic medicine for myeloma.

Genomic testing and precision medicine would be life changing for myeloma patients. Having biologically matched treatments could add years of good quality life and from the patient perspective, then can stop thinking about what will happen when their myeloma comes back and they would have hopeful futures. □

TRANSLATING COVID-19 CHALLENGES INTO PRACTICAL GUIDANCE FOR THE FOOD SECTOR

Dr Rachel Ward
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Institute of Food Science and Technology (IFST) is the UK's leading professional body for those involved in all aspects of food science and technology.

Our core aim is to promote the advancement and application of food science and technology for the benefit, safety and health of the public.

Access to safe, nutritious and affordable food is critical to UK national security. In the current COVID-19 pandemic, food has not been identified as a likely source or route of transmission of the SARS-CoV-2 virus. However, the food system is being impacted both economically and socially, across the entire food chain, in relation to: human resources, such as changes in key personnel; supply chains of ingredients, packaging, finished products and equipment; sourcing as manufacturers may need to rely on alternative suppliers at short notice; and transportation of people, materials and goods. These wide-ranging impacts were, and still are, occurring concurrently with consumers buying additional food and other consumer goods and supplies through retail channels to cope with the pandemic and consequences of lockdown.

The resilience of the food system, and food business operators within it, and its capability to supply food to meet the needs of the UK population relies upon complex interdependencies and upon competent food technical professionals involved in keeping food systems operations working safely, even when at full capacity. The work and expertise of food technical professionals are especially of value when it comes to adapting successfully to changing circumstances without compromising quality or safety.

The publication by the FSA of the quantitative risk assessment relating to SARS-CoV-2 and food was well-timed and helped Food Business Operators (FBOs) to ensure they were taking the right steps to manage any potential food safety risks relating to COVID-19. The activities and reports issued by the Parliamentary Office of Science and Technology (POST) on

COVID- 19 from March 2020 onwards have also been of value in providing background context. Guidance from Food Standards Scotland took a sectoral approach to food, addressing food safety and the operational impacts of the pandemic alongside public health implications. This was beneficial to all food businesses operating across the UK as it looked at the issues operators in the food system were having to deal with in the round.

In contrast, early in the pandemic, there appeared to be a lack of focus by UK government on food and the needs of the food system to support continued national food security and supply. The advice given in England and Wales was more departmentally segmented forcing FBOs to visit multiple websites seeking out either healthcare sector-related advice or generic advice and drawing their conclusions on how best to apply this advice in the food sector. This did not recognise that all players in the food system have their own unique food safety challenges and duty of care that is impacted on by any change within the working environment. Large operators have their own in-house teams to manage this often-conflicting risk; smaller businesses were left more vulnerable.

Over 95% of the UK's 7,400 food and drink manufacturing businesses are SMEs (small and medium sized enterprises) who rely on their Local Authority's Environmental Health Officers (EHOs) for food hygiene and food safety advice and guidance. This local authority EHO resource is constrained within normal operations and this capacity challenge became critical for engagement with food operations on the ground as EHOs stepped up into their broader public health roles. The COVID-19 pandemic has highlighted that there is no alternative route to get to FBO SMEs and provide them with supporting holistic advice in a time of rapid change.

In order to provide supportive and timely guidance for our food professionals and the wider food system, IFST set up a COVID-19 Advisory Group comprised of experienced professional members to monitor and translate the emerging state of knowledge for the food system relating to COVID-19. This group created and collated resources to proactively reinforce best practices, especially hygiene practices; guide food business through re-purposing and closure/re-opening; and signpost to trusted resources from authoritative bodies. These resources were made available on a freely accessible IFST COVID-19 Knowledge Hub https://www.ifst.org/resources-policy/covid-19-knowledge-hub.

IFST was able to leverage its professional members' in-depth knowledge of the food system and their insights into the specific technical challenges arising from COVID-19 to notify Governments of issues needing to be addressed in order to achieve effective public health measures whilst ensuring continued capable food safety and hygiene controls. IFST also requested specific food sector related advice from public health bodies, given the unique food hygiene operating environment compared to other manufacturing sectors. Our resulting positive engagement as a professional body provided independent technical professional inputs and oversight for Governments as they worked through creating guidelines and tools for the food sector.

An earlier approach that dealt with sectors of economic activity as opposed to advice that was aligned by government departmental responsibilities would have benefited the food system and other sectors. Advice from BEIS OPSS for food service businesses has now been developed and updated as issues arose and the need for food sector guidance recognised. More recently, the 'Here to Help' campaign by FSA late this summer is now providing helpful resources.

The scale of the food supply chain and its importance to the daily lives of millions in the UK is reflected in the number of government departments and agencies that have responsibilities and legitimate interest and involvement with the food supply chain. The intricacies and duplication of responsibilities across UK and devolved nations' government bodies complicates and confounds engagement and communication. A greater focus and more proactive alignment on food and the food system across the whole of UK government, including the devolved nations is, in our view needed, especially regarding strategy and resilience, regulatory approaches taken, best practices developed and guidance provided. There is a critical need for responsive and coordinated engagement across all stakeholders in the food system to create shared and comprehensive understanding of the food system and an environment of common endeavour not only in times such as these, but also on-going.

IFST fundamentally believes that professional bodies can play a key role in facilitating the translation of new developments for practitioners and policy makers by applying the expertise and experience of our professional members. We would therefore urge all government departments to recognise and make best use of the independent and expert resources available to them – especially in times of crisis.

IFST COVID-19 KNOWLEDGE HUB

https://www.ifst.org/resources-policy/covid-19-knowledge-hub

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INTERPRETING GENETIC VARIANTS: ENABLING FINE-SCALE GENOME MAPPING AND PRECISION MEDICINE

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Honorary Senior Clinical Research Fellow, Inherited Tumour Syndromes Research Group, Cardiff University
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The human genome consists of 3 billion base-pairs (bp) - letters of DNA code. An individual human may differ from the reference genome at more than 5 million of these, as well as larger variants from 2 bp to, in the case of an individual with Down syndrome, a whole extra chromosome of 48 million bp. Deciding which, if any, of these variants is clinically significant is perhaps the greatest challenge facing genomic medicine now that obtaining the sequence of an individual's genome is easy.

Twenty years ago it could take months to analyse one gene of perhaps 2,000 bp. If a variant was found it might then take the same amount of time to establish it was pathogenic, i.e. causative of disease. At this time testing of a particular gene might only be performed in one or two laboratories worldwide, for reasons of local expertise in testing and interpretation, but this has changed. It took 13 years to establish the first draft of the reference human genome sequence, published in April 2003, but such are the advances in technology that an individual's genome can now be sequenced in two days. In terms of DNA sequencing any gene can now be sequenced in any genetics laboratory, but the local expertise in interpretation remains, usually based on local research interests. However, this too is changing as it is realised that national and international pooling of data and expertise are required to interpret variants. No longer can, or indeed should variant interpretation be left up to individuals, because this is a major factor in disparity of interpretation between centres, leading to upsetting and potentially dangerous confusion to both clinicians and patients. Families span borders, so the interpretation of a variant shared across them should not be disparate. It also improves quality and thus safety if interpretation is carried out by single expert multidisciplinary groups, which are increasingly becoming international entities as the science of interpretation matures and becomes a recognised entity. [1, 2, 3]

MUTATIONS AND VARIANTS

Variants result from mutations in genes and, because genes encode proteins ultimately this results in protein variants. For example, blood groups B and O are variants of group A. One variant is referred to as a genotype, but the sum total of all an individual's variants may also be referred to as their genotype. Mutations are caused when mistakes are made in DNA replication. This is commonly due to DNA damage caused by endogenous chemicals, such as free radicals produced during normal metabolism, or exogenous chemicals such as those found in tobacco. In addition, although DNA replication is robust, it not entirely error-free, because of the very nature of the chemical structure of DNA. Hence, there is a whole army of DNA repair enzymes designed by evolution to minimise, but not eliminate mutations. If there were no mutations, there would be no variety, and without variety a species cannot evolve and ultimately it becomes extinct. If a mutation occurs in the *germline*, the specialised cells that produce eggs and sperm, then that variant may be passed on to offspring and become heritable, responsible for a variant in all cells of the body – a *constitutional* variant. If a mutation occurs in another cell of the body, a *somatic* mutation, then it may ultimately lead to a cancer. Twenty years ago the vast majority of clinical genetic tests were for possible inherited constitutional variants, but now genetic tests for somatic and constitutional variants related to cancer are in the majority.

An expressed characteristic, a phenotype, is a function of

genotype and environment. Genotypes work in combination with the environment to cause phenotypic variety: e.g. skin colour, height, and susceptibility to disease. As the environment of any one gene includes the other 20,000 genes and their variants so we get to genomics, the sum totality of all genes and variants acting in concert with the environment they all find themselves in. This may seem dauntingly complex, but it is no more complex than the cracking of the Enigma code 80 years ago, and we have the benefit of modern computers spawned by that challenge.

Phenotypic variation is acted upon by selective pressures in the environment in the fight for survival. A variant that enables an individual to produce more offspring will result in it becoming more common and *vice versa*. The G614 variant in the spike protein of SARS-CoV-2 is replacing the original D614 because it confers greater infectivity. This is Darwinian evolution acting as I write: perpetual work in progress. If a variant occurs in a somatic cell and confers a growth advantage then that may lead to a tumour and eventually cancer, usually after other mutations have occurred. It should be noted that genetically, a population is defined by the frequencies of its genetic variants.

THE IMPORTANCE OF GETTING IT RIGHT

It is said that "Any idiot can find a mutation, but only wise men can interpret them." So, not only can the consequences of a variant be severe, but so can misinterpretation. On top of this, indecision and delay affecting timeliness can also have adverse clinical effects. There is less value in interpreting a variant after a patient has succumbed to their disease, although their relatives may benefit.

There are two major parameters to consider in variant interpretation: how certain is it that it is causative of disease, its *pathogenicity*, and to what degree does it cause disease, which bears on *actionability*. These two factors are independent, but often confused. Close study of blood groups in the 1950s and since have established beyond all doubt that individuals with group A are at a greater risk of stomach cancer than group O. [4] However, the degree of risk, the Hazard Ratio, is only ◊ 1.13, so nowhere near clinical actionability (>2). In addition, as with any test, interpretation and actionability depends on the clinical context, considering the whole person. The problem is that not all variants can be assigned simply as pathogenic or not pathogenic: many lie somewhere in between, so-called "variants of uncertain significance" or VUS. In part this is often a function of the degree to which they cause disease. A weakly acting variant needs more data to be sufficiently certain as to its effect, a recognised issue in the science of variant interpretation.

HOW TO GET IT RIGHT

Many lines of evidence can be used in interpretation. A mutation that predicts cutting a protein short is generally pathogenic, but one which changes one amino acid out of a thousand or more may well not be. How a variant tracks with disease in a family is useful, as can specific clinical tests. Subtle signs, however, may only be obvious to a trained and skilled clinical eye, hence expert phenotyping by medically-trained individuals is an absolute necessity – an example of getting a sensible answer if you ask a sensible question. Clinical tests, including genetic tests, must be performed and interpreted under the direction of a medical practitioner, as the Academy of Medical Royal Colleges has advised. [5]

EXAMPLE 1: PREDISPOSITION TO CANCER

Lynch syndrome (LS) is a common condition potentially affecting up to 1/100 of the population. [6] It predisposes to bowel, womb and many other cancers from a young age, with a lifetime risk of cancer up to 85%. [6, 7] NICE guidance is that all bowel cancers should be tested to see if LS is the cause.[8] A patient is found to have the variant MLH1 c.306G>T p.(E102D), but a Genetic Counsellor sees that despite 17 entries on the international reference database it is classed as a VUS by the Variant Classification Expert Panel and seeks clarification. [9, 10, 11, 12]

The variant has a 72% (~3:1 on) chance of being pathogenic from considerations of evolution conservation, but >95% certainty (19 to 1 on) is required for clinical purposes. [12, 13] Fortuitously, UK data very recently analysed by Dr Fiona McRonald's team at Public Health England (PHE) can be used, as gathered by PHE through the National Cancer Registration & Analysis Service (NCRAS) under Section 251 of the NHS Act (2006). [14] This shows the variant has been seen in 6 of 2041 individuals with LS-type cancers in the UK, but in none of 113,654 non-Finnish Northern Europeans unaffected by cancer. [15] This gives a Hazard Ratio of 57 (CI: 1.1 – 2,800) and a probability, if random, of 0.000 000 003%. Factoring in the starting probability of 72% gives a final probability of pathogenicity of 99.999 999 998 8% (83 billion to 1 on). Hence, it can be concluded beyond all reasonable doubt that this variant is pathogenic. As a result relatives may be tested for it to see if they warrant regular surveillance for cancer or prophylactic surgery, as may the other 23 families with this variant, plus those yet to be diagnosed with it. This illustrates the enduring utility of an international expert group using data made publicly available and interpreted according to peer-reviewed criteria, based on objective probability, not subjective opinion.

EXAMPLE 2: PHARMACOGENETICS

2012: A 52y old NHS Consultant is prescribed an selective serotonin re-uptake inhibitor (SSRI) antidepressant, but suffers a severe adverse drug reaction (serotonin syndrome toxicity) and unable to tolerate treatment has to take 2 years off work. Testing for the genes CYP2C19 and CYP2D6 that produce the enzymes responsible for metabolising SSRIs is unavailable in the UK. A Dutch laboratory is able to report absent CYP2D6, but also variant CYP2C19*17 conferring high activity, inconsistent with the phenotype. 2018: An expert from the Karolinska Institute is consulted and reveals it has since been discovered that a rare novel loss-of-function variant CYP2C19*4B is composed of both *17, a controlling region variant which turns the gene on, and *4, a variant at the start codon which prevents protein production (Figure 1). [16] As the earlier pre-2012 assay was unable to detect *4B, because it could not detect *4 in the presence of *17, the mystery is resolved.

Fortunately, if the patient should suffer depression in the future they can be treated with Vilazodone, a new SSRI introduced after 2012 due to the high prevalence of side-effects of conventional SSRIs due to the high prevalence of low activity variants of CYP2C19 in persons of BAME origin (20-40% vs 2% in Northern Europeans). In addition, as the patient will not activate Clopidogrel they can be warned that they must be given an alternative anticoagulant if they should require a cardiac stent, to avoid death from iatrogenic thrombosis. [17] They

Figure 1

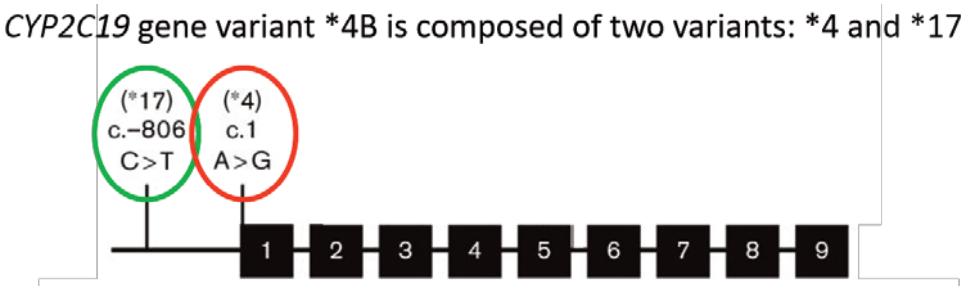


Illustration of the *CYP2C19* gene, showing variant *4B is composed of both *17, a gain-of-function variant in the controlling region (highlighted in green), and *4 (red), a loss-of-function variant which abrogates the start codon so preventing protein production. Thus, *4B is a loss-of-function variant.

can also be advised that as they have zero CYP2D6 activity then they require smaller doses of opiates and proton pump inhibitors (PPI), minimising side effects from those medicines as well. In contrast, persons of BAME origin frequently have high CYP2D6 activity, and so are *inter alia* at risk of inadequate analgesia when treated with opiates.

This illustrates how variants can act in concert, interpretation can change with time as techniques improve and knowledge is acquired, and knowledge of population-specific variant frequencies is needed for precision medicine, all confirming: "You can get your genome for less than $1000, but you need a $100 million Institute to interpret it." Severe adverse drug reactions are common: everyone is waiting for the drug that will affect them. They are dangerous, cause considerable morbidity and mortality, poor compliance with treatment and incur great expense to the NHS. However, they can be foreseen and avoided by genetic testing, but knowledge, availability and application in the NHS is so far minimal.

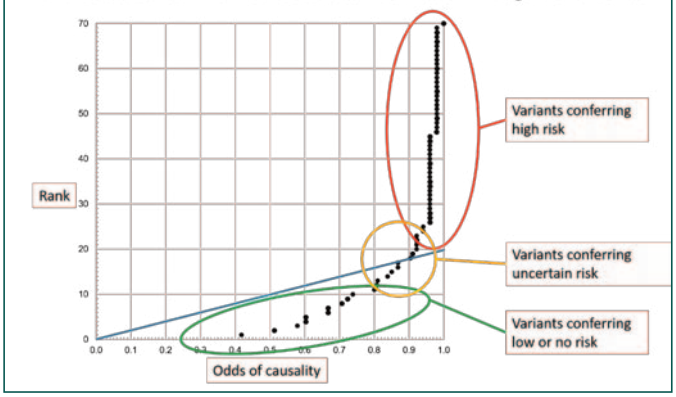
EXAMPLE 3: NEUROFIBROMATOSIS TYPE 1 AND BREAST CANCER RISK

Neurofibromatosis type 1 is a disfiguring and disabling condition that affects 1/3000 individuals, predisposing to multiple benign and malignant tumours. A raised risk of breast cancer (NF1-BC) is seen, often young onset and more malignant, but breast screening is controversial. Is there a genotype-phenotype correlation that could guide management? Gathering data on *NF1* gene variants seen in patients with NF1-BC reveals that a minority of variants (probably those conferring a gain of function) predispose strongly, whereas one variant seen commonly (whole gene deletion) which causes total loss of protein function is not seen in NF1-BC, revealing variant heterogeneity (Figure 2). [18] This illustrates the hazards of generalising variant effects at the level of a gene, but at the level of individual variants the fine detail may guide precision medicine.

CONCLUSIONS

Gone are the days of individuals working alone. The interpretation of genetic variants requires large multidisciplinary groups working on freely-available data, contributed to by all for the greater good. Patient groups support this approach.[19] However, this necessitates provision for and support *in perpetuum* of large inter/national multidisciplinary expert groups and their associated databases, such as the International Society for Gastrointestinal Hereditary Tumours (InSiGHT) initiative (which is currently only supported by charitable and research funding from abroad) and CanVIG-UK. [20, 21]

Figure 2



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STEM Learning UK

SCIENCE EDUCATION: SUPPORTING THE UK AS A SCIENCE SUPERPOWER

Baroness Brown of Cambridge

If the UK is to remain a "science superpower", we must invest in world-leading science education for every young person in the UK. As Chair of STEM Learning, Baroness Brown has seen the power of investing in teachers and will share recent evidence on its positive impact on young people. Professional development (CPD) for science teachers is an effective way to ensure great science education is available to all young people – and, as you will read, it pays for itself through reduced need to recruit and train new teachers.

This summer (July 2020), the Government published a Research and Development (R&D) Road Map setting out an ambitious long-term objective for the UK:

"to be a science superpower and invest in the science and research that will deliver economic growth and societal benefits across the UK for decades to come, and to build the foundations for the new industries of tomorrow."

The Road Map recognises that R&D requires people: researchers, innovators and technicians. Alongside them, a science superpower needs many thousands of people in skilled roles supporting and facilitating their work, managing facilities and projects, allocating finance, assessing intellectual property and so on. Indeed, growth in highly skilled jobs is one of many reasons why the Government is committed to R&D.

However, when it comes to the question of where we will find all these people, the Road Map focuses on the UK's openness to global talent and smoothing the pathway for those who have chosen a career in R&D. It is silent on the vital question of science education in our schools, on how we nurture our young people so that they can contribute to and benefit from living in a science superpower.

SCIENCE EDUCATION FOR ALL – FOR ALL THE RIGHT REASONS

The UK needs an excellent science education for every young person. As a society we will profit from widening the talent pool, drawing on the talent of all our young people to help us realise our ambition as a science superpower. We must ensure that everyone, regardless of background, has the opportunity to gain the skills needed to reap the rewards that flow from innovation.

Science education has the potential to help us close the gap for disadvantaged communities. OECD research found that "taking more science courses benefits disadvantaged student seven more than it does their more advantaged peers".

Science education also has wider benefits, including supporting people to make good choices for themselves and their families, for their health and well-being. And to participate as citizens, as the UK decides how to govern new technologies in fields such as geoengineering, autonomous systems and genome editing.

Living in a science superpower, our young people need science education to understand both the potential and the risks of the exciting opportunities created by research. We have a moral duty to ensure our young people have science education to prepare them for the choices they will make as adults, parents and citizens.

THE POWER OF INVESTING IN TEACHERS

At the heart of science education is great teaching from skilled teachers. As a McKinsey report put it: "No education system can exceed the quality of its teachers. The only way to improve outcomes is to improve instruction".

As Chair of STEM Learning, I have come to appreciate the extraordinary power of investing in teachers. Each teacher teaches many young people, so developing that and supporting them to become a great teacher, who engages and inspires their students, benefits thousands of young people over the course of that teacher's career. Research consistently shows that quality of teaching has the greatest impact on pupil outcomes.

And we need great science teaching at every level.

The foundations for science are laid in primary schools. This is why science is a core subject in the national curriculum, alongside English and maths. Primary science can and should be engaging, harnessing children's natural curiosity and imagination to help them develop a wide range of skills, including literacy and maths as well as scientific thinking. However, primary schools need support to teach science well. Very few of their teachers studied science beyond the age of 16, so they need to develop their knowledge and skills to teach science with confidence.

Secondary schools face different challenges. Secondary science subjects include fast moving fields that require teachers to continually refresh their knowledge (biology), teach practical work safely (chemistry) or require substantial mathematical skills (physics).

Moreover, secondary science teachers are often asked to teach physics, chemistry and biology to the younger students, even though these are three very different disciplines and many degree courses concentrate on a specialist subfield. Nonetheless, we expect biology teachers to teach physics and vice versa. One Headteacher likened this to asking a geography teacher to teach history or music – perhaps not impossible, but certainly hard to do well without support.

The challenges grow as you move up the school, due to the difficulty of recruiting and retaining specialist science teachers, particularly in physics. This means that science GCSEs and even A levels may be taught by non-specialists, whose lack of knowledge and confidence adversely affects student outcomes. It is hard for a biologist to teach GCSE - let alone A level - physics.

Research shows that these issues around teacher supply disproportionately affect students from working class and minority ethnic backgrounds. Schools in disadvantaged areas struggling to recruit and retain experienced science teachers.

Fortunately, we know what works – investing in teachers to develop them as skilful, inspirational professionals. Quantitative analysis of national data on outcomes shows STEM Learning's professional development (CPD) for teachers improves student achievement in science at every level:

- Primary science: schools where teachers engaged with CPD improved their results (Key Stage 2 assessments for science) 50% faster than other schools.
- GCSE: schools utilising CPD saw an increase of over 10% in the proportion of students achieving a good grade in two science GCSEs – more than double the progress of other schools. This means that, in 2018/19, 16,000 additional young people achieved two good science GCSEs.
- A level: entries for STEM A levels have increased by around 8.5% over the past three years. 80% of entries were from schools using STEM Learning CPD – comparing them with schools that did not use CPD, we estimate that CPD accounted for 40% of the overall increase.

The impact of teacher CPD extends beyond attainment. CPD develops inspiring science teachers who understand the real-world context – how science is applied – and use this to enrich their teaching and inspire their students.

This is reflected in evidence from student surveys that, after CPD, teachers inspire more positive attitudes towards science, with more students – girls and boys – aspiring towards STEM careers. Student confidence also grows, with more considering themselves "the kind of person who could have a STEM career".

A POLICY THAT (MORE THAN) PAYS FOR ITSELF

The UK needs great science education to support its great ambitions as a science superpower. We know how to make that happen – investing in teachers so that every young person can benefit from great teaching in science, regardless of their family background or where they live.

Currently, STEM Learning connects with over 230,000 teachers, reaching every primary and secondary school, and every post-16/FE college in the UK. This provision is supported by a unique collaboration of Government, charities and businesses – but it is Government support through the Department of Education that provides the foundation that unlocks investment from others and enables the whole enterprise.

And this Government investment pays for itself. For, in addition to improving student outcomes and aspirations, CPD for science teachers encourages experienced teachers to stay in the profession, reducing the need to spend money training new teachers (and helping schools solve those staffing shortages that I mentioned earlier).

An independent study by Education Datalab showed science teachers are 160% more likely to remain in the profession if they take part in STEM Learning CPD, rising to 190% for newly qualified teachers. Over the past three years, this support has helped over 1,100 secondary science teachers stay in the profession – around 3% of the total science teaching workforce. Based on conservative (IFS) figures, we estimate this saved the UK at least £58.5m in teacher training costs, a return on investment of 153%.

Of course, the true return is even greater, since this calculation is based simply on savings on teacher training. It does not take account of the benefits of science education, the widening of our talent pool to support our ambition to be a science superpower, the opening up of opportunities this will create, or the intrinsic good of scientifically literate citizens, able to make good decisions for themselves and their country. □

MAKING STEM A BUSINESS PRIORITY

Donald Morrison, Jacobs' People & Places Solutions U.K./Europe Senior Vice President and General Manager and Global Executive Sponsor of Digital

Science, technology, engineering and mathematics (STEM) is at the epicentre of developing the future and addressing complex issues such as urban migration, catastrophic climate threats, cybersecurity and natural-resource stresses. Despite the number of U.K. undergraduates studying STEM subjects increasing by 16% over the last decade (compared to an overall increase across all subjects of 13%) undergraduate numbers for EU students increased by 52% and the rest of world rose by 63% (source: ABPI 2019). The U.K. Government's commitment to invest £600 billion in infrastructure will help fund many STEM jobs, so how do we ensure we have sufficient pipeline of STEM skills in the U.K?

Collaboration between business, education and Government is clearly key to investing in and delivering the workforce of the future; raising young people's skills, aspiration and knowledge of STEM careers. A STEM education has economic, social, cultural and ethical value, with positive impacts on social mobility and the U.K.'s levelling up agenda, as well as promoting diversity and equality in future careers.

Government clearly recognises the importance of these skills – with focus already brought to T Levels, apprenticeships and extra university places for STEM subjects, and we welcome its ambition to make 'the U.K. a scientific superpower' and support the development of technologies to reach net zero carbon emissions by 2050.

At Jacobs, we are equally supportive of closing the STEM skills gap; it's a clear business priority for us. We work to solve some of the toughest challenges faced by our clients and communities. This means bringing diverse teams of

Pictured with Jacobs President and Chief Operating Officer Bob Pragada (far right), Professor Brian Cox talks to 16 to18-year-olds from local London schools about the skills they will need for the future.

multidisciplinary specialists together to create solutions which focus on delivering outcomes with social, environmental and economic benefits. Our people work on everything from traditional engineering design, to economic and environmental assessments, cyber security, digitalisation of client asset bases, carbon footprint reduction, to complete programme delivery. Putting their knowledge and imagination together, they reinvent the way we solve problems and shape the next generation of smart solutions. That demands all sorts of expertise and experience, from scientists, engineers and project managers to economists, aquatic ecologists, data scientists and digital specialists.

So, it's business critical that we promote STEM and be a key contributor to the broader skills solution, to keep pace globally, and to help drive a vibrant economy for all. It's important for us to provide career pathway opportunities for disadvantaged communities and to make a social value impact where it matters most.

As a business, we're working to influence positive change. Through our STEM engagement, we can influence the education and career decisions of future generations and attract a diverse and broad spectrum of talent with the future skills needed – ensuring a steady pipeline of skilled professionals.

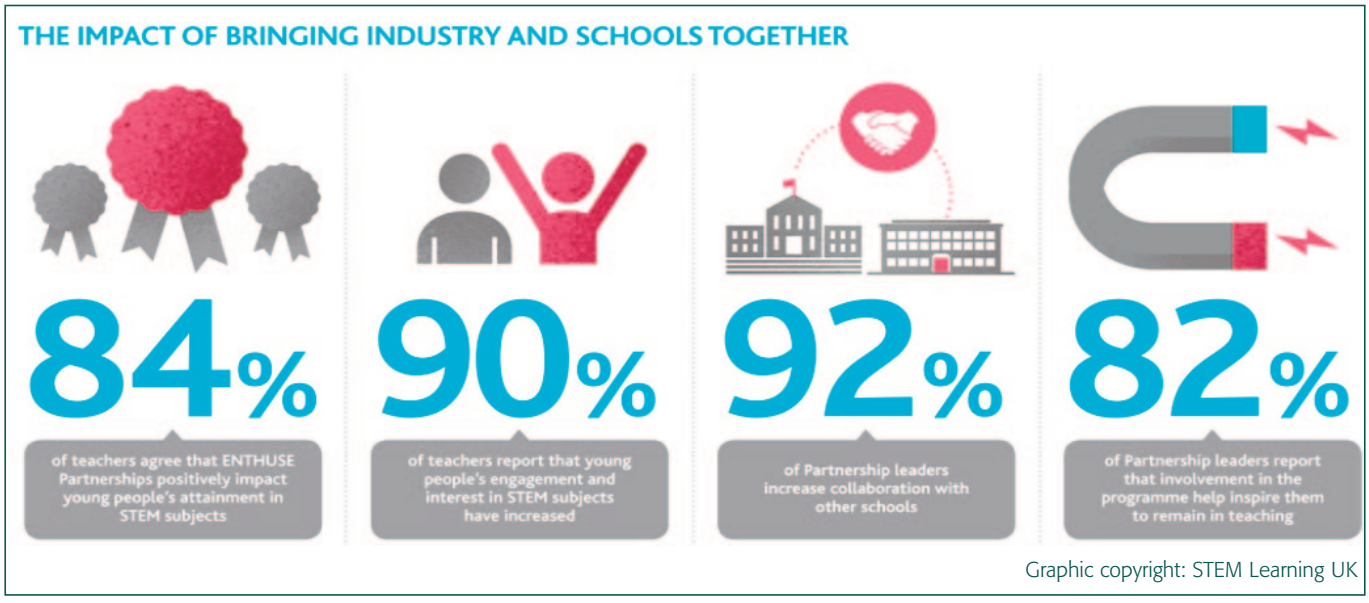
INVESTING IN STEM EDUCATION

A lot of the STEM discussion is around the "national" STEM skills shortage. Yet we see the need for different STEM skills in different parts of the country, for example, science and nuclear engineering skills in our operations in Cumbria and Warrington, and digital and project management skills in our Birmingham and London teams. The North of England is one of the most dynamic, innovative and creative parts of our country; investing in the right STEM skills here will underpin the Northern economy's future productivity and competitiveness. Jacobs employs 3,000 people in our Northern cities and regions, teams delivering transformative infrastructure projects for the region. Use of social value measurement tools, like Simetrica-Jacobs' equity weights (estimated using a Green Book compliant method), for priority setting for education and employment connected to infrastructure investment, can help shape better outcomes in more challenged areas.

By working together, local and regional partners across business, education and government can better understand the specific STEM jobs and skills that are needed in specific parts of the country.

Working in conjunction with STEM Learning U.K., for example, we're bringing schools together to form 'ENTHUSE Partnerships'. These make lasting improvements in the quality of science education, with each partnership school cluster raising aspiration and achievement for thousands of young people. It's about having an impact where its most needed. STEM employers can invest, leveraging the

> *"We recognise the quality of teaching has the greatest influence on achievement, career destination and the power to change the lives of young people."*
>
> Tricia Stephenson Jacobs STEM Lead, Europe



Graphic copyright: STEM Learning UK

Aligning these partnerships with, and embedding the language of, the Skills Builder Universal Framework (SBUF) is also essential.

Graphic copyright: SBUF

Government's investment in continuing professional development for science teachers, and engaging with schools through STEM Learning's network that we'd otherwise not reach. Jacobs is currently piloting three partnerships, supporting schools in Bristol, Manchester and Glasgow to drive and create sustainable improvements.

Considering the current fourth Industrial Revolution and the impact of COVID-19, future jobs highlight the need not just for technical knowledge, but for creative ingenuity, non-cognitive skills and agility. Over the last four years the Skills Builder Framework has been developed to make sense of how essential skills are progressed. It breaks down eight essential skills into sequential steps from expectations of children to a high level of mastery. We work with our people to raise their individual awareness of their own skills through the lens of the framework. It provides the foundation we need to ensure everyone builds the essential skills to thrive in the future workforce. It helps us shape both the technical and softer skills development for our 800+ graduates, interns and apprentices currently training in the U.K.

PROMOTING GENDER DIVERSITY AND EQUALITY

To develop the STEM skills the U.K. needs, it continues to be vital that we collectively promote gender diversity and equality in STEM learning and the workplace. As an employer of more than 10,000 people in the U.K., diversity powers our collective strength and our ability to stay ahead to create the new standards our future needs. Relationships with organisations like the Careers Enterprise Company help break perceptions by encouraging young women to succeed in STEM and Apprenticeship routes.

Our global Action Plan for Advancing Justice and Equality, builds on our existing global inclusion and diversity strategy, TogetherBeyond℠, and sets actionable initiatives and measurable objectives in Jacobs' continuing efforts to address embedded and systemic racial inequities.

BUILDING INDUSTRY EXPERIENCE VIRTUALLY

Industry and commercial experience are essential to gaining a better understanding of career pathways. In response to lockdown, we rapidly developed, tested, and delivered a suite of on-line STEM initiatives, making a positive impact in our local communities through a collaborative, inclusive and sustainable way to support young people, parents and teachers.

> *"It has been great …to participate and find out about the spectrum of jobs within engineering, from health and safety to interior design."*
> Alex, 15 yrs. old participant

Katie and Rebecca, two of our Engineering Degree Apprentices in the U.K., are inspiring young women and girls to consider engineering as a profession.

Our virtual work experience programme takes students through the design of a science research facility giving the opportunity to develop STEM skills ranging from project management to architecture, and other critical skills like problem solving and understanding multiple data sources. Students participate who may otherwise be disadvantaged by distance or resources, making virtual delivery more inclusive. Going forward we're engaging our clients and other industry partners with resources to support their own education programmes.

As we look to the future of work and how our future talent force needs to evolve, interdisciplinarity is at the heart of the majority of solutions we create for clients. We intentionally put multiple disciplines around a client problem. So, having a pipeline of future talent that have studied science, engineering and other disciplines provides diversity of thought and helps us find the best range of solutions and better outcomes. STEM skills are essential for tackling the biggest issues of our time. Across our business, our people are working on projects to safeguard the environment, and improve the security, connectivity, resilience and productivity of the U.K., so it's vital that we inspire and support the education and career decisions of our future generations.

Every young person deserves a world-leading STEM education, one that engages and nurtures their unique talents, and provides the knowledge and investigative, creative and practical skills they will need to participate fully as the creators and citizens of tomorrow. They are the new talent we all rely on to help create an economically vibrant, greener and more equitable U.K. and a more sustainable world. If we are to achieve net zero by 2050, it is the STEM skills and the young people we are training now who will 'reinvent tomorrow'. □

STEM Learning UK

SCIENCE EDUCATION IN PRACTICE: TRANSFORMING ASPIRATIONS AND ACHIEVEMENT

Allie Denholm
Headteacher
Heworth Grange

As an experienced Headteacher, Allie Denholm understands first-hand the importance of skilful teaching to raise children's aspirations and achievement. Here she discusses what works – and how to develop great science teachers – drawing on her own experience transforming science education and raising attainment.

WHY SCIENCE EDUCATION MATTERS

What drives me, more than anything, is helping children, especially those facing challenging circumstances. I want to be where I can make the biggest difference - this has taken me from working in leafy semi-rural schools in Sussex to schools in the northeast, working with children in very disadvantaged areas.

Wherever I work, one constant is making sure the children in my school get a great education in science. Children do really well from studying science – it is a powerfully facilitating subject that gives them a great footing for everything else, whatever they want to do next. And children need to understand the world they live in, from environmental issues to the nuances around Covid. Science education empowers them to be great citizens, to look after themselves and their families.

MY JOURNEY IN SCIENCE EDUCATION

In 2005 I had just been appointed as Head of Science in a lovely leafy school in East Sussex. The school had good uptake of science but was a little bit stuck in its ways - I wanted to engage and inspire our students and make science the most popular subject in the school. I was excited, but also a bit daunted and knew I needed support to realise my ambitions. Like many teachers on a leadership path, I went from being a classroom teacher - who had helped to coordinate work but never had to manage staff - to being a manager in charge of 14 teachers and five technicians.

Fortunately for me, I had access to professional development (CPD). The new National Centre for Science Learning was running its first "New and Aspiring Heads of Science" course – exactly what I needed! It was (and is) a highly practical course that blends face to face training with project work that you do as part of your day job – and helps you do that job better. Experienced teachers and leaders shared their experience, including how to get the best out of staff and lead with confidence across all three science subjects. Residentials built peer support networks, sharing experiences to build confidence and knowledge. With this support, I led science to become the most successful subject in the school - GCSE results were outstanding and 80% of sixth formers chose to study science.

HOW TO DELIVER GREAT SCIENCE EDUCATION – DEVELOP GREAT TEACHERS

My own experience showed me the importance of professional development for teachers, the power of CPD to transform outcomes for children. This was the key to success in my next job, as Assistant Head at a school in a deprived area of Hastings. I was asked to sort out science – results were poor, staff lacked confidence and teacher turnover was a problem. It took just six months to turn this around - using CPD to raise teaching quality and staff

confidence, skills, energy and motivation. I invested in leadership CPD for the most promising, which helped us to hold on to them as future leaders who could keep science strong at the school.

I also used CPD to transform outcomes at my next school in South Shields, in a very challenging area where 70% of the children qualified for pupil premium funding and it was difficult to recruit and retain science teachers. With children from disadvantaged backgrounds, it is even more important that their school engages them, raises their aspirations as well as their attainment. We were able to close the gap through a relentless focus on staff development, using CPD to train staff to do a great job of supporting children from disadvantaged backgrounds.

WHAT GREAT TEACHERS DO: HOW TEACHER CPD MAKES A DIFFERENCE

Great teaching starts with the children in front of you – you need the skills to assess and the confidence to adjust to meet them where they are. You need to ask yourself "I'm going to be presenting this concept today. What ideas and experiences am I taking for granted?"

For example, in biology we may be talking about animal and plant species that children have never come across. In South Shields, even though it was on the coast, there were children who had never been off their estate to walk to the sea. Another challenge is scientific literacy - children from disadvantaged backgrounds are typically significantly behind their peers in terms of literacy. Science is littered with phrases and terminology that, from the perspective of the child, feel like they are reading a foreign language, words like species, calibration or momentum. These need to be explained or children will feel bewildered and disengage.

Teachers who have benefited from professional development understand what to watch out for, how to "scaffold" concepts to build understanding not bewilderment. And when such a teacher does (inevitably) overlook something, they will know the signs and have strategies for bringing the students back in. For example, when I moved to South Shields, my first practical with year 11 was carnage. Nothing to do with behaviour, they simply had no idea how to manipulate objects, to use the equipment, because their previous teachers had not been skilled up to teach them this. Children from very disadvantaged backgrounds have often not had the chance play with toys like Lego that teach you how to manipulate objects. Fortunately, I had the skills to step back and adjust, strip it back to basics to build up their skills.

Checking understanding is a key aspect of teaching. Less skillful teachers tend to operate on transmit, rather than letting the children speak - they will ask closed questions that invite one word answers. Skilful confident teachers use open questions – this can feel risky because you may find the children do not understand something and you need to improve or change how you are teaching it. But a skilful teacher is not frightened when a child does not understand – they respond to the challenge of explaining it, perhaps in a different way for the child who did not latch onto it the first time.

WHAT DO WE NEED NOW TO ENSURE A GREAT SCIENCE EDUCATION FOR ALL OUR CHILDREN

I am now Headteacher at a big secondary school in Gateshead where just over half of our children are in receipt of people premium – and many more whose families are only just managing. My mission is to help these children achieve as much as children who are not disadvantaged – developing the skills and confidence of my staff is key. Even with all the other challenges we currently face, I am committed to developing my staff to become great teachers.

Indeed the challenges created by Covid mean that our children need skilful teaching more than ever. We need CPD to support teachers producing online learning, which is a new area for most teachers. Back in the classroom, skilful questioning is key - we need to understand where individual children are in their learning after such a long period out of school. Assessing this through tests would not be good for well-being, but "diagnostic appraisal" - a skilful teacher asking skilful questions - can find out as much as a paper test without risking damage to the child. We also need to be skilful in our choices about what we cover, what to prioritise within the curriculum, what foundation concepts do the students need to build their understanding - this kind of strategic adaptation takes a lot of skill, this is exactly the sort of thing that teachers learn from good CPD..

Our children need skilful teachers more than ever and I know that my school can deliver great science education by developing great science teachers. I hope that the Government will continue to invest in CPD for science teachers – it is transformative. □

THE POWER OF PLACE: MAXIMISING THE LOCAL ECONOMIC IMPACTS OF RESEARCH AND DEVELOPMENT

Daniel Rathbone, Assistant Director, Campaign for Science and Engineering

Dr Daniel Rathbone is Assistant Director of the Campaign for Science and Engineering, the UK's leading independent advocate for Science and Engineering. In this role he is head of policy for CaSE, shaping its policy work and engaging with Parliament and Government. Daniel has a background across the physical sciences and has previously worked for the House of Lords Science and Technology Committee and the House of Commons Library.

The UK Government's hugely welcome commitment to increasing the public research budget to £22bn by 2024/25, provides it, UKRI and others with the opportunity to be more creative in how they support research and innovation. Far from the turn of the 2010s, where a ring-fenced budget left the Government with little room to manoeuvre, the UK can afford to be bold with its investment in research.

However, the Covid-19 pandemic has put serious pressure on the ability of the research sector to continue to fund and facilitate research. This not only brings unprecedented questions to the way in which research-intensive organisations need to be supported in the short and medium term, but also poses questions about how the UK public sector can most effectively and sustainably invest in research to create the best outcomes for the citizens of this country.

Here at the Campaign for Science and Engineering (CaSE) our work on increasing research and development (R&D) intensity in recent months has focussed on two main strands ahead of the Comprehensive Spending Review, due to conclude this autumn. The first is working with our members to identify ways in which the effects of the Covid-19 pandemic on the research sector can be mitigated. The second, and the focus of this article, is working to create an evidence base for how R&D investment can support economic growth in the regions and nations of the UK and drive the Covid-19 economic recovery. Our report "The Power of Place", published back in May, sets out a number of recommendations for the Government as it draws up its own R&D place strategy. We were really pleased to see that some of these were already taken up by the Department for Business, Energy and Industrial strategy in its recently published R&D roadmap.

We have developed an evidence base for the impact of place-based regional R&D investment on local economic growth by working with our diverse, UK-wide membership. We have held discussions in Scotland, London, the West of England, the West Midlands, the North East, Northern Ireland, Wales and the North West. Our discussions have brought together senior representatives from academia, industry and local government to review areas such as the structure of partnerships between organisations and the opportunities that R&D investment could bring for local economies.

In our work we have covered the many different types of places in the UK, including urban metropolitan areas, smaller towns and cities and their rural hinterlands. The issues faced by those carrying out R&D in these different types of places can often be quite different. Our findings were in three broad categories: building on excellence and developing a brand, local leadership, and supporting small businesses.

BUILDING ON EXCELLENCE AND DEVELOPING A BRAND

We found that investment is likely to give a greater return

when it builds on existing excellence and it is difficult to re-create the conditions that give rise to excellence just by spending money – it is a process that has often happened organically over many years. Therefore, investment should be focussed on R&D excellence that already exists – even if it is small and nascent.

It is also important to improve the branding of regions to highlight their strengths. By clarifying their distinctive strengths and sectors in order to present a pitch for national and overseas investment regions should be able to attract greater UK and global investment.

To be most effective, local and regional branding should be mapped on to areas where there is already a sense of local or regional identity and the appropriate local bodies exist in order to take advantage of that brand and any investment that comes with it.

THE IMPORTANCE OF LOCAL LEADERSHIP

Strong leadership from both civic leaders and the research sector is vital to realising the full benefits of local R&D investment. Leaders from local authorities, combined authorities and LEPs need to have much greater involvement in regional R&D conversations. Those examples we have found of successful local and regionally R&D investment, such as NETPark in County Durham and the National Graphene Institute at the University of Manchester, have been driven by strong civic leadership by a small number of committed individuals. However, this works both ways and it is incumbent on leaders in the research community, both in businesses and universities to build a strong narrative to show local civic leaders what R&D can do for the local growth agenda.

There is also a need for combined authorities and other local leaders to assess the levers they currently have at their disposal to design and implement tailored regional interventions, and should consider making the case to Government if they believe more levers are needed. Central and local government should also work together closely to improve national coordination between local and national R&D priorities. This will help maintain the breadth of the UK research base by ensuring that regions do not all focus on the same areas or disciplines.

Investment in R&D cannot be considered in a vacuum. Attracting and retaining highly skilled graduates in a region is important in order to attract innovative businesses to that region. This is often affected by the wider perceptions of a region and quality of life factors outside of R&D, such as housing affordability. Improving local infrastructure and housing will help equip places for increased research intensity and making places more attractive to live will help retain skilled people, a topic that has come up during every conversation we have had. It is important that decisions made about regional R&D are linked up with other regional development decisions across local and national Government. There is a role here for UKRI to encourage all parts of Government to think about these issues holistically.

SUPPORTING SMALL BUSINESS

University-business collaborations are crucial to local research and innovation ecosystems and promoting a region. This is particularly true for the collaborations between universities and small and medium sized enterprises (SMEs). Universities often act as an anchor point around which a local innovation ecosystem can be built. However, research ecosystems are often complex and fragmented, which can hinder SMEs from accessing finance and innovation support easily. Therefore, there needs to be greater support from local and national government to enable SMEs to form collaborations with universities and to secure R&D investment.

EU structural funds currently support a large number of SME collaborations and help build research capacity across the country. This support is not spread evenly. Some areas, such as Wales, are more heavily reliant on this type of support. Therefore, careful consideration will have to be given to how domestic schemes such as the long-awaited Shared Prosperity Fund replace this support, in order to continue to build research capacity in less research intensive parts of the UK.

WHAT NEXT?

Since we carried out the evidence gathering for our report the context in which the "levelling up" and R&D investment agenda will be taken forward has changed dramatically as a result of the Covid-19 pandemic. However, the fundamental challenge of encouraging regional economic growth will remain the same and has taken on even more importance as the UK emerges from the pandemic and looks to rebuild the economy. Furthermore, the barriers facing this agenda are unlikely to be changed by the pandemic, if anything public investment is likely to be even more crucial. Therefore, it is still vital that Parliament and the Government takes on board the evidence we have gathered and the recommendations we have made to ensure that the regional investment in R&D has the greatest possible economic impact.

CaSE will be continuing our discussions around the country with our members and continue to engage with the Government and Parliamentarians as proposals are developed for the UK R&D Place Strategy. Strong evidence will be essential to inform policymaking and ensure that a place-based approach to research funding will in fact deliver the intended outcomes. We hope that our contribution to the evidence base will support policymakers in building a more productive and prosperous nation. □

COVID-19: THE ROLE OF RESEARCH AND INNOVATION IN TACKLING THE PANDEMIC

Dame Ottoline Leyser
CEO of UK Research and Innovation (UKRI)

The UK's response to the COVID-19 pandemic has demonstrated the importance of research and innovation in navigating the crisis and it will be central in how we manage to build back better. UKRI has a clear role to play in our continued fight against the pandemic and in our recovery from it.

These uncertain and challenging times bring into sharp focus the central importance of research and innovation in the future of the UK and beyond. As the new CEO of UK Research and Innovation (UKRI), the largest UK public funder of research and innovation, I am determined that we meet our responsibility to ensure we are investing every penny of taxpayer money entrusted to us wisely.

UKRI brings together seven research councils spanning the full range of disciplines from engineering to history, and medicine to geoscience; with Innovate UK focused on the research and innovation needs of the business community; and Research England which works in close collaboration with the higher education funding bodies of the devolved administrations to support universities. Bringing these organisations together allows us to connect research and innovation communities, institutions, businesses and wider society, in the UK and around the world. Informed by our networks and expertise we are working across the whole research and innovation system.

Our vision is for an outstanding research and innovation system in the UK that gives everyone the opportunity to contribute and to benefit; enriching lives locally, nationally and internationally.

With a budget of over £8 billion, it is our responsibility to ensure the health of the whole system, now and in the future.

As a steward of this system, we will work with many other actors, including our close partners such as Higher Education Institutions, innovative businesses, investors, not-for-profit organisations and policy makers, and a wider set of partners such as those in the education system and civil society.

The UK's response to the COVID-19 pandemic has demonstrated the importance of research and innovation in navigating the crisis and it will be central in how we manage to build back better. UKRI has a clear role to play in our continued fight against the pandemic and in our recovery from it.

The UK has an excellent research base. These strong foundations have allowed us to act quickly to mobilise the research community to rise to this new challenge. Our councils have a rich understanding of their domains and deep relationships with universities, institutes and businesses across the UK. It is this strong research base, connected under the UKRI umbrella, that has allowed us to respond so rapidly and effectively to the pandemic.

Working closely with partners across the wider research community, such as the National Institute for Health Research and the Office for National Statistics, UKRI-funded research has made major contributions to progressing the UK's understanding of the spread of COVID-19, its impact on society, and to efforts to develop new diagnostics, therapeutic medicines and vaccines.

Research is addressing the many impacts of COVID-19, which are diverse, complex and evolving; not just improving our understanding of the virus itself so we can develop treatments and vaccines but also the economic, social, psychological, and environmental impacts of the pandemic on society. UKRI's response to the pandemic has touched on all research disciplines across all areas of our remit.

UKRI is also investing heavily to help innovative businesses survive the economic impacts of the pandemic and build for the future. Businesses have been able to apply for new funding to support the development of technologies to help tackle both the health and economic impacts of the pandemic. We have also been able to provide

UK Research and Innovation

further investment for hundreds of businesses already receiving UKRI support to ensure they stay afloat during troubled times and are able to continue developing their innovations and bring them to market.

Whilst we continue to work hard to address the issues we are facing now, it is critical that we also learn from experience to ensure that the UK has a coherent framework for future responses based on preparedness and resilience. This is essential both to address the evolving R&D needs in the current pandemic and for preparedness for any future infectious diseases with pandemic potential.

Beyond this, as we look to the future, UKRI is working hard to provide the country with the infrastructure, environment and research and innovation culture required to thrive and build a greener, healthier and more resilient UK.

Since the start of the pandemic, UKRI has invested more than £400 million into some 250 COVID-19 related research projects and more than 1,500 of the most R&D intensive small and medium size firms. Here are just a few examples of UKRI-funded work.

CASE STUDY: CREATING NEW VACCINES

Even before the new coronavirus emerged, UKRI had strategically invested millions in vaccine development and manufacturing research, for example through the Medical Research Council and the Cell and Gene Therapy Catapult. Now, UKRI is funding two vaccines that are in human trials. Professor Sarah Gilbert and Professor Robin Shattock are leading two teams based at the University of Oxford and Imperial College London respectively.

The technology used to develop the Oxford COVID-19 vaccine has been named ChAdOx1. It is based on a harmless, weakened adenovirus that usually causes the common cold in chimpanzees. Chimpanzee adenoviral vectors are a very well-studied vaccine type, having been used safely in thousands of subjects. It has been genetically changed so that it is impossible for the adenovirus it to grow in humans. This also makes it safer to give to children, the elderly and anyone with a pre-existing condition such as diabetes. ChAdOx1 was chosen as the most suitable vaccine technology as it has been shown to generate a strong immune response from one dose in other vaccines.

Imperial's vaccine uses a different approach. Unlike traditional vaccines that are typically based on a weakened form of a virus or particular proteins made by the virus, the Imperial vaccine instead uses bits of genetic code, called self-amplifying RNA.

Once injected into muscle, the RNA allows cells to produce copies of a protein found on the outside of the virus. This trains the immune system to respond to the coronavirus, so the body can easily recognise it as a threat in future. The current trials will show what dose is needed to produce an immune response safely.

CASE STUDY: IMPACT ON THE ENVIRONMENT

UKRI funded research is looking at how the pandemic has affected our environment. Projects include looking at the effect on air quality whilst much of the world was in lockdown, studying emissions data to understand the potential impact on respiratory illnesses and thinking about how we can build back in a more sustainable, greener way, for our economy and society.

The UK Centre for Ecology & Hydrology (UKCEH) has provided emissions data and analysis as part of its National Capability programmes. Air pollution levels during the lockdown period provide valuable evidence on how air quality might change as sources are reduced, for example during the UK's transition to net zero greenhouse gas emissions.

CASE STUDY: SUPPORTING INNOVATIVE BUSINESSES

In April, the government charged Innovate UK with delivering £750m of investment and support for UK businesses driving innovation and development during the COVID-19 pandemic. Alongside grants and loans for existing Innovate UK customers, an early package of funding saw £42m made available to 'fast track' over 900 new products and services specifically designed to boost economic recovery from the impact of COVID-19.

We have funded a huge variety of projects across a range of sectors. Just some examples:

- **Radical Fibres Ltd** will create the next generation of personal protective equipment using materials that capture viruses.
- **The National Theatre** is developing a cutting-edge entertainment platform, giving performers a digital stage for global audiences.
- **Volunteero Ltd** has developed a social media app to connect local communities and allow volunteers to target support to their most vulnerable neighbours.
- **i3d Robotics** is building a virtual-reality training/teaching platform that will enable medical students to upskill remotely and perform simulation surgeries.
- **Elchies Estates Limited** is setting up virtual farmers' markets to replace traditional markets that closed down as a result of the COVID-19 outbreak, providing a platform for local businesses and farmers to sell produce. □

THE LOW CARBON ENERGY TRANSITION: BRIGHT TIMES AHEAD FOR ECOSYSTEMS?

Dr Alona Armstrong, Senior Lecturer in Energy & Environmental Sciences, Deputy Director of Energy Lancaster, Lancaster University.

Society faces the impending and interlinked challenges of climate change and ecosystem collapse. Science indicates that we need to address both urgently, necessitating solutions that are implementable, scalable and applicable across the world. With supportive policies in place, land use change for renewable energy could be a win-win solution to the climate and ecological emergencies.

Energy production is the greatest single contributor to greenhouse gas emissions globally, prompting decarbonisation efforts across the world. In recent years, the UK has taken significant steps to reduce the carbon intensity of electricity, with the National Grid reporting a decrease of 59 % from 2013 (529 g CO2/kWh) [1] to 2019 (215 g CO2/kWh). This reduction in carbon intensity was due to the diminishing contribution of coal, with the gap filled by renewables (Figure 1). Globally, solar photovoltaics (PV) account for about 60% of the expected growth in renewable energy capacity additions. [2] Within the UK, as of May 2020, there was 13.5 GW of PV with 57% of the capacity comprising ground-mounted solar parks. [3] Historically, solar parks were often below 5 MW, given the limit imposed by the feed-in tariff. However, in May this year, the UK's largest solar park – Cleve Hill Solar – at 350 MW was approved by the Secretary of State for Business, Energy and Industrial Strategy. [4] Whilst development of ground-mounted solar parks provides low carbon electricity, contributing to the nation's net-zero targets, the implications of the land-take need to be considered.

Whilst the deployment of PV is a positive move in terms of climate change mitigation, the land-take, including the impact of increasing solar park sizes, raises questions about the impacts on the hosting ecosystem. Whilst land-take for solar parks is relatively small compared to the size of the UK (see Box 1) we are living in a time of land scarcity and of increased pressures on the environment to provide other essential resources such as food, fibre and space for recreation. Critically, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (for ecosystems what the IPCC is for climate) identifies land use change, not climate change, as the biggest driver of

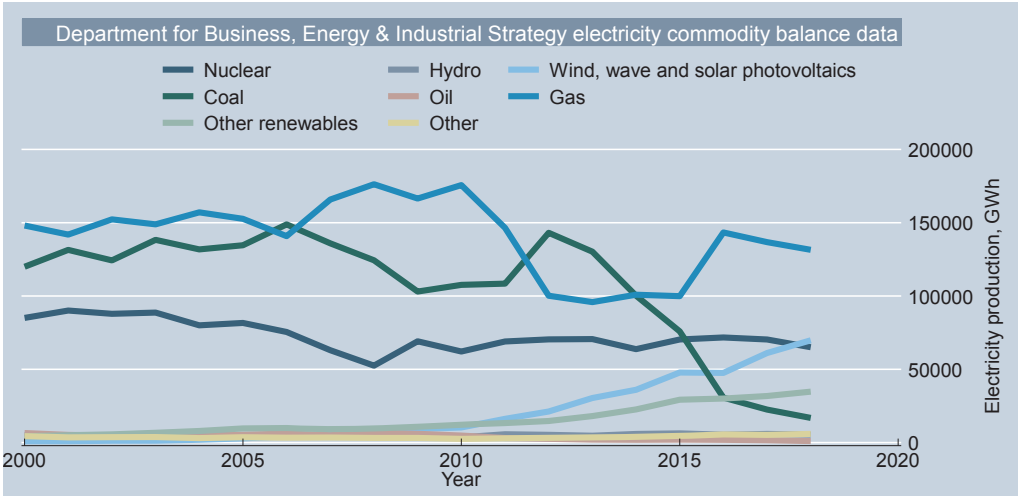


Figure 1. Change in sources of electricity in the UK from 2000-2018. Data source: BEIS [20]

BOX 1. SOLAR PARK FACTS & FIGURES.

Solar parks take up 1.8 ha per MW, equating to a total land-take of 14,281 ha in March 2020. This represents 0.06% of the total land area and 0.8% of the land area taken up by urban and suburban areas. Solar parks provide approximately 6.87 TWh of electricity per year, approximately 2 % of total demand.

Data sources
Unpublished: land areas of 1032 solar parks in March 2020.

Renewable Energy Planning Database: Capacities of solar parks. [16]

CEH land cover: total, urban and suburban land areas. [17]

DUKES: average load factor for 2019 [18] and total electricity demand. [19]

the decline in nature. [5] Consequently, there is a risk that we swap global climate change for local scale ecosystem degradation – out of the frying pan and into the fire? More compellingly, there is an underutilised opportunity to embed ecological co-benefits into the design and operation of solar parks, delivering much needed low carbon energy ***and*** ecosystem improvements, contributing to both energy and environment policy goals.

WHY ARE SOLAR PARKS GOOD PLACES FOR ECOLOGICAL ENHANCEMENTS?

Solar parks offer significant opportunities for ecological benefits for several reasons. Firstly, unlike many land use changes, their footprint (i.e. the area of the ground in contact with the infrastructure) is very small – around 5% of the total solar park area, leaving much space for ecological enhancements. Solar parks are secure and relatively undisturbed areas, thus offering the potential to host rich ecosystems, as observed on the Salisbury Plain due to military ownership limiting disturbance. [6] Moreover, the land is 'paid for' for between 25 and 40 years, providing opportunities for gains in both the short-term (e.g., development of a species rich sward if it was previously a low-grade arable field) and long-term (e.g., establishment of hedgerows). Finally, the physical presence of the solar arrays provides climate niches, [7] which could mitigate climate change impacts.

THE POTENTIAL IS THERE, BUT WHAT CAN WE DO?

We need to ensure that policy takes a positive approach, aiming to embed as many ecological benefits as possible. At a national level, stipulation of the need for *'net environmental gain'* in the 2018 Defra 25 Year Environmental Plan's delivers to this. [8] Moreover, *'net environmental gain'* is reflected in the National Policy Planning Framework, [9] although care must be taken that the low carbon electricity produced is not used to fulfil this criterion. Industry must also take up the mantle, embedding an ecologically beneficial approach in both development and operation. Many companies are already active in this area, evidenced by the Solar Trade Association's 'The Natural Capital Value of Solar' report [10] and the individual profiles of numerous companies. Moreover, there is a commitment across the industry to be good land stewards, detailed in the Solar Trade Association's Ten Commitments. [11] However, ensuring ecological betterment is central *industry-wide* remains a challenge given the economic nature of the energy industry and often-limited ecological expertise of solar park developers, operation and maintenance companies, and asset managers. [12] Ensuring that net environmental gain beyond low carbon electricity is driven through the planning process is one means to achieve sector-wide take up. Moreover, the post-Brexit Agricultural Bill offers significant scope. Specifically, if the Environmental Land Management Scheme allows 'dual use' there is the potential for payment for ecosystem services to be incorporated into business cases for solar parks. Finally, increasing awareness that ecologically beneficial site design and management does not have to cost more could increase uptake. For example, many sites are mowed in their entirety, yet reducing mowing strips in front of the panels to prevent shading will reduce costs and offer biodiversity benefits.

WHAT KNOWLEDGE IS THERE?

Whilst there is much potential, how do we know how best to design and manage solar parks? Given the relative immaturity of solar parks and the research funding landscape, relatively few studies have been undertaken. However, a NERC-funded collaboration between Lancaster University and the University of York produced the Solar Park Impacts on Ecosystem Services (SPIES) decision support tool.[13] It is grounded in over 700 pieces of peer-reviewed scientific evidence that links land management actions to ecosystem services impacts. It enables users to select management actions they are considering (e.g., grazing and habitat provision) and provides the implications for ecosystem services (e.g., biodiversity and soil quality), or users to select ecosystem services of interest and provides management actions that impacts them. The easy-to-use SPIES tool was co-developed with a cross-sectoral group of stakeholders, including developers, operation and maintenance firms, asset managers, consultants, local

government, farmers and nature conservation bodies such as the RSPB. This has assured it is fit for purpose, with ecological consultants, for example Wychwood Biodiversity, using it as part of their package of work; renewable energy investors, such as Low Carbon, encouraging all their ecologists to use it; and local government ecologists suggest planning applicants use it. A SPIES policy briefing can be found at https://www.lancaster.ac.uk/spies/.

However, more research and innovation are required - we are progressing this at Lancaster University through collaborations with a host of stakeholder partners. For example, we are examining the potential for solar parks to boost pollinator populations. If managed well, solar parks could provide appropriate habitats and forage resources for pollinators, with benefits for surrounding agriculture and implications for the Defra Pollinator Strategy along with food, energy and biodiversity goals. Within UKERC, [14] we are developing a standardised protocol for quantification of the ecosystem service and natural capital value of solar parks. The protocol includes biodiversity, soil, water, and atmosphere impacts, with the aim of guiding the solar industry and providing evidence for any payments under the new Agricultural Bill. Currently, there is no knowledge of the impacts of land use change for solar parks on land carbon sequestration, despite the relevance to net-zero targets; we are working to fill this gap. Resolution of the impact of floating solar on the hosting water bodies is also limited and we are working with UK Water Companies to further knowledge. The impacts could be positive, with good ecological outcomes and reductions in water treatment costs, but alternatively could be negative or negligible. We are also contributing to the Prospering from the Energy Revolution programme within EnergyREV, [15] investigating the environmental impacts of smart local energy systems.

HOW CAN PARLIAMENTARIANS HELP?

To capitalise on the win-win potential of land use change for renewable energy, we need to progress knowledge drawing on research, industry, and policy expertise. This knowledge needs to be embedded in policy and industry practice. The pandemic recovery, the desire to build back better and to grow back greener provide the perfect opportunity to achieve this. Now is the time to develop strategies, collaborations and generate roadmaps to ensure the decarbonisation of our energy system is coupled with the enhancement of our invaluable natural ecosystems. If we do this well, we stand much to gain economically, environmentally and socially.

Footnotes

1 https://www.nationalgrideso.com/media/national-grid-electricity-system-operator-data-shows-record-breaking-year-britains

2 https://www.iea.org/reports/renewables-2019

3 https://www.gov.uk/government/statistics/solar-photovoltaics-deployment

4 https://infrastructure.planninginspectorate.gov.uk/projects/south-east/cleve-hill-solar-park/

5 https://ipbes.net/global-assessment

6 https://nerc.ukri.org/latest/publications/planetearth/spr15-plain/

7 https://ec.europa.eu/environment/integration/research/newsalert/pdf/solar_park_impacts_microclimate_plants_greenhouse_gas_emissions_479na4_en.pdf

8 https://www.gov.uk/government/publications/25-year-environment-plan

9 https://www.gov.uk/government/publications/national-planning-policy-framework--2

10 https://www.solar-trade.org.uk/about/the-natural-capital-value-of-solar/

11 https://www.solar-trade.org.uk/sta-solar-farms-10-commitments/

12 https://services.parliament.uk/bills/2019-21/agriculture.html

13 https://www.lancaster.ac.uk/spies/

14 https://ukerc.ac.uk/

15 https://www.energyrev.org.uk/

16 https://www.gov.uk/government/publications/renewable-energy-planning-database-monthly-extract

17 https://www.ceh.ac.uk/land-cover-map-2015-statistics

18 https://www.gov.uk/government/publications/quarterly-and-annual-load-factors

19 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904805/DUKES_2020_Chapter_5.pdf

20 https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes □

PARLIAMENTARY LINKS DAY 2020
PUBLIC TRUST IN SCIENCE

By Dr Stephen Benn, Director of Parliamentary Affairs, Royal Society of Biology

Parliament's flagship science event – Parliamentary Links Day – took place for the first time in its 33 years *online* on Tuesday 14 July 2020.

A remarkably wide and distinguished group of people from Government, Parliament and the scientific community took part in this year's event.

As can be seen from the invitation Links Day is organised by the Royal Society of Biology on behalf of a wide range of the scientific community including all the core sciences.

An Early Day Motion – co-sponsored by the Father of the House Sir Peter Bottomley MP and signed by Members on all sides – was tabled on the Commons *Order Paper* congratulating the Royal Society of Biology on its role in organising Links Day.

This year the theme was **Public Trust in Science** with discussions dominated by the high-profile research and scientific advice that has been central to the UK's pandemic response.

Links Day was co-sponsored on a cross party Parliamentary basis by Stephen Metcalfe MP, Chi Onwurah MP, Carol Monaghan MP and Layla Moran MP – and the morning's session was chaired by Stephen Metcalfe.

Dame Eleanor Laing MP

He introduced Dame Eleanor Laing MP who as Deputy Speaker welcomed everyone on behalf of Parliament and

The Deputy Speaker welcomes everyone to Links Day 2020

launched the event from the House of Commons itself.

Amanda Solloway MP

The first Keynote Address was from Amanda Solloway MP, Minister for Science, Research and Innovation. Her message was that science is for everybody and that in her view, increased public engagement can only be a good thing.

The Minister of Science Amanda Solloway MP

PANEL DISCUSSION

There then followed the panel discussion between four of the country's most distinguished scientists: Professor Sir Venki Ramakrishnan, President of the Royal Society, Dame Anne Glover, President of the Royal Society of Edinburgh, Professor Dame Nancy Rothwell, President and Vice-Chancellor of the University of Manchester and Co-Chair of COST, and Professor Sir David Spiegelhalter, Past President of the Royal Statistical Society.

Questions included whether trust has been damaged during COVID-19, the best ways to communicate value and the uncertainty of models, and how better public engagement, training and experience for research trainees can be best achieved. Sir Venki said that the public's "near complete compliance with lockdown," despite its economic and social costs, "showed the trust that the public placed on scientific advice." He said scientists must continue their efforts to reduce conflicts of interest, increase transparency, and avoid group-think in order to uphold public confidence. "When we are rewarded by this trust we must show ourselves to be trustworthy. We must be clear that uncertainty is part and parcel of science and not blame science or scientists when the conclusions or the evidence changes."

Sir David Spiegelhalter on the Panel with Sir Venki Ramakrishnan and Dame Anne Glover and with Dame Nancy Rothwell (not shown here)

Chi Onwurah MP

The second Keynote Address was delivered by the Shadow Minister Chi Onwurah MP Shadow Minister for Business, Energy & Industrial Strategy. She said that lessons must be learned from the pandemic as it should be used an opportunity to change the direction and culture of innovation so it is more inclusive. She also emphasised that there needs to be high investment in education and lifelong skills.

Rt Hon Greg Clark MP

The morning session concluded with two sessions involving major figures from Parliament and Government. The first was with the current Chair of the Science & Technology Select Committee the Rt Hon Greg Clark MP. He spoke about the importance of transparency and, noting the "rehabilitation of experts", his view that there is going to be an increased role for science in public policy after this pandemic.

Clark said that large numbers of people had watched the Government's scientific advisors being questioned by his select committee live on the BBC and Sky, and commended public health experts for taking part.

"It's gratifying that the hearings have attracted so much attention. Even though the scientists have a lot on their plate, it is important that we learn the lessons on the way, including those that can be applied later in the pandemic.

Opposition Shadow Minister Chi Onwurah MP

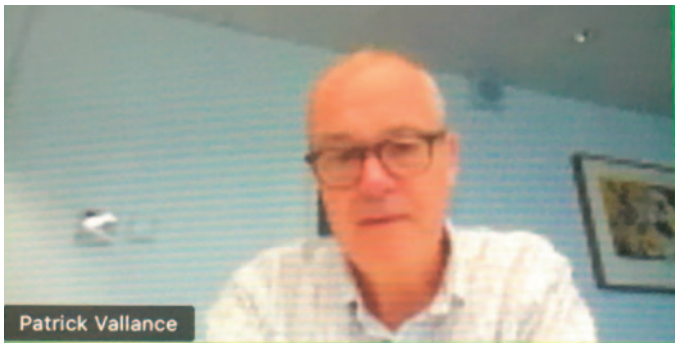
Being able to ask not just one but 10 questions on a particular topic is something that is unique to a select committee."

Sir Patrick Vallance

The morning session was concluded by Sir Patrick Vallance, the Government's Chief Scientific Adviser – whom as Stephen Metcalfe observed "needs no introduction".

Sir Patrick said that since the beginning of the pandemic in the UK the public are more likely to listen to scientific advice and that trust in science has increased. His experience of supporting government, especially through the pandemic, has led him to believe there is an absolute understanding that science is important across a range of policy areas. He noted that previously this had not always been the case. He was asked whether COVID-19 will change the way we conduct clinical research in the UK. He answered that it will, in some ways, and gave as an example the rapid way in which funding agencies have been able to support research, which could lead to a reduction in bureaucracy.

A brace of Science & Technology Select Committee Chairs Stephen Metcalfe MP (Chair 2016-2017) and Rt Hon Greg Clark MP (Chair from 2020)



Sir Patrick Vallance – the Government's Chief Scientific Adviser

Responding to questions Sir Patrick said the Government was wrong to initially keep the advice of the SAGE advisory board and the names of its members secret, but that the transparency shown since and further openness in sharing research and data would help boost trust and understanding and improve local policy responses.

This year's Links Day was originally supposed to be streamed live via YouTube (and a record number of people had signed up to watch) but the platform suffered a catastrophic failure on the day. Fortunately all the contributions are now available online at https://www.youtube.com/royalsocbio □

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. It is chaired by Darren Jones MP, who was elected in succession to Rachel Reeves MP on 6th May 2020.

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.

Current Inquiries:

- Post Office and Horizon - Opened 4 March 2020
- My BEIS inquiry - Opened 5 March 2020 Published 11th July 2020
- Net zero and UN climate summits - Opened 6 March 2020
- The impact of coronavirus on businesses and workers - Opened 13 March 2020
  Deadline 31 August 2020
- Delivering audit reform - Opened 18 March 2020. Deadline 31 July 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.
- Decarbonising heat in homes – Opened 2nd October. Accepting written evidence until 13th November 2020.

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.

Current Inquiries

- Electronic Waste and the Circular Economy - Opened 13 March 2020
- Technological Innovations and Climate Change: Offshore Wind - Opened 6 April 2020
- Technological Innovations and Climate Change: Hydrogen - Opened 7 May 2020
- Greening the post-Covid Recovery - Opened 13 May 2020. Deadline 14 August 2020
- Energy Efficiency of Existing Homes - Opened 18 May 2020. Deadline 13 July 2020
- Biodiversity and Ecosystems – Opened 13th July

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

SCIENCE AND TECHNOLOGY COMMITTEE

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

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).

Current Inquiries

- UK Science, Research and Technology Capability and Influence in Global Disease Outbreaks
  Opened 20 March 2020. Deadline 31 July 2020
- 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.

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.

Current Inquiries

- Management of the Coronavirus Outbreak - Opened 3 March 2020
- Pre-appointment hearing for the role of Chair of NICE - Opened 4 March 2020
- Social care: funding and workforce Opened 10 March 2020.

Deadline 31 July 2020

- Delivering Core NHS and Care Services during the Pandemic and Beyond - Opened 22 April 2020. Published 30th October.

- Safety of maternity services in England – Opened 24th July 2020.
- Workforce burnout and resistance in the NHS and social care – Opened 30th July 2020.

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

MEMBERSHIP OF HOUSE OF COMMONS SELECT COMMITTEES

BUSINESS, ENERGY AND INDUSTRIAL STRATEGY COMMITTEE

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
Ruth Jones MP, Labour
Charlotte Nichols MP, Labour
Mark Pawsey MP, Conservative
Alexander Stafford MP, Conservative

ENVIRONMENTAL AUDIT COMMITTEE

Rt Hon Philip Dunne MP, Conservative, Chair
Duncan Baker MP, Conservative
Sir Christopher Chope MP, Conservative
Feryal Clark MP, Labour
Barry Gardiner MP, Labour
Rt Hon Robert Goodwill MP, Conservative
Ian Levy MP, Conservative
Marco Longhi MP, Conservative
Caroline Lucas MP, Green Party
Jerome Mayhew MP, Conservative
John McNally MP, Scottish National Party
Dr Matthew Offord MP, Conservative
Alex Sobel MP, Labour
Shailesh Vara MP, Conservative
Claudia Webbe MP, Labour
Nadia Whittome MP, Labour

HEALTH AND SOCIAL CARE COMMITTEE

Rt Hon Jeremy Hunt MP, Conservative, Chair
Paul Bristow MP, Conservative
Amy Callaghan MP, Labour
Rosie Cooper MP, Labour
Dr James Davies MP, Conservative
Dr Luke Evans MP, Conservative
James Murray MP, Labour
Taiwo Owatemi MP, Labour
Sarah Owen MP, Labour
Dean Russell MP, Conservative
Laura Trott MP, Conservative

SCIENCE AND TECHNOLOGY COMMITTEE

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
Carol Monaghan MP, Scottish National Party
Graham Stringer MP, Labour
Zarah Sultana MP, Labour □

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 Lord Patel

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.

Current Inquiries

- Ageing: Science, Technology and Healthy Living - Opened 25 July 2019
- The science of COVID-19 Opened 7 May 2020. Deadline 3 July 2020

HOUSE OF LORDS SCIENCE AND TECHNOLOGY COMMITTEE

The Lord Patel KT, Crossbench, Chair
The Baroness Blackwood of North Oxford, Conservative
The Lord Borwick, Conservative
The Rt Hon. the Lord Browne of Ladyton, Labour
The Baroness Hilton of Eggardon, QPM Labour
The Lord Hollick, Labour
The Rt Hon. the Lord Kakkar, Crossbench
The Lord Mair CBE, Crossbench
The Baroness Manningham-Buller LG DCB, Crossbench
The Viscount Ridley DL, Conservative
The Baroness Rock, Conservative
The Baroness Sheehan, Liberal Democrat
The Baroness Walmsley, Liberal Democrat
The Baroness Young of Old Scone, Labour

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.

And those produced in 2019 and 2020 were:

631: Edge computing
630: Digital sequence information
629: Cloud computing
628: Remote sensing and machine learning
627: Managing land uses for environmental benefits
626: A resilient UK food system
625: Marine renewables
624: Food fraud
623: Natural mitigation of flood risk
622: Online extremism
621: Infrastructure and climate change
620: 3D bioprinting in medicine
619: UK insect decline and extinctions
618: Bioenergy with carbon capture and storage (BECCS)
617: Climate change-biodiversity interactions
616: Low-carbon aviation fuels
615: Climate change and aviation
614: Brain computer interfaces
613: Non-custodial sentences
612: Autism
611: Human Germline Genome Editing
610: Misuse of Civilian Drones
609: Access to Critical Materials
608: Online Safety Education
607: Improving Witness Testimony
606: Compostable Food Packaging
605: Plastic Food Packaging Waste
604: Climate Change and Fisheries
603: Climate Change and UK Wildfire
602: Developments in Wind Power
601: Sustaining the Soil Microbiome
600: Climate Change and Agriculture
599: Early Interventions to Reduce Violent Crime
598: Advances in Cancer Treatment
597: Climate Change & Vector-Borne Disease in Humans in the UK
596: Chemical Weapons
595: Reservoirs of Antimicrobial Resistance
594: Limiting Global Warming to 1.5°C
593: Cyber Security of Consumer Devices

POSTbriefs are responsive policy briefings based on mini-literature reviews and peer reviews. Those produced in 2019 and 2020 were:

40: Proposals to increase UK recycling of plastic food packaging
39: Outward medical tourism
38: Understanding research evidence
37: Key EU space programmes
36: Understanding insect decline: data and drivers
35: Evaluating the integration of health and social care
34: Net Gain
33: Research for Parliament: Preparing for a changing world
32: 5G technology
31: Evaluating UK natural hazards: the national risk assessment

POST has also introduced some rapid response articles that summarise the research around COVID-19:

COVID-19: Current understanding
COVID-19: Behavioural and social interventions
COVID-19: Insights from behavioural science
COVID-19: School closures and mass gatherings
Vaccines for COVID-19
Models of COVID-19: Part 1
Models of COVID-19: Part 2
Vaccines for COVID-19
COVID-19 misinformation
Face masks, face coverings and COVID-19
Models of COVID-19: Part 3
COVID-19 therapies
Mental health and well-being during the COVID-19 outbreak
Light switches and clusters: social distancing strategies for COVID-19
Contact tracing apps for COVID-19
COVID-19 and international approaches to exiting lockdown
COVID-19 in children
Immunity to COVID-19
Antibody tests for COVID-19
COVID-19 and social distancing: the 2 metre advice
COVID-19 Vaccines: July update on research
Effects of COVID-19 on the food supply system

COVID-19 in children – July update
Child and adolescent mental health during COVID-19
COVID-19, children and schools
COVID-19: July update on face masks and face coverings for the general public
Immunity to COVID-19: August update
Influenza immunisation programme, NHS winter pressure and COVID-19
COVID-19 vaccines: Immunisation and prioritisation of eligible groups
COVID-19 and the disadvantage gap
Long-term health effects of COVID-19

POST has also recently asked its COVID-19 Expert Database of 5500 experts what their main short-, medium- and long-term concerns are related to COVID-19 and what data they want to see the Government release. 17 articles covering different sectors are all available on the POST website here: https://post.parliament.uk/ category/horizon-scanning/2020/

Ongoing and future projects approved by the POST Board.

BIOLOGY AND HEALTH

In production

Disorders of consciousness
Researching gambling
Influence of industry on public health policy
Reformulation of food products
Testosterone and sports performance
Mental health impacts of COVID-19
Mental health impacts of COVID-19 on healthcare workers and carers
Living organ donation
Developments in vaccine technologies

Scheduled

Childhood obesity
Preventing zoonotic diseases

ENERGY AND ENVIRONMENT

In production

Food waste
Global deal for nature
Heat networks
Sustainable cooling
Effective biodiversity indicators
Reforestation
Hydrogen
Regulating product sustainability

PHYSICAL AND DIGITAL SCIENCES

In production

Algorithms and accountability
Smart cities
AI and healthcare

Scheduled

Digital skills for life

SOCIAL SCIENCES

In production

Screen time in young people
Distance learning

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

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PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY

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UK Research and Innovation

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UK Research and Innovation

Arts and Humanities Research Council | Biotechnology and Biological Sciences Research Council | Economic and Social Research Council
Engineering and Physical Sciences Research Council | Innovate UK | Medical Research Council
Natural Environment Research Council | Research England | Science and Technology Facilities Council

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.

Association of the British Pharmaceutical Industry

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The Association of the British Pharmaceutical Industry (ABPI) represents innovative research-based biopharmaceutical companies, large, medium and small, leading an exciting new era of biosciences in the UK. Our industry, a major contributor to the economy of the UK, brings life-saving and life-enhancing medicines to patients. Our members are researching and developing over two-thirds of the current medicines pipeline, ensuring that the UK remains at the forefront of helping patients prevent and overcome diseases. Topics we focus on include:

- All aspects of the research and development of medicines including clinical research and licensing
- Stratified medicine
- Vaccines, biosimilars, small and large molecules, cell therapy and regenerative medicine

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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.

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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.

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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.

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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.

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British Antarctic Survey (BAS), an institute of NERC, delivers and enables world-leading interdisciplinary research in the Polar Regions. Its skilled science and support staff based in Cambridge, Antarctica and the Arctic, work together to deliver research that uses the Polar Regions to advance our understanding of Earth as a sustainable planet. Through its extensive logistic capability and know-how BAS facilitates access for the British and international science community to the UK polar research operation. Numerous national and international collaborations, combined with an excellent infrastructure help sustain a world leading position for the UK in Antarctic affairs. For more information visit www.bas.ac.uk @basnews

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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)

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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.

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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.

SCIENCE DIRECTORY

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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.

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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.

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The British Society of Soil Science (BSSS) or "BS cubed" as it is fondly known was founded in 1947 by a number of eminent British soil scientists. It was formed with the aims: to advance the study of soil; to be open to membership from all those with an interest in the study and uses of soil; and to issue an annual publication.

Nowadays BSSS is an established international membership organisation and charity committed to the study of soil in its widest aspects. The Society acts as a forum for the exchange of ideas and provides a framework for representing the views of soil scientists to other organisations and decision making bodies. It promotes research by organising several conferences each year and by the publication of its two scientific journals, the European Journal of Soil Science, and Soil Use and Management.

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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

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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

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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.

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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.

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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
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- Primary; our local **Meet-a-Medic Programme** since 2005

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

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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

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The Francis Crick Institute is a biomedical discovery institute dedicated to understanding the fundamental biology underlying health and disease. Its work is helping to understand why disease develops and to translate discoveries into new ways to prevent, diagnose and treat illnesses such as cancer, heart disease, stroke, infections, and neurodegenerative diseases.

The Crick was formed in 2015, and in 2016 it moved into a brand new state-of-the-art building in central London which brings together 1500 scientists and support staff working collaboratively across disciplines.

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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.

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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.

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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.

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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.

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FirstGroup are the leading transport operator in the UK and North America and each day, every one of our 110,000 employees works hard to deliver vitally important services for our passengers. During the last year around 2.2 billion passengers relied on us to get to work, to school or college, to visit family and friends, and much more.

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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.

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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.

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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.

Institute of Food Science + Technology

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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.

IKE Institute of Innovation & Knowledge Exchange

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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)

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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.

The Institute of Materials Finishing

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The Institute of Materials Finishing is the premier technical organisation representing industry, academia and individual professionals in both the UK's and global surface engineering and materials finishing sector.

We actively promote continual education and knowledge dissemination by providing both distance learning and tutored training courses, as well as a technical support service. We also provide bespoke courses that are tailored to an employer's specific needs. The Institute also publishes *Transactions of the Institute of Materials Finishing* and a bimonthly newsletter (*IMFormation*), as well as holding regular regional and international technical meetings, symposia and conferences.

Institute of Measurement and Control

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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

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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 Institute of Physics and Engineering in Medicine

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IPEM is a registered, incorporated charity for the advancement, in the public interest, of physics and engineering applied to medicine and biology. Its members are medical physicists, clinical and bio-engineers, and clinical technologists. It organises training and CPD for them, and provides opportunities for the dissemination of knowledge through 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 Advancing Chemical Engineering Worldwide

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.

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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.

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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.

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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.

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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

London School of Hygiene & Tropical Medicine
Contact: Professor Peter Piot, Director
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Email: director@lshtm.ac.uk
www.lshtm.ac.uk

The London School of Hygiene & Tropical Medicine (LSHTM) is a world-leading centre for research and postgraduate education in public and global health with over 4,000 students and more than 1,300 staff working in over 100 countries across the world – including at two MRC Units in The Gambia and Uganda which joined LSHTM in 2018. Our depth and breadth of expertise encompasses many disciplines, and we are one of the highest-rated research institutions in the UK.

Marine Biological Association

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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.

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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.

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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.

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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.

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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.

SCIENCE DIRECTORY

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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.

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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.

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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.

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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.

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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.

Contact: Garry Graham,
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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.

QUADRUM INSTITUTE

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Opening fully in mid-2018, the Quadram Institute will be an interdisciplinary research centre capitalising on the academic excellence and clinical expertise of the Norwich Research Park. Its mission is to understand how food and the gut microbiota link to the promotion of health and preventing diet and age related diseases. The Quadram Institute brings together fundamental and translational science with a clinical research facility for human trials and one of Europe's largest gastrointestinal endoscopy units. This will synergise interactions between basic and clinical research, delivering a step change in the understanding of the role of food in health.

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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.

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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.

The Royal Institution
Science Lives Here

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The Royal Institution (Ri) has been at the forefront of public engagement with science for over 200 years and our purpose is to encourage people to think further about the wonders of science. We run public events and the famous CHRISTMAS LECTURES®, a national programme of Masterclasses for young people in mathematics, engineering and computer science, educational activities at the L'Oréal Young Scientist Centre and policy discussions with science students. And through the Ri Channel we share the stories behind cutting-edge science with people around the world.

THE ROYAL SOCIETY

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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.

Royal Society of Biology

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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.

ROYAL SOCIETY OF CHEMISTRY

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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.

society for applied sfam microbiology

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+44 (0)207 685 2596

*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

SUT Society for Underwater Technology

Society for Underwater Technology
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Fax: 020 3440 5980
E-mail: info@sut.org
Website: www.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.

Society of Chemical Industry

SCI: where science meets business

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SCI
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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

SCS SOCIETY OF COSMETIC SCIENTISTS

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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.

Society of Maritime Industries

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The Society of Maritime Industries (SMI) is the voice of the UK's maritime engineering and business sector. Promoting and supporting companies in Commercial Marine, Maritime Defence & Security, Ports & Terminals Infrastructure, Marine Science & Technology, Maritime Autonomous Systems and Digital Technology.

UK INNOVATION & SCIENCE SEED FUND

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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

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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

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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 Established 1926

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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

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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.

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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

Tel: 020 7222 7085
Email: office@scienceinparliament.org.uk
www.scienceinparliament.org.uk
follow us on Twitter @ParlSciCom

Monday 26th October 2020
Discussion Meeting on Sources, health benefits and global challenges of protein
Sponsored by kind permission of the Nutrition Society
5:30pm – 7:00pm Virtual Meeting

Monday 9th November 2020
Discussion Meeting on How will COVID-19 impact on the Government's 'Ageing Society' Grand Challenge mission?
Sponsored by kind permission of The Physiological Society
5:30pm – 7:00pm Virtual Meeting

Monday 23rd November 2020
Discussion Meeting on aspects of Covid-19
Sponsored by kind permission of UKRI
11:30am – 1:00pm Virtual Meeting

Monday 7th December 2020
Discussion Meeting on Autonomous Transport
10:30am -12:00pm Virtual Meeting

Monday 18th January 2021
Discussion Meeting on UK Telecommunications and Infrastructure
5.30pm – 7.00pm Virtual Meeting
(preceded by the Annual General Meeting)

Monday 15th February 2021
Discussion Meeting on Sector Deals for SME's
5.30pm – 7.00pm Virtual Meeting

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

https://www.foundation.org.uk/Events/Upcoming

Wednesday 2nd November 2020
Webinar on "Future Priorities for UKRI"
6:00pm – 7:00pm Virtual Meeting
https://www.foundation.org.uk/Events/2020/Future-Priorities-for-UKRI

Tuesday 17th November 2020
Discussion meeting on "Science and Government" as a part of the Foundation Future Leaders Conference 2020
10:00am – 12:00pm Virtual Meeting
https://www.foundation.org.uk/Events/2020/Foundation-Future-Leaders—-Annual-Conference

Wednesday 18th November 2020
Discussion meeting on "Research and Innovation in Industry" as a part of the Foundation Future Leaders Conference 2020
10:00am – 12:00pm Virtual Meeting
https://www.foundation.org.uk/Events/2020/Foundation-Future-Leaders—-Annual-Conference

Thursday 19th November 2020
Discussion meeting on "Science, Technology and Research in Universities" as a part of the Foundation Future Leaders Conference 2020
10:00am – 12:00pm Virtual Meeting
https://www.foundation.org.uk/Events/2020/Foundation-Future-Leaders—-Annual-Conference

Wednesday 25th November 2020
Webinar on "Online teaching in higher education post-Covid"
6:00pm – 7:00pm Virtual Meeting
https://www.foundation.org.uk/Events/2020/Online-teaching-in-higher-education-post-Covid

ROYAL SOCIETY OF CHEMISTRY

Wednesday 18th November,
12:30 – 3:00pm
'Science and the Parliament' Webinar
To register attendance:
https://www.rsc.org/events/detail/45373/science-and-the-parliament

ROYAL SOCIETY

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

THE ROYAL INSTITUTION

Details of all events and booking Information can be found at www.rigb.org/whats-on

ROYAL SOCIETY OF BIOLOGY

For further details please contact Karen Patel or Dr Stephen Benn at events@rsb.org

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THE NUTRITION SOCIETY
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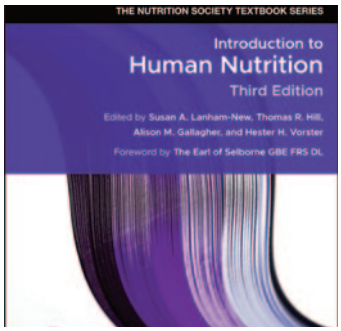

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- **Energy metabolism**, *Dr Gareth Wallis*
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