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# SCIENCE IN PARLIAMENT sip

WINTER 2021-22

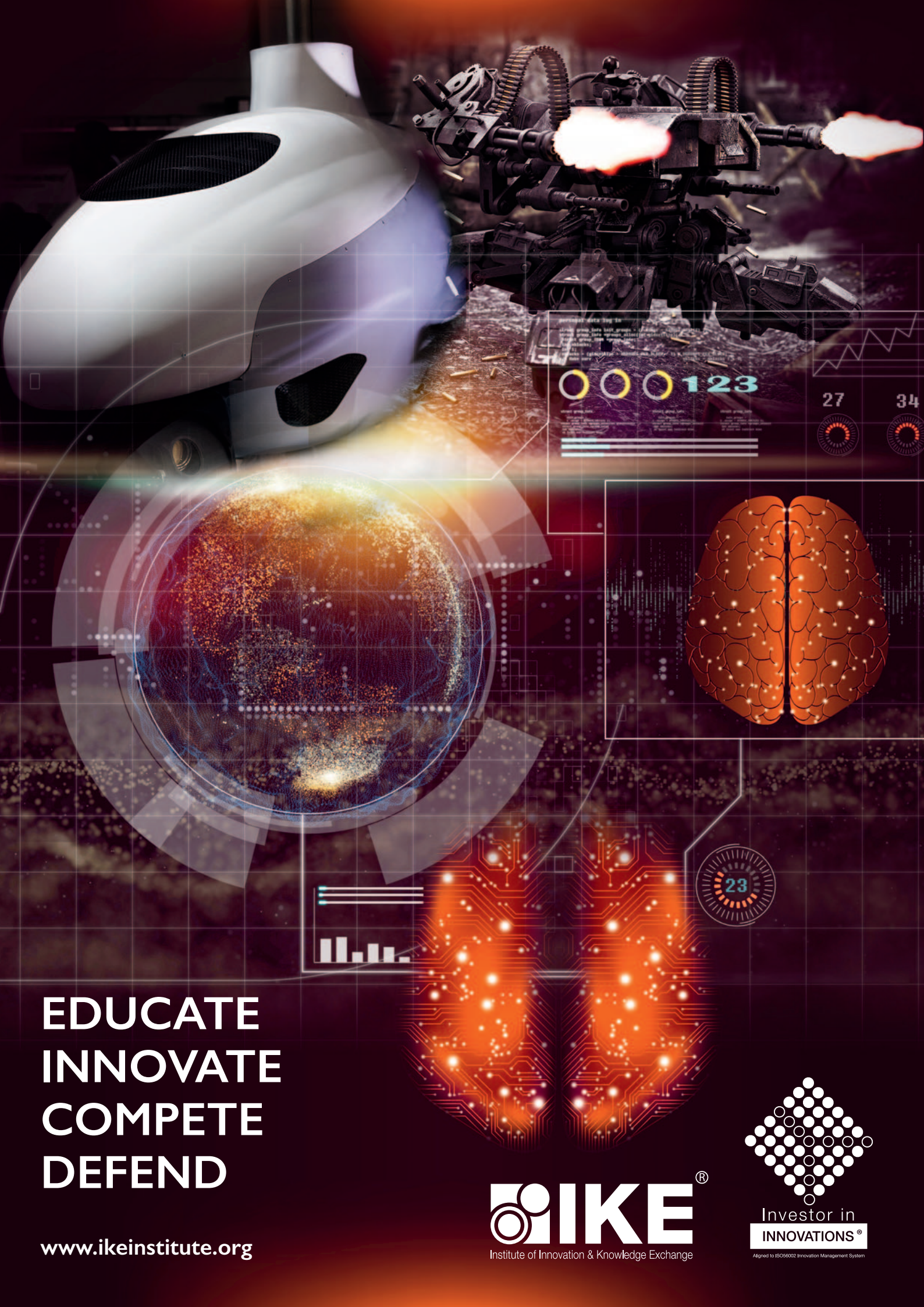
The Journal of the Parliamentary and Scientific Committee – All-Party Parliamentary Group




## STEM for BRITAIN

### 2021 Awards

L-R: **Susan Grayef,** London Group member, SCI - Society of Chemical Industry, sponsor of The Westminster Medal; **Lucinda Bruce-Gardyne**, Trustee, SCI; **Nikita Mayur Patel**, Winner, Gold, for Biosciences and The Physiological Society Prize; **Ben Fernando,** Winner, Gold, for Physics and The Westminster Medal; **Bryony Parker**, SCI; **Dr Andrew H Parton**, SCI London Group; **Ben Cooper**, Winner, Gold, Engineering; **Scott Harper**, Winner, Gold, Mathematics; **Stephen Metcalfe MP**, Chairman, Parliamentary & Scientific Committee.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34
23
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Stephen Metcalfe MP
Chairman, Parliamentary & Scientific Committee (All-Party Parliamentary Group)

**A warm welcome to the Winter 2021-22 edition of the journal, and a very Happy New Year.**

In addition to our usual features we have what I believe is a record number of articles for a SiP issue. My thanks to our distinguished contributors, many of whom participated in the Autumn series of discussion meetings.

Just before the final discussion of the year, on the 29th November, I was informed by our President, Lord Broers that he had decided to resign from the House of Lords, and as a result would step down from his role with P&SC at the end of December.

Our sincere thanks to Alec for his tenure as our President, and for his 17 years of distinguished service in the Upper House, not least as a former Chairman of the Lords' Science and Technology Committee and as an outstanding advocate for science and engineering in Parliament. We shall miss his wise and friendly counsel greatly, and wish him well in his new life with his family in the United States.

A successor to Alec will be elected at the AGM in mid-March.

The Programme Committee chaired by Carol Monaghan MP has agreed dates for the 2022 discussions. The themes and speakers will be relayed to you in the weeks and months ahead. My thanks, as always, to Carol, John Slater and Karen Smith for all their work in producing the programme. I am hopeful that we will return to Parliament for the majority of our meetings this year, while others will continue to be held by Zoom, thus maximising overall attendance.

I was delighted to welcome the STEM for BRITAIN 2021 winners to a special awards ceremony and reception in Portcullis House on the 6th December.

As you will appreciate this was the first opportunity to recognise the achievements of these early-career researchers in person, given that this year's competition was held online.

My thanks to representatives of our sponsors and the Learned Societies for speaking at the ceremony. We are most grateful for their generous support.

You can see a number of photographs taken at the event on the front, inside and back cover.

Applications for STEM 2022 closed in early December and I am pleased to say that there has been a very healthy response. The five judging panels (Biological and Biochemical Sciences, Chemistry, Engineering, Mathematics and Physics) will determine shortlists by the end of January. The 60 finalists will be asked to record a short video presentation of their poster which will appear on the SfB website a couple of weeks before the event takes place in Parliament on Monday 7th March.

I am grateful to Isabel Spence, Ben Allen, Doris-Ann Williams MBE and Leigh Jeffes, and the STEM for BRITAIN Organising Committee for all their hard work, in planning the event.

Finally, I am delighted to extend a very warm welcome to fifteen new members to P&SC, who have joined us over the past three months.

They are: the Universities of Aberdeen, Liverpool, York, Chester, St Andrews, West of England, Buckingham, Sunderland; De Montfort, Cardiff Metropolitan, Bangor, Oxford Brookes, Middlesex, and Roehampton Universities (taking the number of UK University members to 69); the National Mathematics and Science College (the first in our new category of sixth form colleges); the Leeds Institute of Fluid Dynamics. Professor Graham Machin who has joined as an Individual Member. I am also pleased to report that number of members from previous years have re-joined the Committee.

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.

# CONTENTS

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

# A DEFENCE OF INNOVATION

Clare Cameron FIKE
Director Defence Innovation
Ministry of Defence

**Defence is pioneering a culture that is innovative by instinct by empowering the Armed Forces and Defence civil servants to generate and exploit ideas and opportunities. These ideas deliver innovative solutions to solve Defence problems, and enables the UK to advance its military capability to stay ahead of evolving threats. Clare Cameron, Director Defence Innovation explains.**

To rapidly modernise Defence in the face of evolving threats, we need to deliver cutting-edge military capabilities at the speed of relevance. Science, technology, and innovation have a vital role in providing solutions that contribute significantly to overcoming those capability challenges that we identified in the Defence Command Paper, *Defence in a Competitive Age.*[1] To enhance our approach to innovation, science and technology, the Department received £6.6 billion from the Spending Review 2020, to invest in Research and Development (R&D) over the next four years. Within this, £1.1 billion is to invest in projects and programmes that go after technologies and innovations that have the potential to change *the way* Defence operates. They represent the Department's willingness to innovate at scale, and at pace.

Our current approach includes a pipeline of investments optimised to quickly develop technologies, concepts, and integrated systems, and get them into the hands of the Armed Forces; whilst also respecting our responsibilities to the public purse. An example of this is the Directed Energy Weapons (DEW) programme to produce advanced laser and

RAF Synthetic Fuel

radio frequency demonstrators. This type of technology seeks to solve military issues: operating without ammunition would significantly reduce our operating costs while giving us a new idea of frontline flexibility.

Another example is the Enhanced Command and Control Spearhead, a programme started in 2019 to integrate Artificial Intelligence into the the Army's command and control systems. Last year, a demonstrator was deployed to a live operation in Estonia. The Artificial Intelligence technology used vast amounts of data to provide soldiers with abridged and critical information on the surrounding terrain and environment. Through this development of automation and smart analytics, the technology was able to cut through masses of complex data. It demonstrated our commitment to reduce the cognitive burden on human input and speed up decision-making processes for the benefit of those serving on the front-line.

The 2015 Strategic Defence and Security Review[2] galvanised Defence to innovate. It included a commitment to spend around £800 million over ten years on innovation, through the Defence Innovation Fund. This, and the recognition across Defence of the strategic imperative, has resulted in an enormous effort across Defence. The Defence and Security Accelerator (DASA) has been established to provide an effective means to attract innovative suppliers, small and large; the Armed Forces have all created innovation hubs and assigned units to experimentation; the National

Security Strategic Investment Fund has been created to secure investment in critical technologies.

So far, the Defence Innovation Fund alone has invested around £138 million, with more innovation investment coming from the single services and Strategic Command. These investments have meant we can put funding behind how we are solving Defence problems to deliver innovative solutions. An example includes the Royal Air Force's innovative idea for recycling waste hydrocarbons, decarbonising the military. This project offered the opportunity to save money for Defence and the taxpayer by removing the requirement for costly external waste management whilst benefitting the environment. Just last November, the RAF received a Guinness World Record for the first flight using only synthetic fuel, demonstrating Defence's commitment to leading the way on creating a sustainable future. The Royal Navy also announced that they are testing drones that will help rescue anyone at sea, making it easier for ships to identify a casualty's location. This was funded through our internal ideas scheme. With the right people and processes in place, we can support and fund ideas that solve problems anywhere in Defence. As the ecosystem of innovators grows, so does the diversity of ideas, increasing our innovative culture, driving change and modernising Defence.

All our investments focus on achieving advanced military capability, and to continue to do this, Defence must engage effectively with an ecosystem of innovators outside Defence. The Defence and Security Industrial Strategy[3] (DSIS) enables industry, government and academia to work together to drive research, enhance investment and promote innovation. DSIS provides the commitment to find ways for Defence to procure with greater agility from small businesses and to transform our relationships with Defence Primes. DASA has established relationships with small businesses and academia across the UK, enabling contracts to develop technologies that the innovators may never have seen a use for. All are vitally important for implementing innovation and delivery of novel, cutting edge capability to the Armed Forces.

Underpinning this activity, investment and renewed engagement, Defence must change how we do business. The Acquisition and Approvals Transformation Programme (AATP) is driving changes that make Defence and its acquisition system more agile – through speed, tempo, adaptability, and resilience. We should acknowledge that, to get ahead of our adversaries, we need to take risks with our portfolio of investments. We need a new approach to risk: there are risks in investing in new ideas. Investments may not lead to viable or valuable capabilities. Sometimes this is because the idea cannot work with the current state of technology, or sometimes important security or safety issues emerge. We need to be confident in stopping projects that are failing and then learning from them – if we take those lessons and embed them then it is not wasted investment; it is on the journey to success. A culture of innovation is about learning and understanding that just because a product hasn't worked, it does not mean it has failed or is a loss of our investment. That doesn't mean a lack of due diligence or planning; however, it does mean a more conscious, nuanced approach to risk, be it commercial, financial, performance or time. Defence Innovation is managing this by working and benchmarking with other innovative organisations, demonstrated by its recent Investor in Innovations Standard Accreditation aligned to ISO56002 with the IKE Institute.

As we continue to build on a hard fought-for culture where to innovate is our instinct, we will invest in the science and technology needed for the visible and invisible battles of today and tomorrow, and we will change the way we train, fight, learn, manage and lead Defence.

**References**


1 https://www.gov.uk/government/publications/defence-in-a-competitive-age

2 https://www.gov.uk/government/publications/national-security-strategy-and-strategic-defence-and-security-review-2015

3 https://www.gov.uk/government/publications/defence-and-security-industrial-strategy


Royal Navy Mad Fox Autonomous Vessel

# MATHEMATICS IS INDISPUTABLY THE GREATEST SUBJECT IN THE WORLD

Dr Nira Chamberlain
Immediate Past President of the Institute of Mathematics and its Applications

*"Archimedes will be remembered when Aeschylus is forgotten, because languages die [but] mathematical ideas do not."*

This quote comes from one of the greatest British mathematicians of all time - G.H. Hardy. It would not surprise me if Hardy's view was that mathematics is indisputably the greatest subject in the world. This view is one with which I totally agree. Too many times I hear people telling me that they "are no good at mathematics" as if it were a badge of honour! Would we be so proud to say that "we are illiterate!". As a nation we should be proud of mathematics and our mathematicians.

G.H. Hardy

It can be argued that mathematics is part of our history, our culture and our future. A former Prime Minister once said:

*"If countries are going to win in the global race and children compete and get the best jobs, you need mathematicians and scientists – pure and simple."*

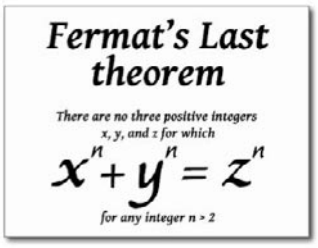
Mathematics is a beautiful and powerful subject; it is the poetry of logical ideas. What other subject is the foundation of science, engineering, technology and artificial intelligence? It influences the structure of art and music. Mathematics teaches geography to geographers, economics to economists and physics to physicists. Mathematics is truly a global phenomenon.

The definition of mathematics is *the science of structure, order, and relation that has creatively evolved from elemental practices of counting, measuring, and describing the shapes of objects.*

The most interesting part of this definition is the phrase creatively evolved. Mathematics is not a cold mechanical subject where we learn by rote and the answer is always right or wrong. As the definition implies, mathematics is a creative evolving subject. No matter at which level you use it.

The British pure mathematician, Andrew Wiles, worked on the hardest problem in mathematics (Fermat Last Theorem) for seven years in the 1980/90s, and employed a creative way that eventually solved it.

Today, mathematics teachers up and down this country use innovative ways to inspire and teach pupils, embracing technology whilst communicating their passion for the subject!




Nevertheless, some argue that mathematics has it limits and can't be used on real world problems, Albert Einstein once said:

*"As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality."*

I do disagree with Albert Einstein to a certain extent. Where the laws of mathematics break down, are not fit for purpose or where knowledge is incomplete, through mathematical modelling mathematicians have then challenged themselves to finding that elusive solution.

Without computers and advanced technology, where knowledge is incomplete, mathematicians in the past have used mathematical models to discover Black Holes and even discovered the planet Neptune.

With computers and advanced technology, where knowledge is

incomplete, mathematicians in the past have used mathematical models to develop the delta wing for Concorde (the fastest passenger jet in the world), created a cost capability trade off model to provide evidence that the HMS Queen Elizabeth Aircraft Carrier should be built, or developed a crowd dynamics simulation to increase safety at new football stadiums and public events.

In saying this I do more agree with this view Albert Einstein has of mathematics:

*"How cam it be that mathematics, being after all a product of human thought which is independent of experience, is so admirably appropriate to the objects of reality?"*

Today we are faced with global challenges such as COVID-19 and climate change. Mathematics/mathematical modelling will have an important part to play in resolving these. This could even be the next generation of mathematicians building on the work that we do today.

Concorde

It is important that we train and support our mathematicians at whatever stage they are at in their career, so we can tackle this and future challenges.

In schools, how can we impart a passion for mathematics to the pupils?

The British mathematician Sir John Kingman once said:

*"Mathematicians are better if they stay a bit childish and play the game as a game. This is the key to teaching mathematics, it's not to flood people with practical problems, rather it's to say that this is the best game that has ever been invented. It beats Monopoly, it beats chess and it happens that it can enable you to land rockets on the moon. The real mathematical advances have been made by people who just loved it."*

Katherine Johnson, the NASA mathematician depicted in the 2017 film "Hidden Figures", is a good example of this.

For the mathematician themselves, one can only truly appreciate mathematics, by getting right in the middle of the challenging intellectual arena, to constantly pursue and conquer the logical battle for that elusive truth. One of the most influential and universal mathematicians of the 19th and early 20th century, David Hilbert, once said:

*"Distance in four dimensions means nothing to the layman. Even four-dimensional space is wholly beyond ordinary imagination. But the mathematician is not called upon to struggle with the bounds of imagination, but only with the limitations of his logical faculties."*

He goes on to say:

*"A mathematical theory is not to be considered complete until you have made it so clear that you can explain it to the first [person] whom you meet on the street."*

As a mathematical community we recognise the importance of communicating our ideas to the general public in a way that it is transparent and challengeable. It's important for us to break down barriers to non-mathematicians, but in return we like non-mathematicians to listen and to challenge our opinions. This is the way we all mutually grow together.

So, in conclusion; mathematics is indisputably the greatest subject in the world! Why? Because it is the language of the world. Mathematics crosses racial, geographical and cultural boundaries. The real mathematical advances, as stated by Sir John Kingman, have been made by people who just loved it.

I am not asking us all to love it but let's us all appreciate mathematics. Why? Because our country needs it. □

# THE IMPORTANCE OF MATHEMATICS IN UNDERSTANDING DISEASE SPREAD

Dr Kit Yates
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University of Bath

**From the very earliest days of the pandemic, mathematical modelling has played a vital role in informing evidence-based policy. Deciding between different policy options before they are implemented, especially in the context of a new disease during a pandemic, is a difficult problem to which mathematical modelling presents a possible solution.**

Despite its potential utility, mathematical modelling has suffered severe reputational damage at various stages of the UK's response, leading many to question the appropriateness of its use. Here I will argue, that despite its shortfalls, modelling is the single best tool we have to peer into the future. When carried out properly it beats 'common sense', 'gut feelings' and 'wishful thinking' hands down. The aim of the game is to build a framework in which we can formalise our assumptions and build a mathematical representation of the situation we are trying to model. We can then run that model forward to suggest the future pandemic trajectory under different policy considerations in order to evaluate their impact.

Perhaps the starkest example of the influence of mathematical modelling in decision-making comes from March 2020, when the UK public were first getting to grips with the potential scale of the problem. A highly influential report co-authored by the MRC Centre for Global Infectious Disease Analysis was published on the 16th of March 2020. The projections in the infamous 'Report 9' were that 500,000 people in the UK would die as a result of an entirely unmitigated pandemic, while if the government continued with their current mitigation strategy 250,000 would lose their lives. These dramatic figures were largely credited with pushing the UK government to trigger the first lockdown a week later. In the aftermath of the first wave, modellers later suggested that that week-long delay in locking down may have cost tens of thousands of British lives.

As we emerged from the first covid wave in the UK, modelling was used to generate forecasts for the likely outcomes over the coming winter. The modellers' reasonable worst-case scenario of 85,000 deaths from July 2020 to March 2021 was widely reported in the media as being overly fatalistic. As it transpired the eventual covid death toll during that period was almost 100,000 despite the two lockdowns to which the UK was subjected for a month in late 2020 and during the early months of 2021.

On many occasions epidemic modelling has had an important influence on the policies which have been put in place in response to the coronavirus epidemic. On other occasions modelling predictions have been ignored, sometimes with dire consequences. Modelling can play an important role in predicting the future trajectory of the pandemic but also in understanding the current state of affairs. It is important, however, to recognise the limitations of mathematical modelling and to appreciate the uncertainty under which the modelling predictions are generated. Mathematical modelling can provide a useful guide for what might happen in the future but should never be relied upon to give predictions which are 100% certain. Despite this inherent uncertainty, mathematical modelling remains the best way we have of formalising our current state of knowledge in an attempt to gain a glimpse of what may happen in the future.

As the UK sought an exit strategy from the third lockdown in early 2021, multiple academic groups provided modelling which informed the timeline of the government's 'COVID-19 Response - Spring 2021' Roadmap. SPI-M (The Scientific Pandemic Influenza Group on Modelling – the modelling group which feeds into SAGE) have also done crucial work on evaluating the importance of different interventions, for example, by identifying the significant reduction in transmission brought about by implementing work-from-home orders.

## THE UTILITY OF MATHEMATICAL MODELLING

Mathematical modelling provides a framework to aid decision-making when choosing from a range of transmission-impacting policy options. In the absence of quantitative evaluations informed by modelling, policy makers are left only with subjective opinions about what might work best. Without objective assessments of the effectiveness of interventions, policy maker's decisions may boil down to little more than guesswork, meaning that the rationale for decisions is difficult to justify in hindsight.

Strange as it may sound, as well as offering a crystal ball for us to peer into the future, mathematical modelling can also help us understand what is happening in the present or even in the past. For example, during the first wave of the pandemic, we did not have the capacity to test everyone who needed to be tested. Reported cases peaked at around 6000 per day, which, given the resulting number of hospitalisations and deaths, was a clear underestimate. Mathematical modelling was used to reconstruct the possible case numbers, suggesting that daily cases in fact peaked at over 100,000 new cases per day.

Prescient as it may sometimes appear, mathematical modelling can never hope to be a perfect tool for providing 20-20 foresight. Sometimes data are missing or incomplete meaning that the foundational assumptions on which models depend are shaky. Sometimes the model may not include all of the important facets of reality. For example, when modelling care homes in the first wave of the pandemic, modellers did not consult sufficiently with domain specific experts. Care home industry practitioners identified agency staff, often working across multiple care homes and with little access to sick pay, caring for the extremely vulnerable as presenting a significant risk. Some of these intersecting factors, were not anticipated or modelled by the mathematicians, meaning that the recommendations based on the modelling were dubious at best.

## MODELLING UNDER UNCERTAINTY

There are many sources of uncertainty with which modellers need to contend. Incorrect inferences or assumptions can render models useless, or worse, dangerous. It is important that modellers be transparent about all of the assumptions which feed into their models and all the potential sources of uncertainty which might impact upon their results. If modelling is to be used to inform policy then it is also important that the caveats surrounding the modelling are couched in terms simple enough to be understood by the intended audience.

Identifying key model parameters is the first major contributor to uncertainty. In the context of an epidemic these might include anything from the likelihood of exposure to the virus, the impact of school closures, the efficiency of vaccines or the rate of hospitalisation once infected. Where available, parameters should be based on evidence. It goes almost without saying that earlier on in the pandemic evidence will be scarcer and the parameter values correspondingly less certain. Some parameters will change over time (e.g. the public's adherence to proposed mitigations/restrictions) and will need to be regularly updated with new data.

A second type of uncertainty relates to the structure of the model itself. No matter how accurately parameters are estimated, if the model does not accurately capture the key disease dynamics then the results of the model will be inaccurate. As we saw with the care-homes example above, structural issues can arise if the appropriate domain experts are not consulted when models are built. As with parameter values, the model structures may need to be refined as the most important features of the disease and its transmission come to light.

Inherent randomness in the processes which underlie the epidemic supplies a third main type of uncertainty. Randomness appears, for example, in the duration of the incubation period of a disease or in the time for which individuals are infectious. Different people will take different times to progress from infection to hospitalisation and there will be variation again in the timing from hospitalisation to death for individuals who eventually succumb to the disease. Modellers attempt to characterise these different forms of inherent variability and to convey this uncertainty in their results by running their models many thousands of times and presenting not just the most likely outcome but ranges of different outcomes within which the future trajectory of the epidemic may reasonably be thought to lie. Uncertainty surrounding parameters can also be dealt with by exploring a range of different options and presenting a corresponding range of predictions.

The fourth type of uncertainty that can derail modelling predictions are those relating to the unknown future. Government policy changes, extreme weather events, political protests and other unforeseen scenarios can fundamentally change the dynamics of the pandemic in a way which is not predictable. As we have seen with Alpha, Delta and Omicron, the emergence of new variants can also render previous model predictions redundant.

□

# INFECTIOUS DISEASE MODELLING FOR POLICY DURING THE COVID-19 PANDEMIC

Dr Ellen Brooks-Pollock OBE PhD FIMA
Associate Professor of Infectious Disease Modelling at the University of Bristol

**Everyone has a different story about when they first realised that coronavirus would dominate our lives in 2020. For me, that was late January 2020 when my colleagues and I started to explore how the new coronavirus might spread in the UK. Unless something radically changed, it looked like huge numbers of people would be infected in the UK and worldwide.**

## SIX DEGREES OF SEPARATION

In 1929, the Hungarian writer Frigyes Karinthy wrote a short story called Chains about the idea that everyone on Earth is only six or fewer handshakes away from everyone else. As the characters discuss in the short story, the easiest way is to identify well-known people who effectively link disparate parts of the human social network. Karinthy's story involved the 1.5 billion inhabitants of Earth in 1929. Now we are a population of 7.9 billion and the amazing fact remains that we are all in a sort of germ equilibrium and that a new submicroscopic entity in someone's nose in China can replicate and travel across the world extremely efficiently.

## WHO-MEETS-WHOM?

Because of the importance of social contacts for disease spread, infectious disease researchers have been conducting surveys of people's normal social contacts for years. People with high numbers of social contacts are important to know about for rapid spread, but equally important are the everyday social contacts that make up the majority of interactions in the world. Before the pandemic, an average person would meet 10 other people every day. Of course, no-one is average, and a quarter of people meet fewer than 5 people a day and another quarter meet more than 20.

Older people tend to have fewer social contacts than younger people, and they are more likely to make those contacts at home. Young adults make most of their contacts at work. Children tend to have high numbers of contacts, and, not surprisingly, nearly half of children's social contact hours are at school.

## PREDICTING THE EFFECT OF LOCKDOWN

During the pandemic, we have been using detailed social contact data to predict the effect of social distancing measures. For example, we were able to show that without other measures, preventing gatherings of more than 50 people was likely to have a small impact on transmission. Or that stopping face-to-face teaching in universities cut the students' social contacts made in half.

We used people's social contact patterns in mathematical model to estimate the number of people they might infect if they had COVID-19. Roughly speaking, the more social interactions someone has, the greater the potential for infecting others. The average number of cases produced by an average infected person is called the R number.

The R number is now a familiar metric for describing the state of the pandemic. Modellers calculate the R number every week that are published by the UK government. At the start of the COVID epidemic in the UK the R number was about 3, meaning that on average each COVID case infected three other people. When the R number is greater than 1, the number of cases grows exponentially. Following lockdown on 23 March 2020, the R number dropped dramatically to around 0.6 – and the number of cases started shrinking.

## RE-OPENING SCHOOLS IN MAY 2020

Following the first 2020 lockdown, the SAGE Children's Task and Finish Group was convened to look at the impact of schools reopening. Using data on social contact patterns, we made predictions on how much the R number might change if children went back to school. We looked at scenarios from two weeks on/two weeks off to half the school alternating attendance, to only primary, or only secondary schools re-opening.

At the same time, evidence was emerging that children,

especially younger children, seemed to be less susceptible to infection than adults. Combined with the fact that less than 1 in 20 social contacts occurs at school led to the conclusion that allowing primary school children back to school would have a relatively small impact on overall case numbers.

Our best estimate was that opening primary schools would have at most a modest impact on transmission, increasing the R number to around 0.9 – critically still less than 1. However, we estimated that opening primary and secondary schools together could tip the balance and increase the R number to something around 1.2 – allowing infections to start increasing again. In our analysis, we found that adopting other measures, like contact tracing and general COVID security, could allow secondary schools to open without fuelling the epidemic in the community.

## SCHOOL CLOSURES AROUND THE WORLD

The UK wasn't alone in closing schools. By the beginning of April 2020, 173 countries had closed their schools due to COVID-19, and as of October 2021, 14 countries still have not re-opened their schools completely (figure 1). The UK fully closed its schools for a total of 109 days, which was less than average. Other countries adopted less stringent school measures than the UK, for example Japan's schools were fully closed for only 24 days, or more stringent approaches, for example Ireland closed its school doors for 154 days. Social contact data provided an evidence base for re-opening schools in the UK.

## THE SCHOOL RUN

It became clear when looking at our predictions that whatever happened in schools was much less important than what was going on outside schools. Opening schools didn't just increase social contacts within school for children, but it allowed parents to go back to work and renew their old social contacts.

We started using this insight for more than just whether schools were open or closed – we could use the R number based on social contacts to chart the route out of lockdown (figure 2). We incorporated Test-Trace-Isolate into the calculations by assuming that a proportion of social contacts would not take place if someone had symptoms. We incorporated the wearing of face masks, handwashing and standing 2-metres apart by reducing the chance of transmission across social contacts that occurred at work, in shops or on public transport. In this fictitious world, we can limit large gatherings, prevent long-distance travel and mandate regular testing. Exploring a full range of possible interventions, of "what ifs" is exactly what infectious disease modelling is useful for.

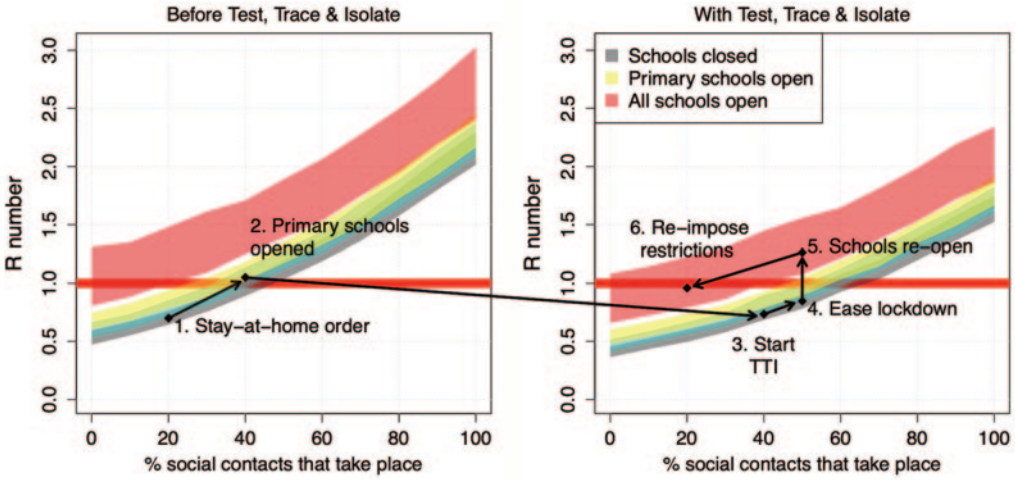


Figure 2: The UK's route out of lockdown, as depicted by the University of Bristol's infectious disease modelling.

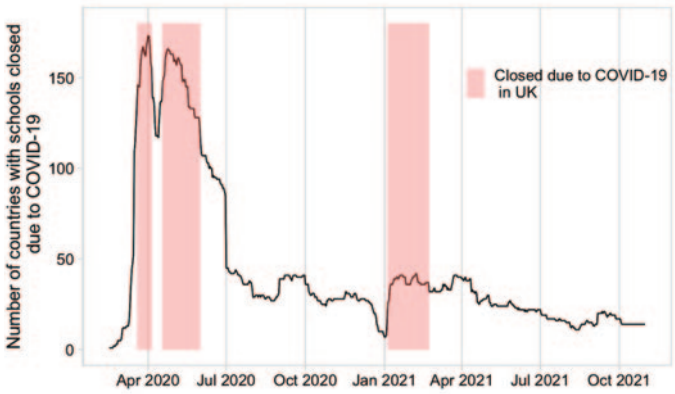


Figure 1: The number of countries that closed their schools due to COVID-19 in 2020 and 2021. The red shaded areas indicate when schools in the UK were closed. Data from UNESCO Institute for Statistics data.

## MODELLING-POLICY INTERACTION

The predictive nature of infectious disease modelling lends itself for use in policy, preparedness and capacity planning and for evaluating policies to mitigate epidemic spread. The impact of some interventions can be predicted with simple reasoning but often multiple interacting factors combine to create complex outcomes. In these cases, infectious disease models can be an aid to formalize thinking and quantify qualitatively obvious results. Modelling is sometimes described as a mechanism for collating facts and educated guesses into a single framework that can guide policy decisions.

Of course, policy decisions are rarely made on epidemiological evidence alone, but take into consideration the impact on many factors. It is critical to have a two-way flow of information between modelling and policy. Policy questions shape modelling work, and in return modelling evidence can shape policy. The SPI-M (Scientific Pandemic Influenza group on Modelling) secretariat are scientists who work with the SPI-M chairs to turn a policy 'ask' into a modellable question, and then translate the model results back into relevant evidence and advice. SPI-M would be an academic forum without this link to decision-makers.

## WHAT NEXT FOR OMICRON?

We continue to use the type of modelling described here to understand the transmission of Omicron and other variants in the UK. While vaccination, boosters and natural immunity has reduced the R number, variants like Omicron that evade the immune system push it back up. Infectious disease modelling will continue to play an important role in controlling the virus. □

# SUPPORTING POST-PANDEMIC RECOVERY THROUGH INNOVATION

Professor Julian Beer FIKE
Deputy Vice Chancellor,
Research, Innovation and Enterprise
Birmingham City University

**Universities proved their worth during the Covid-19 outbreak. Now they must be at the forefront of innovation if we are to rebuild our economies post-pandemic. Professor Julian Beer explains how Birmingham City University (BCU) is making that vital step.**

## UNIVERSITIES AT THE HEART OF INNOVATION-LED RECOVERY

### UNIVERSITIES AND FUTURE IMPACT IN SUPPORTING ECONOMIC RECOVERY

**Over the next five years, UK universities will:**

- Provide over £11.6 billion of support and services to small enterprises, businesses and not-for-profits;
- Attract £21.7 billion of national and international public funds to spend on collaborative research with businesses and organisations.
- Universities' contribution to local regeneration projects will have a value of over £2.5 billion.

Source: Universities UK/ Frontier Economics (2021)
*The Economic Contribution of the Higher Education Sector in England.*

The Government's UK Innovation Strategy flagged the rich diversity of structures and approaches in the global R&D response to COVID, and emphasised the need to nurture university-business interaction and knowledge sharing to drive future innovation.

This role has been strongly echoed by industry, exemplified by Lord Karan Bilimoria, President of the CBI, who stated that "Universities have a key role within research, skills and innovation, which is going to drive the UK to build forward better."

As cited in the evidence for the UK Innovation Strategy, whilst many UK businesses are at the cutting edge of technology, too few currently excel in adopting existing innovations. As such, the percentage of UK businesses that were innovation-active declined to 38% in 2016-18 from 49% in 2014-16.

From a regional perspective, innovation in Local Enterprise Partnership (LEP) areas across the West Midlands has historically lagged behind the best performing English regions. The Enterprise research centre, for example, cited an innovation gap in Greater Birmingham and Solihull and the Black Country LEPs of 8-12 percent below English best practice.

Consequently, universities such as Birmingham City must ensure that we embrace our position at the heart of economic and social

## UNDERPINNING INTERDISCIPLINARY, COLLABORATIVE SUPPORT

### EXAMPLES OF BCU SUPPORT FOR INNOVATION

- Supported over 215 newly registered graduate start-ups from 2017-18 to 2019/20.
- Over 6,000 interactive and engaged relationships with small business - 1,691 formally assisted to start, grow or innovate since 2017/18.
- Ranked 9th in the UK, and 1st in the region in terms of volume of Knowledge Transfer Partnerships.

Sources: i) HESA (2021) *Higher Education Business and Community Interaction Survey*; ii) BCU; iii) Innovate UK KTP Monitor (2021)

transformation, whilst also ensuring that appropriate mechanisms are in place to empower innovation-led recovery.

BCU's mission is to be the 'University for Birmingham' through facilitating growth, innovation and productivity. This is exemplified by our unique and pioneering work in STEAM-based innovation - an interdisciplinary cross-collaborative approach that combines STEM with Arts, driving innovative capacity and solutions to today's challenges.

The government-backed STEAM agenda has underpinned new interdisciplinary and collaborative research partnerships; driven open innovation with regional and national businesses and entrepreneurs; facilitated considerable levels of public and community engagement through access to facilities and workshops; whilst also making a substantial contribution to local growth and regeneration.

Reflecting the aforementioned importance of partnerships to advance growth and innovation, BCU has undertaken a significant level of outreach activity with regional businesses, policy-makers, and entrepreneurs. This has underpinned the creation of a new suite of customer-led tools and products to support open innovation, address complex problems, and drive post-pandemic recovery.

## STEAM-BASED OPEN INNOVATION

As an example, since opening in 2018 STEAMhouse Phase 1, the physical manifestation of the STEAM approach at BCU, has become a pivotal hub for the West Midlands. The Centre has built regional innovative capacity through the creation of a collaborative community, driving growth through developing business ideas, skills, knowledge and ambition.

Over this period, STEAMhouse has welcomed nearly 18,000 visitors, and provided 7,500 hours of support for early stage businesses to establish and grow, and for small to mid-sized enterprises to develop business strategies and turn concepts into prototypes. This has resulted in 275 businesses assisted to innovate, the formation of 65 new enterprises, and the launch of 73 ground-breaking new products.

The COVID-19 pandemic and the various measures introduced to slow its spread required the use of embedded STEAM tools and practice at BCU to reimagine service delivery, embodying our applied approach to innovation.

Across 2020/21, innovative new products and services were introduced, enabling us to pivot an offer to over 475 members from being tactile and physical, to one that was remote and hands-off. This included an online learning platform, specialised STEAM learning kits for home delivery, and a remote prototyping and production service enabling members to keep innovating, co-creating, learning new skills, and developing business ideas.

The Government-backed STEAMhouse Phase 2 building, a £70m 120,000 sq.ft collaboration and innovation centre, is scheduled to open early 2022. This will enable businesses, academics, artists and innovators to benefit from the deployment of 5G and state-of-the-art IT facilities, creative project space, and dedicated facilities for STEAM learning, prototyping and co-working.

## NATIONAL ACCREDITATION FOR COMMITMENT TO INNOVATION

The COVID-19 pandemic and current Government strategy such as Build Back Better, also underlined the vital importance of innovation and reinforces the need for a bold vision from which to move forward. In this context, BCU is proud to have achieved the Investor in Innovations Standard Accreditation aligned to ISO56002 from the Institute for Innovation and Knowledge Exchange (IKE Institute) – just the second university in the country, and the first in the region, to be handed the accreditation.

In addition to our work in developing STEAM, the unique quality mark also recognises our work with businesses and partners to drive innovation and growth, as well as the ground-breaking research taking place across the institution across a range of disciplines.

Whilst providing a benchmark for innovation output, the award also places onus upon continued growth and development of innovation practice, and knowledge exchange supporting regional innovation capabilities and innovation readiness.

Accreditation will underpin the delivery of the highest quality development pathways, innovative practice and learning for the regional business community and practitioners, alongside our student and staff body, driving productivity, diversification and economic prosperity.

Business and research partnerships play an essential role in driving innovation activity – a vital enabler in levelling up the UK's economy. Working with the IKE Institute, we will strive to support improved innovative capacity, through an agile, practitioner focussed, collaborative and responsive system.

**www.steamhouse.org.uk** □

STEAMHouse BCU

# PLAN FOR ACTION FOR UK BUSINESS INNOVATION, 2021-25

Paul Mason
Director - Innovation Policy, Innovate UK.

**If science is the process of understanding how *the world imposes its will on you*, then technology is surely the process whereby *you impose your will on the world*. Through technology-enabled business innovation companies make and supply better medicines, vaccines, food, energy, water, housing, entertainment and many other life-enhancing things. And they make them available at scale, so we can all benefit. In short, business innovation improves lives.**

The vaccines created in short order to help address the Covid-19 global health emergency have demonstrated, firstly, how important business innovation is (it is companies that are manufacturing and supplying the vaccines at scale) and, secondly, how good the UK is at it.

Innovate UK has just published its Plan for Action for UK Business Innovation in which we describe some of the major innovation opportunities available to UK businesses.

We want the UK to be one of the very best places in the world for innovative businesses to grow and deliver sustainable economic growth and societal and environmental benefit. For the UK to be a global hub for innovation.

We will help implement the Government's Innovation Strategy by highlighting the most compelling opportunities for UK


Supporting these 5 Themes are 6 Strong Foundations. These are things that make innovation more successful. They are science and research strengths; design; responsible innovation; talent and skills; equality, diversity and inclusion; and place. We will support our work in the five themes with programmes in each of these areas.

businesses, bringing the right people together to take advantage of them, and investing in the best innovative programmes and projects. We will inspire, involve and invest in UK business innovation.

We see innovation opportunities in 5 key areas, our 5 themes, which are Future Economy, Growth at Scale, Global Opportunities, Innovation Ecosystem and Government Levers. The new plan describes opportunities in each area, the obstacles that exist to fully realising each, and what we, with partners, intend to do through the programmes we run to help UK businesses.

### 'Global partner of choice'

The UK is home to 0.9% of the world's population and contributes 3% of global GDP. For a business this means that 99% of possible customers, and 97% of potential spend, lies elsewhere. It is for this reason that taking a global perspective is incredibly important for UK businesses that wish to survive and succeed over the longer term. We will run programmes that help UK companies undertake innovation activities with collaborators in other countries, helping build the supply chains of tomorrow and attracting inward investment. Our ambition is that UK companies realise **Global Opportunities** through becoming the partners of choice for innovators based overseas.

### 'no-one ever shrank their way to greatness'

Growing your business is the best way to service large global markets and to ensure long term sustainability. As the saying goes 'no-one ever shrank their way to greatness'. This is the thrust of our second theme, **Growth at Scale**, which seeks to help companies improve the internal capabilities and access to the finance and markets they need to scale up.

### "the best way to predict your future is to create it".

Sometimes it is right to make innovation support available to all companies, operating in any market. To 'let a thousand flowers bloom'. And we will allocate a proportion of our resources to open-scope programmes. But when you look hard at the trajectory of global markets, and the new opportunities opened up by advances in technology, it becomes clear that to succeed in some areas the UK needs the benefit of critical mass. To build the industries of the future, we need to think about and plan for the industries of the future. As Abraham Lincoln said (apparently) "the best way to predict your future is to create it". In our **Future Economy** work we look out towards a UK economy in 30 years and will run programmes to help create a vibrant, inclusive and socially and environmentally positive economy in areas such as net zero, health and well-being, and advanced technology.

### 'If you want to go fast, go alone. If you want to go far, go together'

So states the famous African proverb. Every breakaway rider in the Tour de France who has been caught by the peloton (and they usually are) knows this. This mantra is often said. Less often is it seriously attempted. Less often still does it become 'the way things are done around here'. And yet innovation, and building a business, is a long-term game.

Digital photography was demonstrated in 1976. It took almost 30 years, until 2003, for US digital camera sales to exceed those of 35mm analogue ones. It has taken over 20 years for Google to become what it is now, from its roots in Stanford's US Patent (number 6,285,999 filed by Page and Brin on Jan. 9, 1998) for page ranking. The UK is now a leading global centre for cell and gene therapy (12% of all trials, and the third biggest cluster of companies in the world, are here), but the thematic programmes that led to that were initiated by Technology Strategy Board (the forerunner of Innovate UK) and MRC in 2009.

This is why our work with partners is so important, and why a major theme of the strategy is to maintain and nurture a brilliant UK **Innovation Ecosystem.**

### 'Government pulling the right levers'

Government has an enormous role in fostering innovation and in helping companies to grow. As Mariana Mazzucato points out, the public sector has an essential role in supporting innovation; key technologies that makes the iPhone function were government funded: the Internet, GPS, touch-screen display and the voice-activated Siri.

Government can encourage companies to invest earlier in riskier technologies through grant funding. It can act as a lead customer. It can help ensure an innovation friendly regulatory environment. It can help shape standards and guidance.

The UK Government is committed to playing its part in supporting innovation in the UK. As evidence, see the UK Innovation Strategy published in July. Innovate UK are actively taking forward important parts of that strategy and helping Government use its power to support innovation.

### 'Brilliant partners'

In the development of this strategy, we have consulted very widely, with hundreds of businesses and innovation experts, and we have drawn on over 14 years' experience of designing and running national innovation programmes ourselves. Programmes that have demonstrated impressive returns of, on average, £7 for every £1 invested, returned an estimated £30bn to the economy and created around 100,000 jobs.

The ambition in the Plan for Action is to raise the UK's game in innovation, and this has to be a team effort. Along with our sponsor body BEIS, and DIT, this strategy has commitments from and will be implemented by ourselves, BBB, BSI, DASA, DSTL, IPO and NPL. It will draw in the collective resources of our partner bodies, UKRI, Innovate KTN and the Catapult network.

We hope to go further by going together.

### 'fine words butter no parsnips'

I think we have created an excellent innovation Plan for Action. One that will help businesses to grow. One that will improve the quality of life of people living in the UK and elsewhere. One that will help protect our planet and its environments.

But this excellent innovation plan will have absolutely no positive impact unless it is implemented. Will only have limited impact if it is not implemented well. And will only have great impact if it is implemented brilliantly. To corrupt Peter Drucker's famous quotation, implementation "eats strategy for breakfast".

The UK is well-placed to implement this strategy successfully. Our scientists produce 14% of the most highly cited papers in the world [1] and have won 134 Nobel Prizes [2].

We have world-class companies in many sectors, including in aerospace, automotive, health, infrastructure and construction, manufacturing, agriculture and food, design and creative industries, high value services, and in the enabling and emerging technologies that will underpin progress. Our research and innovation ranks 4th in the Global Innovation Index[3]. The UK's time zone, capital markets, venture community, long-established rule of law, outstanding service industries, and the prevalence of English as a language all contribute to make the UK a good place to innovate and do business.

In other words, we have the ingredients to succeed. But a meal does not cook itself. What lies ahead, for us and our partners, and for UK businesses that engage in our programmes, is 4 years of pain-staking implement work. I, for one, am looking forward to it.

## OUR 12 COMMITMENTS TO UK BUSINESS

We can summarise the main elements of the plan in our 12 commitments to UK business, which read

### Our 12 commitments to innovating UK businesses

1. We will inspire, involve, and invest in innovation
2. We will focus on opportunities for the future economy
3. We will support companies to grow rapidly
4. We will help businesses to succeed on the international stage
5. We will make it easier to gain innovation support
6. We will help government use its power to support innovation
7. We will help UK companies benefit from the excellent research base
8. We will help businesses make better use of design
9. We will use responsible innovation to take account of wider societal impacts
10. We will help companies enhance the capability of their people
11. We will be inclusive and fair, and bring in under-represented groups
12. We will help build, and help companies benefit from, local strengths

Nothing we are setting out to do will be easy. We can anticipate a few disappointments and failures; but we can also expect significant successes. All of us living in the UK, in partner countries, and around the world, rely upon the outputs of business innovation to address global challenges and enhance our lives.

I look forward to the date in 2025 when we look back at a job well done. Together.


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# WHY PRE-NORMATIVE RESEARCH IS NEEDED FOR STANDARDISATION OF EMERGING SCIENCE AREAS


Professor Richard JC Brown
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**Measurements are essential. All aspects of everyday life, not to mention practical science, technology, engineering and medicine, involves measurements that we rely on for our health, commercial prosperity, quality of life and the protection of the environment. Our measurement infra-structure ensures these measurements are fit-for-purpose, providing confidence in these measurements at a stated level.** [1]

It is only when measurements are stable and comparable that we can make progress in science and therefore in society. This requirement is particularly important when fostering innovation, increasing efficiency, bringing products to market faster and, equally, allowing them to fail faster[2]. In much of traditional science this comparability relies on simply defined measurements with traceability to the well-established International System of Units. The measure of time is a simple example. This measurement is clearly well defined, related to the second (a well-established and universally agreed measurement unit), and vital for global positioning systems (GPS) and financial trading. The usefulness and fitness-for-purpose of the result is independent of the measurement method we choose to use.

## HIGHLIGHTING THE NEED FOR PRE-NORMATIVE RESEARCH

For complex measurements, such as climate change, and measurements in areas of emerging technologies, such as quantum and digital technologies[3], the situation is not always so clear. The stability and comparability of measurements can be more challenging to assure. This is because what is being measured is often difficult to define, measurement methods are not mature, and sometimes even the units used to express results are not agreed. In these cases, the measurement results are described as being method-defined because they depend on the measurement methods used. Under these circumstances stability and comparability is ensured by agreeing what measurement method should be used and how results should be expressed. This is usually done in the form of a 'documentary standard' describing the measurement methods and associated processes for producing and expressing measurement results.

These documentary standards are essential for allowing emerging or complex areas to make the transition across the technology readiness levels and into the market as products which are able to demonstrate quality assurance and quality control. The value of stable, comparable and standardised measurement is also essential for enabling confidence in decision making for societal challenges[4]. Without these standards there would not be the confidence in the performance of the technology that science needs to progress and that investors need to fund this progress. Standardisation is usually a collaborative process where a consensus is reached between interested parties. Often though, at very early stages this collaborative ecosystem does not exist and needs a jump start to ensure faster progress. This is where national metrology institutes (NMIs), with their expertise in measurement science, have a key role to play as an independent, market agnostic, contributor to, and engine of, the standardisation process.

In particular NMIs can help in emerging science areas at the very start of the standardisation process, where the technology would otherwise not make the jump to a documentary standard, or would make it more slowly. These activities are often referred to as 'pre-normative research', or research undertaken prior to formal standardisation. This is the knowledge framework required before standardisation can begin. Often there is no market driver for this work to take place. This is because at these early technology stages, organisations will often work in isolation – developing their own independent test methods – and not seek the benefits of wider collaboration, not only because relevant communities do not exist but also because companies will often assume that it is preferable to retain proprietary knowledge rather than gain the wider, considerable benefits that standardisation and knowledge sharing brings. Lack of a universally agreed testing regime also means that it becomes much more difficult to verify the claims that are made about these new products. This is where it is important for governments to kick-start the standardisation process through their national laboratory system, particularly using NMIs.

The National Physical Laboratory's (NPL) site in Teddington, South West London. NPL is the UK's National Metrology Institute.

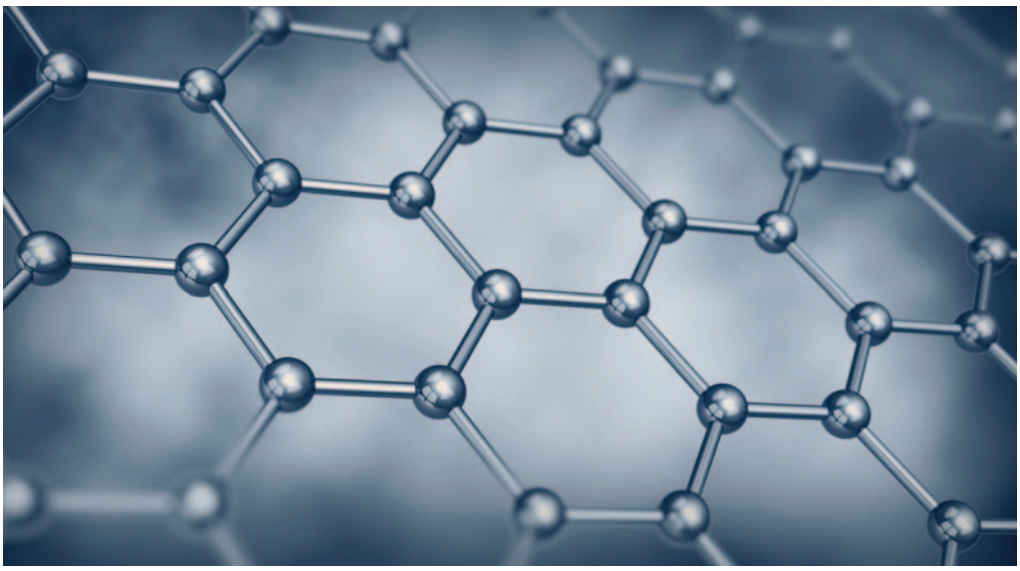
## DEFINING PRE-NORMATIVE STANDARDS

Fundamental contributions, such as documentary standards agreeing relevant nomenclature and definitions for the area, are some of the first outputs required. These set the framework for the understanding of, and communication within, the area. Subsequently, in the early stages of standardisation there is more focus on research into the generation and feasibility of new methods and NMIs can assist with this, together with academic partners. Once candidate measurement methods are developed, an understanding of the characteristics of these measurement methods (in terms of method parameters such as selectivity, sensitivity, detection limits, etc), and how sensitive the outputs are to the inputs, is required. This is very much the preserve of NMIs who can lead the development and documentation of this knowledge. In particular, identifying limiting factors in the measurement technologies is important because resolving these issues via pre-normative research greatly improves the stability and comparability of candidate measurement methods, making them more amenable to documentary standardisation and widespread uptake.

Once this pre-normative research is performed, steps can be taken towards the documentary standardisation of the methods produced. NMIs can help again by bringing these communities together, assisting in the formulation of national and international standardisation committees, and where appropriate driving forward the process by being present on these committees or even chairing them. There is also an important role for NMIs in providing specialist input for parts of documentary standards such as the uncertainty budgets, quality control and demonstration of method validation. Additionally, NMIs have a key role as the national highest point of reference in providing support for those using these standards once they are published, through the provision of reference materials, quality systems, training and the operation of proficiency testing schemes.

## CASE STUDY: GRAPHENE

Graphene has broad applications and great potential to disrupt manufacturing and products. In 2012, NPL began to develop the measurement science required to produce characterisation protocols, in order to progress the technology readiness of graphene, transferring this material from academia to industry. This project resulted in the first graphene ISO standard, defining



A representation of graphene – a single layer of carbon atoms arranged in a two-dimensional honeycomb lattice.

the terminology of graphene and related 2D materials; providing the advanced materials community with a way to communicate defined terms with confidence.

Alongside this, NPL developed the underlying measurement science which supports the reliable and reproducible characterisation of the structural and chemical properties of graphene powders and sheets. This project was the first to investigate the measurement of commercially available graphene in the 'real-world', beyond ideal samples studied in scientific literature, in a reproducible way. It determined measurement methods for the range of lateral sizes, thickness, level of disorder, chemical species, functional groups and contamination of graphene, as these properties are not always well-controlled in commercial materials.

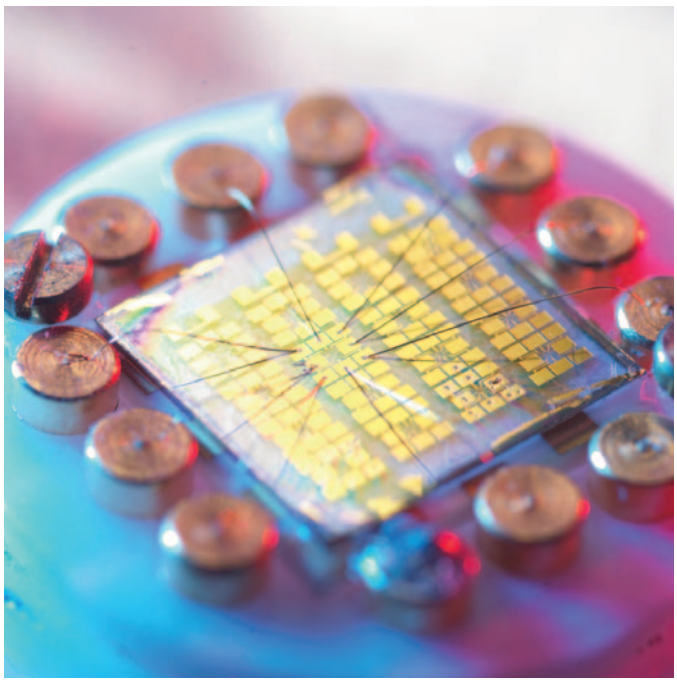
## CASE STUDY: QUANTUM

NPL has delivered in support of the National Quantum Technologies Programme (NQTP) with the objective of strengthening engagement in international standards and benchmarking. Two reports were produced which describe the work NPL did to support this objective, including engagement with the UK quantum community and international activity in quantum technology standards development. In support of a wider awareness and engagement from UK industry in the development of new standards, the reports explain the background to standards, why they are needed and how they are developed. NPL has also worked with partners to deliver a well-attended online meeting with high-profile speakers involving well over 130 people from the UK quantum community at which was described the value of standards, the process of standards development and the current situation in the development of quantum standards.

## CASE STUDY: NANOTECHNOLOGIES

At the beginning of this century an increase in the deliberate application of nanotechnology to commercial products became evident. Alongside this activity there was a growing demand for the standardisation of nanotechnologies. To meet this demand, BSI and NPL established a committee on nanotechnologies and strategically lobbied for the UK to chair both ISO and CEN committees in nanotechnologies. Hence, ISO established a new technical committee for nanotechnology in 2005 with the chair and secretariat being held by the UK.

In the UK and internationally, surveys of standardisation needs were undertaken ranking possible projects in terms of priority of need and timeliness. The UK funded and quickly developed BSI UK documents on terminology, nanomaterial handling and health and safety that were freely downloadable. These were written as forerunners to ISO documents and often formed the basis of later ISO documents. In 2008, 3 years after the committee was formed, its first ISO technical specification was published on key terms in nanotechnologies.



Quantum science, such as this quantum electrical device, is being increasing harnessed to deliver improved information processing, secure communications, high-precision navigation and earlier diagnosis of diseases.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# SHOULD WHOLE-GENOME SEQUENCING FOR NEWBORN BABIES BE INTRODUCED INTO THE NHS?


Dr James Buchanan


Dr Sarah Wynn


Professor Anneke Lucassen


Sarah Wordsworth


Professor Mike Parker

**As DNA sequencing technologies are becoming faster and cheaper, we are on the brink of a genetically-driven era in medicine. The NHS Long Term plan includes the commitment "to be the first national health care system to offer whole genome sequencing (WGS) as part of routine care"[1] and this could ultimately lead to every child born in the UK having all 3 billion letters of their genetic code sequenced at birth. The rationale for WGS of newborns is threefold:**

1. **that this would identify more rare genetic diseases than current screening programmes;**
2. **produce a resource that could be used to make health-related predictions throughout an individual's life; and**
3. **facilitate the creation of a valuable database for research purposes.**

**But this move might also have considerable ethical, social, moral and economic consequences. Is the NHS really equipped and ready?**

## DIAGNOSING DISEASE

One argument in favour of WGS for newborns is that it would identify at birth a greater number of individuals carrying genetic diseases, including rare conditions that could otherwise take months or years to diagnose. There are at least 6,000 known rare diseases which affect around one in 17 people in the UK (3.5 million people). Many of these are caused by tiny variations in the genetic code, sometimes only a single base-pair change, and there is often no family history of the condition. Currently, the newborn 'heel prick' test screens for nine genetic conditions, including Cystic Fibrosis and severe combined immunodeficiency, but WGS could reveal much more, particularly as it doesn't require specifying in advance which diseases to search for. "Being diagnosed at birth through WGS could enable those affected by rare diseases to receive preventative or targeted treatment/ therapies, and avoid a distressing 'diagnostic odyssey' in later life" said Dr Sarah Wynn, CEO of Unique: a charity for those affected by rare chromosome and gene disorders.

Evidence for this comes from early results from Genomics England's 100,000 Genomes Project, in which 4,660 participants with an undiagnosed rare disease had their entire genomes sequenced. [2] This provided a new diagnosis for around 25% of participants, about a quarter of whom were then able to receive more focused clinical care, including dietary change, vitamins and/ or minerals, and other therapies.

## COSTS AND BENEFITS

Ultimately, more rapid diagnoses could translate into significant cost savings for the NHS, as Dr James Buchanan from the Health Economics Research Centre (HERC) at Oxford Population Health explained: "In this study, the diagnosed participants had been living in uncertainty for a median duration of 75 months, and the median number of hospital visits undertaken during this time was 68. One participant, a 10-year-old girl, had endured a seven-year search for a diagnosis, with over 300 hospital visits at a cost of £356,571. But a diagnosis from WGS enabled her to receive a curative bone marrow transplant, costing only £70,000." However, as noted by Dr Buchanan's colleague, Professor Sarah Wordsworth (HERC), "Little is known about the actual costs and benefits of introducing WGS for all newborns, and much work remains to be done to assess whether it would make enough difference to health outcomes to justify the expense for the NHS."

But even when a rare disease is correctly diagnosed, in many cases there are no effective treatments available. Public surveys [3] indicate that while most people would want to know if their child will develop a treatable disease, opinions are

divided over as-yet incurable conditions. Advance warning may help parents prepare, but could also affect the critical early bonding period with their child. Dr Wynn makes the point, however, that early diagnosis of an untreatable disease still allows parents to receive valuable support: "Accessing information and talking with other families experiencing the same rare disease journey is very important to help relieve feelings of isolation, confusion and, very often, grief" she said.

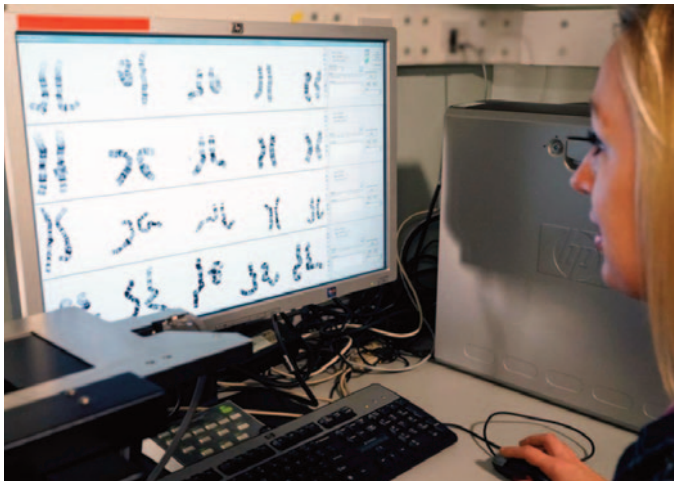
## INTRODUCING DOUBT

However, WGS would also be able to identify a range of genetic variants whose role in disease is more subtle. On the one hand, this could enable millions of people with a higher than average predicted risk of developing a chronic disease to take preventative action. For instance, the genetic condition familial hypercholesterolemia (FH) is described as a 'silent killer' of young adults, as it increases the risk of early heart attacks. There are thought to be around 220,000 FH-positive individuals in the UK, of which less than 8% have been diagnosed. Without treatment, their risk of having a heart attack is 50% for men under 50 years, and 30% for women under 60 years [4]. Identifying these individuals at birth would allow them to take preventative cholesterol-lowering treatments (such as statins) later in life which can significantly lower this risk [5], besides helping to identify at-risk relatives.

However, complex diseases (including most cancers, diabetes and heart disease) are influenced by many environmental factors, besides genetics. Hence, whilst WGS would identify a high-risk group, it could also generate more 'false positive' diagnoses of individuals who will not develop the condition in their lifetime. This could lead to unnecessary treatment and worry, and potentially undermine confidence in the NHS. According to Professor Anneke Lucassen (Director, Centre for Personalised Medicine, University of Oxford), we need to be very careful that major decisions about a child's upbringing are not overly influenced by highly uncertain genetic predictions. "Where WGS makes clear genetic diagnoses, this is likely to be helpful in a lot of cases, but the mistake comes if we think that all genetic tendencies are the same as a diagnosis. We need to get better at communicating uncertainty about genetic variants found in WGS both to the public, and to busy health care professionals."

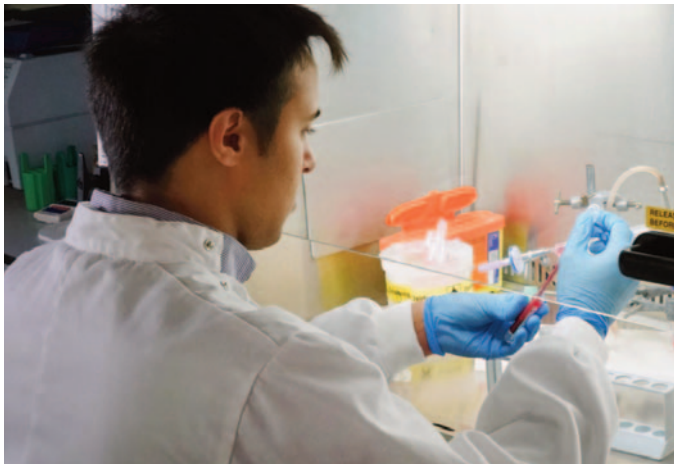
## FAMILY FORTUNES

Diagnosing an individual with a genetic disease often has implications for other family members. Whilst this can be a positive thing, for instance in identifying at-risk relatives and assisting family planning, it could also lead to difficulties if some relatives do not wish to know their genetic risk, or cannot be traced. In addition, parents consent to newborn screening on behalf of their baby, but WGS will create a resource that could be consulted when that child becomes an adult and may then have a different view on how their information should be accessed and used.



Analysing a person's chromosomes
*(Credit: Unique and St George's Hospital)*

Naturally, many parents might also be curious to know what their child's genetic profile predicted for other attributes beyond disease risk, such as appearance, intelligence, sporting prowess or musical abilities. Despite perceptions, these are usually only weakly genetically determined, so how much should parents be able to access the WGS of their newborn to make such predictions? Unless the limits of genetic research are made clear, this could lead to misunderstandings that overly impact a child's upbringing, particularly if private companies start offering 'genomics-enhanced' parenting advice.



Extracting a patient's DNA from a blood sample
*(Credit: Unique and St George's Hospital)*

## DATA USE AND MISUSE

A WGS database could be a powerful research resource, to help improve our understanding of the links between genetics and disease, and suggest possible new therapies and treatments, including gene therapies. But this also raises questions of who should manage this data, and how it would be kept secure. A breach of personal genomic data could have serious consequences, particularly if used by insurance providers, employers, or marketing companies to make decisions. Should access be limited to researchers and clinicians, or could the data be applied in secondary uses, such as aiding the police in criminal investigations? The recent conviction of the California 'Golden State' Killer is an intriguing case study. After a 40-year hunt, Joseph James DeAngelo was finally arrested and sentenced for at least 12 murders and 50 rape offences when investigators used DNA recovered from the crime scene to create a fake profile on GEDmatch, an online genealogy

resource with over 1.4 million members. This identified a group of people with the same great-great-great grandparents as the killer, who were narrowed down to two suspects. But despite ending in a successful prosecution, the case raised concerns on the ethics of using personal genetic information for purposes beyond the individual's intention.

According to Professor Michael Parker (Director, Ethox Centre, Oxford Population Health), there needs to be full transparency about how genetic data may be used, with checks to ensure individuals understand, and that in addition to consent there are appropriate protections in place. "We can't just rely on consent forms with their simple tick-boxes to cover all the ethical implications of WGS. Strong protections need to be in place to stop individuals from being harmed or discriminated against."

It's clear that a newborn WGS programme could be a powerful tool towards reducing the UK's disease burden, yet this could also potentially result in harms at individual, family and societal levels. As Professor Parker noted, we need to pay close attention from the start to agreeing what the objectives for WGS should be before it is introduced, whether diagnosing disease, as a research tool or for wider purposes. "We need to be asking now what kind of health service we want in the future, and what 'excellent care' means in relation to our genetic data and how it is used."

**Dr Sarah Wynn, Professor Michael Parker and Professor Anneke Lucassen debated WGS on newborns with a public audience at the 2021 Being Human Festival. You can watch a recording of the event at https://cpm.well.ox.ac.uk/video/familial-fortunes**

**Oxford Population Health is part of the University of Oxford, and focuses on data-driven and population-level approaches to advance our understanding about the causes and treatment of disease.**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# OUR SCIENCE SUPERPOWER STANDS ON SOLID FOUNDATIONS: THESE NEED NURTURING TOO

Dr Sandra Knapp, President, Linnean Society of London

## At COP26 in November 2021, the UK Government and other nations around the world focused on finding the solutions we and the planet so urgently need to meet the climate change and biodiversity crisis.

Earlier in 2021, we also saw a welcome attention being paid to innovation, with the Government's Innovation Strategy and its promises to make the UK a 'science superpower' a prime example. However, there has been little mention of the country's learned societies in helping to meet these ambitions.

As indicated in the Strategy, environment and energy technologies will be critical in protecting our natural world. But, if we want to make great strides in re-thinking how we use our land and restore biodiversity, we need to go further than creating new tools, and consider our understanding of, and relationship with, the natural world. This requires behavioural change and cross-disciplinary thinking that brings the arts and sciences together, and also goes beyond the realm of academia.

We need an open dialogue with research, business, policy-makers and the general public to foster such innovation, and there is an opportunity to draw on our existing research and innovation ecosystem to facilitate this. Learned societies play a pivotal and unique role in cross-fertilising and disseminating ideas across many groups and represent extensive networks that have been formed over hundreds of years. This is an opportunity missed in the Government's current strategy.

### We're not at a standing start

Take the Linnean Society of

Burlington House 2015

London and our neighbours located in Burlington House in London's Piccadilly (the Geological Society, the Society of Antiquaries and the Royal Astronomical Society). We represent networks of tens of thousands of members – from academics to policymakers and members of the general public – all of whom come together and share ideas. Within the same walls that Darwin's theory of evolution was first presented, we also inspire and connect young, curious minds with nature via innovative art techniques, and provide expert responses to the Government's thinking on key issues such as the economics of biodiversity in the Dasgupta Review.

Learned societies like ours are gatekeepers to an unsurpassed resource on the past, present and future of knowledge. There are over 200 learned societies in the UK, all dedicated to furthering knowledge of our respective subjects, supporting academics, professionals and policymakers, as well as public engagement. We act as publishing houses, provide mentoring, support and training, and much more. For example:

- Learned societies hold international and often Arts Council designated collections. Access to these collections alone has led to notable discoveries and advancements and, combined with the proactive bringing-together of different perspectives, has helped to forge deep international scientific and cultural partnerships.
- Many learned societies provide funding for vital research around the world. For example, the Royal Society, the oldest learned society in the world, fosters collaboration between UK science and abroad by funding international research – they currently have over 700 active researchers funded overseas.
- Learned societies also help to push the boundaries of research and our understanding by focusing resources for scientific exploration beyond higher education's current reach. For example, the Linnean Society's Appleyard Fund, awarded to individuals who are not in full-time employment as biologists, has given foster carer, Eve Hills MRes, the opportunity to contribute to global efforts to resolve human-wildlife conflict and enhance leopard conservation.
- The work of learned societies is making headway towards reducing our impact on the environment as we act as independent advisory bodies that businesses can rely on. This year, the Linnean Society launched its Carbon Action Plan, which will help a range of businesses who are looking for a clear advice on improving their ways of working. Our collections also continue to be crucial for international legislation around biodiversity management.


Hercules beetle, *Scarabaeus hercules*

Seahorses, *Hippocampus hippocampus*

### The UK's physical learned societies are still vital in an online world

Even before the pandemic, learned societies were evolving to meet the needs of the digital age – with lectures and events available on YouTube, digitised collections, and online archives and libraries catalogues online. At the same time, physical presence of these events and objects is still vitally important, so that people can come, see and better understand sources and samples of global significance while collaborating and learning from others in their field.

The physical presence of several societies together holds its own unique value too. For example, referring to the learned societies at Burlington House, Sir David Attenborough described how "locating such organisations in the nation's capital was a recognition of the importance of such subjects should have in the life of civilised society" in a recent letter to the Prime Minister. In fact, independent analysis by PwC found that the societies at Burlington House contribute over £40 million a year in public value from their activities.

Our co-location with other disciplined societies fosters collaboration that allows creativity to flourish. For instance, joined-up approaches to education and learning programmes mean that young people can experience a full range of arts–science activities linked to the national curriculum. Similarly, our collective convening power onsite has the potential to bring together

leading-edge inter-disciplinary meetings, attract key influencers from the worlds of academia, business and policy to challenge the status quo and harness our collective brain power for the benefit of humanity. The learned societies are also unique in the Fellowships they support beyond higher education, whose varied backgrounds offer diverse viewpoints to creatively solve the problems we face now.

### The opportunity to make more of our science superpower

To make the most of this existing infrastructure, Government needs to start thinking about learned societies holistically and as assets for delivering its strategic goals around innovation.

Right now, we are caught in limbo. We act as a resource and facilitator for innovation in line with the Government's ambitions, but at the same time have received little attention. Like many learned societies, the work we do is largely funded by profits from our academic publishing businesses, which unlike the commercial publishing world, all feeds back into our charitable objectives. Yet, at Burlington House we are threatened with eviction from rising rents by our Government landlord, the Ministry of Housing, Communities and Local Government.

Moving the Linnean Society's collections alone would cost in the region of £650,000, diverting funds away from our charitable activities as a learned society – even those online – and threatening the networks and resources that have been built up over centuries. This appears to go against what the Government is trying to achieve.

The Collection Store

In future, some learned societies may even have to sell-off assets just to survive, let alone thrive as significant contributors to the UK as a 'science superpower'. Government must acknowledge the resources we already have in the form of the learned societies. Now is a prime opportunity to support and facilitate the expansion of our knowledge generation and dissemination in the sciences, arts and humanities, that will form the solid foundations of our efforts to reach our international goals. □

# INNOVATING FOR VICTORY: LESSONS ON CLIMATE CHANGE FROM WORLD WAR II

Dr Andrew Bodey

Dr Andrew Bodey is a scientist and science writer with a background in sustainability consulting.

**The challenge of reducing emissions by 2030 appears overwhelming, but history teaches us that the scientific and technological innovations we need can be realised on even this short timescale.**

"The Doomsday Clock stands at one minute to midnight." The magnitude and urgency of the challenge we face was apparent from the opening speech of COP26. We have just a few years left to drastically reduce emissions. If we fail, feedback loops (methane release from melting permafrost, loss of reflective polar ice, etc.) will accelerate climate change and make it far more difficult – perhaps impossible – to tackle the problem. For the 'least bad' outcome of 1.5°C warming, the Intergovernmental Panel on Climate Change recommends halving emissions by 2030, and reaching net zero by 2050 [1]. Even the 2°C target (25% reduction by 2030) appears very difficult to achieve. The grounds for pessimism and defeatism seem very real. The political and technological challenges seem overwhelming. *But we have been here before*.

Eight decades ago, the world was at war. Stakes could not have been higher, and the political aims and economies of nations were uprooted and reoriented towards their respective war efforts. The six terrible years of the Second World War saw intense scientific activity and technological developments. Winning the war relied upon having the best weapons, computers, communication technologies and medicines. And the speed at which these inventions were made and brought into use was phenomenal. During the six years of the war, nuclear weapons, superglue, radar, jet

engines, rockets, jeeps, synthetic rubber, duct tape and helicopters were all invented. Huge advances were made in aeronautics, computing, chemical engineering, medicine and food science. Time was of the essence, and scientists and engineers – backed by governments – rose to the challenge.

Seventy-six years on, we are again in great need of technological solutions – and time is once again of the essence. At current rates of progress, we are heading for disaster. The fusion reactors that are 'still fifty years away' will arrive too late, and lab-grown meat will arrive on our plates long after global warming's feedback loops have kicked in. But history tells us that, with the right investments and organisation, things could be very different. We could soon have geothermal energy in every country, thin-film solar so cheap that it is rolled out onto every roof, and lab-grown sausages that are cheaper than – and just as tasty as – the best pork-based banger.

The problem is that fossil fuels are so good at what they do. They are plentiful, portable, scalable, reliable, energy dense and cheap. Unlike solar and wind, there are no problems with intermittency. Unlike batteries, they add so little bulk and weight that you can use them even for long-haul air transport (gasoline holds 35 times more energy per kg than the best lithium-ion batteries). Fossil Fig 1. Mass spectrometer used for the Manhattan Project, which employed 130,000 people. Just three years after the project began, it completed its aim of developing the world's first nuclear bomb. Various groups from across the political spectrum have called for a Manhattan Project for the Environment - a project of similar magnitude to accelerate the development of key cheap, green technologies. (Image: James E Westcott, Official US Army Photographer for the Manhattan Project / American Museum of Science and Energy) Dr Andrew Bodey fuels can be transported around the globe and burned only where and when they're needed. Oil is so cheap that it *actually costs less than the cheapest fizzy drinks.* (The extra cost of zero-carbon alternatives to various manufacturing materials and transport fuels are shown in Fig 5.) For *alternative* technologies to become *default* technologies, they will have to compete with all this. Innovation is therefore vital.

Fig 1. Mass spectrometer used for the Manhattan Project, which employed 130,000 people. Just three years after the project began, it completed its aim of developing the world's first nuclear bomb. Various groups from across the political spectrum have called for a Manhattan Project for the Environment - a project of similar magnitude to accelerate the development of key cheap, green technologies. *(Image: James E Westcott, Official US Army Photographer for the Manhattan Project / American Museum of Science and Energy.)*


Fig 2. Synthetic rubber production, circa 1940. Rubber was a vital material for vehicles and clothing, and mass production of synthetic rubber became necessary when natural rubber supplies were cut off in 1942. Businesses agreed to share patents and scientific information to solve the rubber crisis. By 1944, 51 new production plants were producing 800,000 tonnes annually.[2] *(Image: Library of Congress, LC-USW33-028402-C.)*

Solutions to all the drawbacks of alternative technologies are in development. The cost of solar and wind are already falling rapidly, and their intermittency can be addressed with grid-scale energy storage - be it electrochemical, thermal or gravitational. Once they have been made affordable, zero carbon fuels - either advanced biofuels (made from agricultural waste) or electrofuels (made by storing energy from renewable electricity in the chemical bonds of a fuel) would have all the advantages of oil. Accelerating the development of these technologies would be a great asset in achieving the 2030 goals, as would progress on other technologies such as hydrogen fuel cells, zero-carbon cement, zero-carbon steel, lab-grown meat and dairy, zero-carbon fertiliser, direct air and point carbon capture, geothermal, nuclear fusion and coolants not based on fluorinated gases.

There are alternatives to technological solutions, and some of them will be necessary. Taxation and rationing are effective strategies – but they will be hard to stomach on the scale required. Halving emissions by 2030 means giving up some of the things we love. We *could* drastically reduce consumption of carbonintensive products, but without truly decent alternatives, we're unlikely to. Solar power is 99% cheaper than it was in 1980, but it's still not *cheap*. We could cycle more, but our workplaces are not going to move closer to our homes overnight. We already have low-tech alternatives to meat and dairy (they grow in the ground), but the world's population is growing much faster than veganism. We could use existing technologies to get out of this mess, but it will be far more politically feasible to develop new ones.

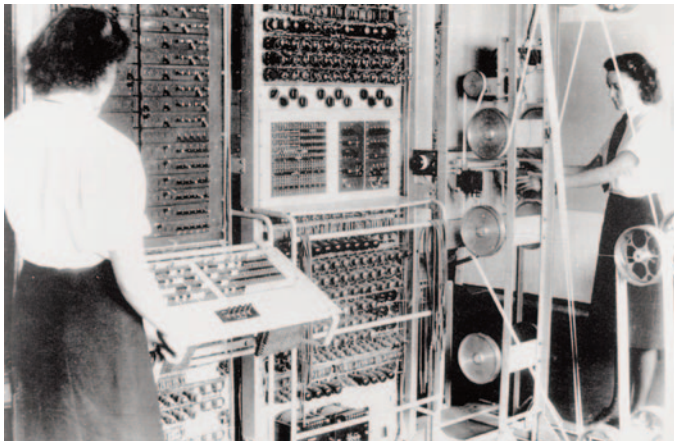

Fig 3. Colossus: the world's first programmable digital electronic computer. Colossus was built at Bletchley Park where some 10,000 staff worked on code breaking efforts during the war. (Image: Unknown author, The National Archives, UK.)

There is an important caveat here. A paradox can exist with technologies that help us do more with less: they can *increase* consumption of the very resources one is trying to conserve. By an effect known as *Jevons Paradox*, they can increase greenhouse emissions. For example, a technology that reduces demand for fossil fuels will apply a downward pressure – at least in the short term – to the fuel's price; this incentivises other players to buy the fuel – and *use it inefficiently*. Furthermore, unless green technologies undercut the cost of fossil fuels by a wide margin, their widespread adoption does not necessarily prevent fossil fuels from being profitably extracted. For these reasons, technological solutions to global warming will need to be coupled with international laws and taxation schemes that ensure that fossil fuels and trees stay in the ground. The value of technological solutions arguably lies in making the transition to a low carbon economy politically feasible.

Just as with a war, a project of this magnitude would obviously not be cheap. But it would be good value when compared to trying to fix the problem once it has become worse, or adapting to it once it has become severe. As the 2008 banking crisis and COVID pandemic have clearly demonstrated, the world can generate vast sums of money in times of emergency. And there will of course be handsome returns for those who can develop any technologies that rival fossil fuels - that drive green premiums into the negative.

Countries can do the research and development together, and gift the intellectual property to the world. Or they can do it individually, and reap the returns on their investments – gifting the proceeds to their citizens who ultimately backed the programmes. This way, countries do not have to rely on broad multilateral action. They do not have to ask 'what about the polluters who do not contribute?'. The answer is simple: those countries will contribute by buying the new

Fig 4. The 19th Century economist William Stanley Jevons. In his 1865 book about the sustainability of fossil fuel use *The Coal Question*[3], Jevons argued that improvements in fuel efficiency tend to increase fuel use. (Image: Unknown author, Popular Science Monthly Volume 11)

**Green Premiums for plastics, steel, and cement**

| Material | Average price per ton | Carbon emitted per ton of material made | New price after carbon capture | Green Premium range |
|---|---|---|---|---|
| Ethylene (plastic) | $1,000 | 1.3 tons | $1,087–$1,155 | **9%–15%** |
| Steel | $750 | 1.8 tons | $871–$964 | **16%–29%** |
| Cement | $125 | 1 ton | $219–$300 | **75%–140%** |

**Green Premiums to replace current fuels with zero-carbon alternatives**

| Fuel type | Retail price per gallon | Zero-carbon option per gallon | Green Premium |
|---|---|---|---|
| Gasoline | $2.43 | $5.00 (advanced biofuels) | **106%** |
| Gasoline | $2.43 | $8.20 (electrofuels) | **237%** |
| Diesel | $2.71 | $5.50 (advanced biofuels) | **103%** |
| Diesel | $2.71 | $9.05 (electrofuels) | **234%** |
| Jet fuel | $2.22 | $5.35 (advanced biofuels) | **141%** |
| Jet fuel | $2.22 | $8.80 (electrofuels) | **296%** |
| Bunker fuel | $1.29 | $5.50 (advanced biofuels) | **326%** |
| Bunker fuel | $1.29 | $9.05 (electrofuels) | **601%** |

Fig 5. The extra cost, or *green premium*, associated with various zero-carbon options for manufacturing materials and transport fuels[4]. Accelerating the reduction of these premiums is vital for their widespread adoption.

technologies after they have been developed. Because they will be efficient and effective – as well as low- or zero-carbon.

It is easy to be pessimistic about global warming. It is easy to see it as a problem that is too big, too complex to tackle. But history has shown us that research in science and technology can solve enormous problems. Fast. And as COP26 has so clearly reminded us: time is once again of the essence.

*"History has shown that when nations come together in common cause, there is always room for hope."*

Her Majesty The Queen, COP26, 1st November 2021


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# THE SCIENCE AND SENSE OF ALLOTMENTS


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While the idea of allotments may conjure up a vision of men in flat caps discussing the merits of their huge vegetables (innuendo fully intended), the reality is somewhat different. The days of Big Al and his "brother" Little Norm running their business from a shed on the allotment as celebrated in Alan Plater's "The Beiderbecke Affair" are part of a dimly remembered and largely fictional past. Modern allotments are used by diverse communities and fulfil a number of roles for their tenants. In addition to examining the history and science of allotments, this brief report will also consider the ecology and chemistry of growing fruits and vegetables and the wider benefits, in addition to exercise and nutrition, of adopting an allotment.

## HISTORY

Allotments are small parcels of land, generally (although not exclusively) owned by local authorities which are then rented out to individuals for the purpose of growing food crops. Allotments can either be temporary or statutory. If they are the latter then, under the provisions of section 8 of the Allotments Act (1925), a local authority must seek permission from the Secretary of State before selling or changing the use of a statutory allotment site. An allotment is traditionally measured in rods, an old Anglo-Saxon measurement. Ten rods was the traditional size of an allotment, (250 square metres - the size of a doubles tennis court) but many are now smaller reflecting lower availability and a reduced appetite for the larger space.

The origin of allotments lies in the loss of 'common land' which was used for growing crops and keeping stock. As the enclosure of land increased, common land was lost and allotments were made available to tenants. Two world wars and the threat of food blockades increased the importance of allotments (particularly catalysed by the 'Dig for Victory' campaign). During the second world war, allotments were estimated to contribute some 1.3 million tonnes of food from 1.4 million plots. After the war with the provision of different sources and types of food, there was a decline in the total number of allotment plots from a total of about 1,400,000 in 1943 to around 500,000 in the 1970s. Figures from the National Allotment Society suggests there are currently some 330,000 allotment plots in the UK however land dedicated to allotments has declined by 65% from a peak between the 1940s and 1960s with almost half having been built on.

The author's allotment in Norwich in July

## SCIENCE

The potential of urban sites and allotments for the production of food has been studied. An investigation of allotment sites in three 'typical' English towns (11 in Bedford, 18 in Luton and 50 in Milton Keynes) was carried out in 2020. Typical crop yields varied with spinach chard producing about 14kg/$m^2$ and, at the other end of the scale, asparagus producing 0.2kg/$m^2$. Yield of the most common crops (e.g. cabbage, onion, potato) are generally lower in allotment grown crops than in those that are commercially produced. It was estimated that, nonetheless, under current growing regimes, allotments could provide about 10% of the annual recommended fruit and vegetable intake for the population in the areas investigated [1].

Soil degradation is recognised as a major land use challenge. At one extreme, a combination of poor farming practices, erosion and low rainfall can lead to the Dustbowls. These affected 100,000,000 acres centred on the panhandles of Texas and Oklahoma in the US in the 1930s. Many allotment holders use self-produced compost or manure on their plots and this has resulted in the plots having higher levels of soil organic carbon, higher C:N ratios and higher levels of total nitrogen than land under commercial cultivation [2] and this helps to retain and preserve soil structure. Allotments were not conceived as having to be maximally efficient and the introduction of more managed growing and cropping could result in an increase in yield and more efficient resource utilisation. One example is the use of water. The water footprint of the 13.5 billion kg vegetables imported to the UK each year, is around 560 million $m^3$. Climate projections for the UK indicate that over the next 20 years, winters will become warmer and wetter, and the summers hotter and drier. A recent study [3] suggests that water mitigation procedures and improvements in allotment crop growing practices such as increased planting density and use of directed watering would allow more crop to be produced for the same amount of water use and result in an increased yield per hectare.

Plant secondary metabolites are ubiquitous. Plants produce a range of metabolites that influence growth and the ecological fitness of the environment and this is crucial to plant and microbial welfare. For example, the nature of the microorganisms (microbiome) in a plant environment can affect plant growth. The plant itself can then, through the production of specific secondary metabolites, influence the microbiome which, in turn may also impact the metabolome of the host plant. Plant secondary metabolites are also the source of lead compounds for many pharmaceuticals and for phytochemicals with beneficial properties in many chronic diseases. However, they can also exhibit a range of toxicological effects and care must be taken when encouraging their production and consumption [4]. Growing plants for flavour and potential physiologically beneficial properties rather than solely for yield is an option in an allotment setting where it is not in a commercial environment but first of all a much better understanding of the nature and biological action of phytochemicals is needed.

There have been a number of reports – often anecdotal – about the various benefits of keeping an allotment. It is only relatively recently that attempts have been made to try to quantify these positive attributes. Spending a greater proportion of time outdoors is of benefit to populations – particularly in Northern Europe – who may suffer from marginal vitamin D deficiency. This must be balanced against potential risks. There have been no detailed studies of the prevalence of skin cancer among allotment holders however it is wise to be aware that cases of melanoma are increasing in the population generally. Members of the Apiaceae family, (including hogweeds) can cause photosensitivity and the furanocoumarins they excrete can, in conjunction with sunlight, cause DNA damage.

The psychological benefits of working on an allotment are now beginning to be the subject of more detailed studies. In a comparison of health outcomes, allotment gardeners reported better perceived general health, subjective health complaints, mental health and social cohesion compared to non-gardeners. Neither frequency nor duration of gardening significantly influenced the reported health outcomes [5]. In a study in the UK, self-esteem, mood and general health were measured in 136 allotment gardeners pre- and post- an allotment session, and 133 non-gardener controls. There was a significant improvement in self-esteem and mood as a result of just one allotment session. Allotment gardeners had a significantly better self-esteem, total mood disturbance and general health, experiencing less depression and fatigue and more vigour than non-gardeners [6].

## CONCLUSION

There is a growing evidence base that suggests that allotments have an economic, health and social value including encouraging increased consumption of fruit and vegetables. Further studies of the role of allotments, their effect on society and the individual are warranted.

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# MAKING THINGS WITHOUT USING FOSSIL CARBON

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**We are all now well aware of the impact of burning coal, oil and gas (often known collectively as fossil carbon) on the climate of our planet. This has been extended to examining the sustainability of plastic packaging over the last few years, both in terms of environmental pollution and potential impact on the climate. However, less attention has been given to consumer products, paints, textiles and a whole range of other products based on carbon chemistry. It is worth exploring where we are and what we can do to lessen the scale of climate change by everyday life.**

## WHAT ARE WE ACTUALLY TALKING ABOUT?

Sustainability can seem to be a nebulous concept without rigorous definition. One route is to separate out the supply chains that leads to the individual products and examine what happens to the products after use. The supply chains we are interested in mostly start with carbon produced from fossil sources, and it necessary to quantify the scale of carbon use so as to enable a full economic (because governments care about this) and commercial (because businesses are driven by this) analysis of options and their likely impact on carbon dioxide emissions (that everyone should care about).

The established methodology breaks down the carbon dioxide emissions of any company within a supply chain into three areas, called Scopes. These are defined (by organisations such as the World Resources Institute and the World Business Council for Sustainable Development) as follows:

**Scope 1 – All Direct Emissions** from the activities of an organisation or under their control. Including fuel combustion on site such as gas boilers, fleet vehicles and air-conditioning leaks.

**Scope 2 – Indirect Emissions** from electricity purchased and used by the organisation. Emissions are created during the production of the energy and eventually used by the organisation.

**Scope 3 – All Other Indirect Emissions** from activities of the organisation, occurring from sources that they do not own or control. These are usually the greatest share of the carbon footprint, covering emissions associated with business travel, procurement, waste and water and what happens to the products in use and at end of life.

Most companies have a good data on their Scope 1 emissions, and there are shared standards for Scope 2 (since they tend to be national energy source related). Figures for the upstream Scope 3 emissions are starting to be collected (ONS is building such a database), but there appears to be no agreed or available measure of downstream Scope 3 emissions. Given that the carbon source for most chemical products is petrochemical, the whole supply chain is effectively putting fossil carbon into the ecosphere, and thus at risk of contributing to climate change. This means that, by 2050, to comply with Net Zero commitments, the whole supply chain will need a new source of non-fossil carbon. This change needs to start now!

## WHAT SIZE OF PROBLEM ARE WE TALKING ABOUT?

The atmosphere is estimated to have a total mass of about 5.148 quadrillion tonnes. At the start of the Industrial Revolution, it has been calculated that the amount of carbon dioxide in the atmosphere was about 2.190 trillion tonnes, but in the last few years that has risen to 3.285 trillion tonnes. The difference means that we have added just over 1 trillion tonnes of carbon dioxide to the atmosphere.

Whilst it is difficult to get accurate numbers, it is possible to estimate the amount of fossil carbon that has been extracted over the last 100 years (when our use of fossil fuels reached significant levels).

Combined, it appears we have extracted 2.115 trillion tonnes of carbon dioxide equivalent over the last 100 years. The difference between this number and the atmospheric number is made up of the carbon dioxide dissolved in the oceans and that locked up in carbon-based materials (both in use and in landfill). The annual rate has grown over this period but we are currently extracting just under 50 billion tonnes of carbon dioxide equivalent a year.

If we focus on the use of fossil carbon outside of its use as a fuel, figures indicate that the fraction of oil and gas going into "chemical uses" has increased (globally) to over 2.6 billion tonnes of carbon dioxide equivalent a year (in 2017). This rate is projected to increase by anywhere between 16% and 26% by 2050, at which point it would be larger than the projected use by transport.

There has been analysis of the use of petrochemicals to make plastics and (according to both global and UK Government figures) is about 40% of the toral petrochemicals use – which equates to just over 1 billion tonnes globally and about 15 million tonnes of carbon dioxide equivalent in the UK.

The rest goes, almost unnoticed, into the production of textiles, paint, and consumer products and many other everyday products which we do not associate with climate change. It is estimated that consumer products put between another 10 and 15 million tonnes of carbon dioxide into the environment every year in the UK – around the same size as plastics! And, as other areas of fossil carbon use decline, this will become increasingly important.

| Source | billion tonnes | |
|---|---|---|
| | production | carbon dioxide |
| Coal | 400 | 1450 |
| Oil | 135 | 425 |
| Gas | 87 | 240 |

## WHAT ARE OUR OPTIONS?

There are two main approaches currently under consideration.

The first is to replace the basic chemical feedstocks with identical molecules but derived from "sustainable" sources. Consumer products usually are derived from the C2, C3 and C4 streams from a petrochemical refinery so, the argument goes, finding sustainable sources of these streams would enable the existing supply chains to continue and minimise the disruption to the entire industry.

An alternative approach is to look at the use of the current chemical species and replace them with other molecules which can be produced by an entirely biological route but deliver the same function in end use. This would require a more complete overhaul of the chemistry using industries.

In truth, the solution is liable to be a mixture of both approaches. Basic science exists to guide us on both approaches but proving that the relevant technologies can be made to work, and pay off the necessary investment, will be far from easy. And the sheer scale of manufacture and finance required means that the timescale required for change in the chemistry using industries is such that we need to address the challenge soon and urgently.

Another factor is that the many decisions that need to be made, and acted upon, up and down the supply chains, are complicated and interlinked, and unlikely to be driven by purely commercial logic. What is needed is a coordinated evaluation of the specific opportunities and the options within them.

## WHAT ELSE DO WE NEED TO CONSIDER?

Chemical feedstocks are not the only area looking for a source of sustainable carbon.

Perhaps the most aggressive research into using sustainable sources of carbon is by the aerospace/aviation industry where it comes close to being an existential threat. Although electric power can be, and increasingly is, used for short-haul flights, there is as yet no credible alternative for long-haul flights. The aerospace/aviation industry worldwide has embarked on a programme to source Avgas (basically iso-octane) sustainably, taking in sources from waste, sewage and biomass. Moving the source of aviation fuel from fossil to sustainable will require carbon equivalent to 900 million tonnes of carbon dioxide globally, of which the UK share is about 35 million tonnes.

A lot of options cite "biomass" as a source, which mostly depends on land use – but there is competition for this resource for food production. Again, numbers vary, but the value looks to be about 150 million tonnes of carbon dioxide equivalent a year. The UK is an effective user of agricultural and horticultural land, so there might not be much capacity for "growing" sustainable carbon in the UK by traditional methods.

## WHAT NEXT?

The chemistry using industries must move to replace fossil carbon as their feedstock if we are to meet our Net Zero targets. If the Government acts to provide a regulatory and innovation framework that supports this change, there is an opportunity to open up new value chain opportunities in the UK. And there also needs to be more coordination between chemistry companies looking for sources of feedstocks, biotechnology companies looking to expand their operation and the potential users of sustainable carbon. We should not treat them as separate sectors – they are complementary partners in the quest to lower the use of fossil carbon.

*The authors would like to thank Ian Howell of Unilever for discussions that led to this article.*

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# A PUBLIC DIALOGUE ON THE SOCIAL AND ETHICAL ISSUES RAISED BY GENOME EDITING IN FARMED ANIMALS

Dr Darren Bhattachary is the CEO of Basis Social, an independent research firm.

**Genome editing is being heralded as one of the most significant breakthroughs in biotechnology in recent years. Applications are broad, and in farmed animals range from increasing yield and productivity by promoting animal muscle growth, to improving their health and welfare, by engineering resistance to viral infections.**

However, the potential use of biotechnology in agri-environmental systems in the UK has a long and often acrimonious history – notably the GM crop and food controversies in the late 1990s and early 2000s. There has been much written on this issue,[1,2] which has focused on a disconnection between expert and lay framings around the governance of the technology. In particular, the debate underscored how risk-based regulatory scientific assessments of the impact of GMOs on human health and the environment can sometimes miss a broader set of social considerations beyond harm – including the purpose of the technology, who benefits from it, and the wider implications for food and farming systems

This context foreshadowed a public consultation launched by Defra in January 2021 on the regulation of genetic technologies in agriculture and aquaculture.[3] The consultation sought views on whether genome edited organisms should be regulated as genetically modified organisms (GMOs), anticipating the question of product safety in relation to farmed animals. It specifically focused on whether genetic changes which could have been introduced by traditional breeding should be excluded from the regulation of GMOs.

As important as these issues are, there is a risk that by focusing the debate on a narrow set of technical concerns misses issues of wider public interest.

The purpose of this dialogue was to create a space for members of the public to help frame the social and issues around genome editing and farmed animals in their own terms. The Nuffield Council on Bioethics commissioned Basis Social, in partnership with Bright Harbour, to conduct the dialogue.

Following a rapid evidence assessment and interviews with expert stakeholders, we ran three-online discussions between 15th Jun – 15th July 2021 with 41 members of the public. In the first session, people were invited to discuss their relationship with food and farming, before being introduced to the technology. We then asked them what they would like to learn more about, before running a 'question time' debate in session two, where people had the opportunity to discuss genome editing with a range of experts in the field. Finally, a range of applications were discussed – focused on disease resistance, increasing yields, improving nutritional value, and creating more docile animals - together with their social and ethical implications.

Participants were recruited from different backgrounds to shed light on the ethical issues surrounding GEFA from a range of vantage points, including their diet, whether they lived in urban, rural or coastal settings, their faith, demographic characteristics, and their attitudes toward genetic science.

Participants framed issues relating to genome editing in farmed animals across four distinct domains:

1. impact on humans (e.g., in terms of the quantity and quality of meat, human health, and cost of food)
2. impact on animals (e.g., in terms of animal welfare, dignity and animal rights)

3. impact on farming systems (e.g., in terms of impact on farmers and business owners, and the future of farming)
4. impact on nature and the 'natural order' (e.g., in terms of environmental impact; and humans' relationship with animals).

Importantly, rather than the focus the debate on the risks and benefits of the technology, the public were keen to consider the type of farming systems they wished to see developed. This vision moved away from intensive farming to a food system which was healthy, affordable, sustainable and had animal welfare at its heart.

The central question for the public in relation to genome editing was as follows: *does applying this technology take us closer to, or further away from, this vision for the future of food and farming*.

In this context, the public could see that there were applications of genome editing that could potentially address challenges in the farming system and tended to be more supportive of uses which help improve animal welfare and tackle diseases. They were less supportive of technologies that impacted on an animal's dignity – such as creating more docile animals that were less stressed about going to slaughter.

While applications were discussed in terms of their consequences and weighing up the benefits or harm that could come through genome editing, they were also discussed in terms of duties both to humans and other animals. As the dialogue progressed, the virtue of decisions and the moral character of our collective actions became more important.

The public were particularly concerned about a tension at the heart of the technology - fearful that the very improvements that might make animals more resistant to disease, may drive the further intensification of farming. Effective governance of genome editing in the public interest becomes critical in this context, and the development of a regulatory system that anticipates rather reacts to technological developments.

On questions of governance, there are several insights from the dialogue that are germane to the Defra consultation mentioned at the beginning of this article.

First, the public interest around genome editing in farmed animals is not predominantly about transgenic material. Such a framing of public debate risks missing the strong interest and desire that people have, to influence the way in which the food they consume is grown and reared

Second, the welfare standards in existing intensive farming systems were a very considerable concern for people, though one they felt they had limited power to influence. Moreover, positioning genome editing as an extension of selective breeding practices, which were seen as being part of intensive farming systems, did not provide an ethical basis for its use. People wanted technologies to drive sustainable changes to our farming system, not maintain (or worsen) the status quo.

Third, the transformative potential of genome editing did not sit easily with the idea of it being a "faster, better" extension of existing farming practices. Specifically, some of the claimed benefits of the technology (from the eradication of diseases, to feeding the planet) were not believed to arise from incremental changes that could have occurred naturally. Rather, genome editing in farmed animals was seen as powerful and invasive, and people wanted to know what the alternatives were. In this context, genome editing technologies should not be looked at in isolation, but rather different as part of a suite of different pathways towards a new future of farming.

Fourth, the current state of our food system was a source of much disquiet for people. Food waste, inequality, the obesity crisis, the environmental impact including water, land use and greenhouse gas emissions, the treatment of animals were part of a wide range of concerns pointing to a systemic problem concerning how we feed ourselves – an issue seen as likely to worsen with a growing population and the climate crisis.

In this content, leaving such a powerful technology to be shaped by market forces, while only regulating downstream risks in terms of harm to health and the human environment, was a significant concern. Rather, government needs to help guide and control the technology to ensure its use is focused on the issues that matter most to people.

Deliberative processes, like this public dialogue, show how such a debate can develop reflectively, taking account of people's different interests and perspectives, and the challenges that face them collectively.

Through the dialogue, we saw that people have a keen interest in food and farming, and the values that underpin it. They want to change rather than perpetuate an unsustainable food system. And while safety is important, its only part of a deeper discussion that people are willing and able to contribute to.

The first generation of GM technologies led to those on different sides of the debate talking past each other. In genome editing, there is the promise of a more sophisticated and precise technology, that opens new possibilities to address challenges to the food and farming system. These challenges have implications for everyone, in the UK and beyond, as well as intergenerationally. The quality of the debate we have in the coming years will not only determine the future of this generation of biotechnologies, but also the direction for our future food systems, our farming industry, and the wider environment. Creating the space for the public to be at the heart of such debates may help to guide the effective governance that will be critical for its success.

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# GENOME EDITING AND THE FUTURE OF FARMING

John Dupré

**Genome editing (GE) is a transformative technology across the life sciences. In fundamental research it is already omnipresent. It opens up a range of exciting possibilities for medicine. It is possible, even likely, that what we eat will, in a relatively short time, be affected by this technology. This technology raises a wide range of social and ethical issues, which is why the Nuffield Council on Bioethics has published a series of reports on the topic. I had the privilege of chairing the working group that produced their just published report on genome editing and farmed animal breeding[1], which is the occasion for this article.**

When earlier technologies for modifying genomes came to public attention in the 1990s, there was a great deal of concern about health risks to consumers. The scientific consensus now, as then, is that these concerns were exaggerated. While any significantly new food should be thoroughly tested, there is little reason to suppose that genetic modification or GE present any risks not present in traditionally bred foods. However, there were also more legitimate concerns about the potential effects on the wider food and farming systems of major technological innovation generally, and these are the concerns that remain vital in the context of contemporary GE. Here I shall mainly be concerned with what GE can and cannot be expected to make possible. I shall return in conclusion to the concerns it raises.

GE is a technology that was first developed in the 1990s, but has taken off in the last decade due to the development of the CRISPR-Cas9 technique. It is an extremely precise method of bringing about changes in the sequence of genomes, most simply disabling genes but, increasingly, by making determinate changes in the sequence of functional genes. Compared to earlier methods of genome editing, CRISPR-Cas9 is a great deal easier and cheaper, which has led to its widespread use in laboratories in the biological community.

I won't try to explain in any detail how CRISPR-Cas9 works; the details can be found in numerous sources.[2] Basically, a precisely engineered molecule cuts the DNA sequence in an exactly determined place, and then recruits innate repair mechanisms to join the severed sequence in a specified way. I shall assume here that the ability to make precise changes in DNA sequence is unlimited. This is, of course, an exaggeration, and this endpoint may never be fully achieved. Nevertheless, it is increasingly reasonable to assume that we will get close to this goal, and in the not very distant future.

What is less widely found, is a proper understanding of what can and cannot be expected from such a degree of control of the genome. The genome is still often thought of as a kind of blueprint in which particular parts ("genes") direct the development of particular parts of the organism's body or behaviour. This, in turn, often fuels a wildly unrealistic picture of what genome editing might be able to achieve, most famously the "designer baby", with maximal, intelligence, beauty, athletic and artistic abilities, and so on, drawn by the expert geneticist on the genome as a musician might produce a melody on a keyboard.

But the vision driving this picture is entirely mistaken.[3] The process of development is vastly more complex than this picture suggests, and involves complex interactions between different genes, other molecules and structures in the cell, and even grosser features of the environment up to and including the social. The function of many genes is to direct the production of one or many proteins, but this is causally far downstream from most whole organism traits. The relationship between genes and organism traits is sometimes referred to as "many-many". A typical trait is affected by many genes, and a gene affects many traits. Hundreds or thousands of genes are said to be correlated with intelligence. But the alleged effects are miniscule and changes in any of these genes are almost certain to affect other

traits in ways that may be highly undesirable.

For various historical reasons it has become common to refer to genes by reference to a trait to which they are related. And while there are technical senses in which it is correct to refer to a gene which, on average, produces a 0.1% increase in intelligence as a gene for intelligence, the usage is unfortunate, as it tends to reinforce the misunderstanding of the genome just described.

There are, however, cases in which a trait can be directly connected with a genetic basis. Perhaps the commonest such class is that of a genetic defect. Cystic fibrosis is a disease caused by a wide range of abnormalities in the gene for a protein called CFTR, which stands for Cystic Fibrosis Transmembrane Conductance Regulator. Despite its misleading name, reflecting only the fact that the protein and the gene were both discovered in the search for the cause of cystic fibrosis, the protein is not the cause of the disease; errors in the protein, traceable to errors in the gene, are the causes of the disease. GE holds out great hope for therapies for genetic diseases caused by malfunctioning proteins derived from faulty genes. It is of much less relevance to farming, whether of plants or animals, since we are not generally disposed to keep animals, still less plants, alive, if they have serious genetic malfunctions.

Sometimes the effect of a defect can be a quite specific in the organism. There are mutations in cattle that cause the loss of horns, so called "polled" cows. This is presumably a defect in wild cattle, as no wild populations are polled. But in domestic cows it is an advantage as it prevents cows from damaging one another or their caretakers. For this reason, most cows have their horns removed in processes that are extremely painful and distressing for the animal. GE holds out the hope of rapid introduction of this trait into domestic cattle, thereby preventing a great deal of bovine suffering.[4]

Sometimes disabling (or "knocking out") a gene can have beneficial effects. An example is provided by the extremely costly viral disease of pigs, porcine reproductive and respiratory syndrome (PRRS). Research at the Roslin Institute in Edinburgh has developed a pig with a disabled gene for a protein called CD163 that is resistant to this virus.[5] CD163 is a protein in the surface of the cell that gives access to the PRRS virus. Although the protein has other functions, it appears that lack of a working CD163 does the pig no detectable harm; presumably the cell finds other ways to serve these other functions. So in the presence of the PRRS virus, the defective gene provides a distinct benefit.

The potential targets for GE are limited by the nature and role of the genome, but may nonetheless be highly significant. Any pig farmer would welcome a PRRS-resistant pig, and it is likely that to the extent that legislation permits, and assuming no serious deleterious effects are discovered, most of the pigs in the world will be derived from pigs thus edited within a decade or two.

The serious worries with such a development are not with potential risks to the safety of bacon, still less with interference in the natural state of the pig—an obscure notion very difficult to interpret after millennia of domestication. One real worry, echoing concerns over GM crops about the power of big biotechnology companies, is where the economic power will fall in the value chains deriving from this "improved" animal. It is interesting that the research commissioned by the Nuffield Council into public attitudes in this area found much more interest in where the benefits would land than in the supposed "naturalness" of the technology.

But the biggest concern, as stressed in the recent Nuffield Council report, is that pig farming is already an industry in which massively intensified farming systems often produce conditions of extremely low animal welfare. The report concludes that many parts of current animal farming are morally indefensible and unsustainable. The most important point with GE, as with any other biotechnology, is that it be implemented in the context of a well-articulated vision of the future of animal farming. What must be avoided is using the technology to sustain and entrench unacceptable farming systems or even, indeed, exacerbate them by enabling even greater stocking numbers. The technology has great possibilities, but these can only be realised in the context of a wide-ranging vision and appropriate regulation.


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# GENOME EDITING AND FARMED ANIMAL BREEDING: THE NUFFIELD COUNCIL REPORT

Pete Mills
Assistant Director, Nuffield Council on Bioethics

**The latest report from the Nuffield Council on Bioethics - an independent, influential body that advises policy makers and others on developments in biosciences and healthcare - explores important questions about the likely effect of the adoption of new breeding technologies across the farming industry.**

The report *'Genome editing and farmed animal breeding: ethical and social issues'* was prompted by the emergence of genome editing (the precise, targeted alteration of a DNA sequence in a living cell), but the Nuffield Council takes a broader prospective genome editing technologies among other breeding techniques. The report sets these breeding techniques in the context of five 'societal challenges' currently facing the food and farming system globally; and it places these challenges at the outturn of a long and complex history of animal husbandry and domestication by humans.

Animals and humans have lived alongside each other in established agriculture since the neolithic age, for approximately 12,000 years. This domestic arrangement has given rise to a number of co-adaptations that have left their mark on the way in which societies and economies are arranged, as well as on the behaviours and biologies of those involved. But it was the selective management of animal breeding in the modern period, contemporary with industrial development, mechanisation and demographic shifts, that led to a step change in 'genetic gain' among many domestic species (even while the underlying mechanisms for the inheritance of traits remained unknown – *see the piece by Professor Dupré in this issue*). As burgeoning human and animal populations became increasingly dependent on emerging agri-food supply chains, the very success of agricultural production also became the source of its greatest challenges.

According to the Nuffield Council report, the challenges that the food and farming system now faces are of at least five kinds.

**1 Animal welfare and health:** achieving acceptable standards of animal welfare across the farming industry in the face of demands for more and cheaper products. This is more than just ensuring that animals are healthy, although maintaining the health of some breeds of animal in some farming systems is also a significant challenge.

**2 Human health:** linked to the health of animals is the health of people who may be affected by infectious disease, the emergence of new zoonotic diseases and the effects of diet. Indirectly, human health could be affected through the emergence of antimicrobial resistant bacteria encouraged the use of antimicrobials in agriculture.

**3 Demand and supply:** a healthy diet requires sufficient, affordable and nutritious food to reach consumers through effective agri-food supply chains.

**4 Social, political and cultural challenges:** supply chains can only operate effectively in accommodating cultural, social and political conditions, for example where there is confidence in food safety.

**5 Ecosystems and environment:** producing animals for food has contributed significantly to deforestation, biodiversity loss and climate change. These five areas of challenge are evidently interconnected but not necessarily aligned – ameliorating one set of conditions (animal welfare, say) may aggravate others (environmental impact or level of supply, for example). While the global food and farming system is unsustainable on its present course, no intervention

comes without some associated cost.

New breeding technologies have been claimed to offer responses to all these challenges in one way or another. The applications that have been researched to date are studiedly benign. Breeding inherently hornless dairy calves to spare them the harm of having their horns (or horn buds) surgically removed was one early demonstration. Creating inherent resistance to devastating viral diseases, such as those affecting pigs, or to those with the potential to cross to humans (such as avian flu), or producing animals that fare better in hot climatic conditions also seem desirable at first blush. However, there is no magic bullet. No single technology – and certainly no breeding technology – will end hunger, conquer disease or abolish animal cruelty. And many breeding goals are obstructed, for the time being at least, by biology: by the genetic complexity of the traits of interest, which makes them difficult to prescribe through genome editing. There are reasons though, for caution. Where genome editing can produce genetic gains, it could be transformative - accelerating the enhancement of traits in previously unachievable directions. And there is no clear sense, as yet, of the limits of its potential.

According to the Nuffield report, it is ethically important not only to pose the question of the direct effects of implementing new breeding technology in a particular setting; but also to ask what the likely effects of the adoption of new breeding technologies across the farming industry will be. This question is relevant to all new technologies including genome editing – hence the reason to place genome editing among, rather than apart from, other breeding practices, such as conventional selective breeding and genomic selection – but it may be relevant to them in peculiar ways. If powerful new breeding technologies are to be introduced there is an ethical requirement, according to the Nuffield Council, to ensure that:
1) they are not used to give rise to animals that may simply endure poor welfare conditions without ostensible, associated health impacts,
2) that they do not lead to generations of animals that are constitutionally incapable of living lives of acceptable quality, and
3) that their introduction does not support or entrench damaging farming practices.

In relation to the implementation of new breeding practices three things are needed:

- clear and meaningful standards for responsible and sustainable breeding (underpinned by research)
- information about what is happening on farms to know how well those standards are being met; and
- encouragement and regulation to steer breeders, farmers and retailers towards a desirable vision for the food and farming system and to guard against overreaching or externalising social costs.

At present, prospective genome editing technologies face the hurdles of retained EU regulations on the release and marketing of genetically modified organisms (GMOs). But if those hurdles are removed, as the Government is proposing, and biotechnology is given a clearer run, it will be important to know that regulation can keep up. This is not a reason to support a more burdensome form of product safety regulation than is necessary, but to recognise that product safety regulation is only one relevant element of governance. According to the Nuffield Council report, a coherent set of policies should inform governance measures that operate across the supply chain, from breeders to retailers, animated by a clear vision of the kind of food and farming system that it is intended to bring about.

The Nuffield Council undertook this inquiry in the recognition that genome editing applications in livestock and aquaculture were relatively near term, raised distinctive and ethically important issues of welfare but, despite this, had been relatively little discussed in the public domain. This made their prospects of acceptance seem less certain, given the significant public interest in previous generations of biotechnologies, and the potential for public debate. The Nuffield Council has recommended action to initiate early, open and informed dialogue with the public in anticipation of this new generation of biotechnologies, (A rapid online public dialogue, commissioned by the Nuffield Council, has demonstrated the range of considerations that citizens brought to bear when thinking about this– *see the piece by Dr Battachary in this issue*.) Now that the Nuffield Council's in depth report is published, it will be continuing its work in this area by engaging with others to take forward its recommendations, including through a major new public dialogue initiative in partnership with the Biotechnology and Biological Sciences Research Council and with the support of Sciencewise (the programme funded by UK Research and Innovation that aims to ensure policy is informed by the views and aspirations of the public).

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# HOW CUTTING EDGE NEURO SCIENCE IS CHANGING LIVES TODAY – A CASE STUDY

Matt Eagles

**I didn't chose to have Parkinson's, a chronic degenerative neurological disease affecting over 145,000 people in the UK and the fastest growing neurological condition in the world, rather it chose me but I rather wish it hadn't. I wanted to be the next Jacques Yves Cousteau and become a world famous Marine Biologist saving sharks in the oceans. Being diagnosed with Parkinson's on my seventh birthday in 1975 rather scuppered my plans.**

I am now 53, entering my 46th year living with Parkinson's

Parkinson's disease affects every aspect of my daily life from getting up in the morning and trying to balance in the shower then nicking myself shaving, getting dressed, putting my socks on in particular. Going downstairs to make my wife a cup of tea and throwing milk and sometimes the whole drink all over the work surface and myself because my arms suddenly twitch.

Doing up shoelaces is a nightmare and trying to eat sometimes just becomes impossible as I cannot get the food on the cutlery to put it in my mouth. Trying to type on a computer keyboard or having a conversation on a mobile phone without cutting the person off at the other end with my ear and even trying to keep a book still while reading and trying to relax all everyday tasks that people take for granted.

I even have to carefully time when I go for a comfort break… I'm not going into detail.

Household furniture is not immune either I have wriggled around so much due to dyskinesia I have had three dining chairs literally collapse beneath me – a cause of much mirth I might add to my wife and my 19 year old step son !!

This is my everyday but it's not all plasters and kitchen roll there are positive experiences to be had.

My symptoms began in the mid 1970's. On a holiday to Cornwall I experienced a frozen left shoulder and a strange gait meant I walked on my tiptoes and I couldn't balance. A neighbour first noticed when he tried to take a picture of me and asked me to stand up straight, I couldn't and bent over, almost double with my hands just above my knees as I fought to get my balance. Years later I found the picture stuffed in a kitchen drawer and studied it, I hadn't realised how bad things had got.

My headmaster in primary school noticed I couldn't stand still in school assembly and during swimming lessons my legs sank as if they had added weights to them and I was trying to swim standing up. Perhaps the most poignant and scary moment though was when my mum was trying to cut my toe nails on the bowl of the toilet and I kept on grabbing for the towel rail which was loose at the best of times and was threatening to fall off completely She didn't believe me when I said I couldn't balance and slapped my leg as tears rolled down my face.

Despite 'knowing' I had idiopathic Parkinson's, at least according to my digital health records, which I only found out 6 years or so ago, my medical team proved my symptoms

Matt newly diagnosed

were not as a result of a brain tumour or indeed juvenile arthritis and then were to spend many years trying to disprove I had indeed got a juvenile form of Parkinson's.

I spent many weeks travelling to and from Booth Hall Children's Hospital. During my appointments. I used to sit on a plastic chair swinging my legs back and forth, my eyes gazing round the room but not seeing anything, my mind thinking I would rather be elsewhere and my reverie only broken by the voice of my mother saying, "Matthew, the doctor is talking to you." I didn't really understand why I was there in the first place apart from the fact for some unknown reason I couldn't balance properly and kept falling over.

The regular out-patient appointments quickly turned into in-patient stays which lasted for weeks, as the medical staff struggled to identify the strange symptoms I was exhibiting. Monday to Friday I spent on the ward being tested and assessed, and at the weekends I was allowed home. Many of the beds on the wards were in individual rooms separated with glass walls giving a degree of privacy – but it didn't cut out the cries of angst from young children in adjacent rooms further along the corridor, frightened and alone. Many a night after watching Coronation Street I had a glass of milk and cried myself to sleep.

A breakthrough in communication on my part came after visiting a doctor at the Manchester Royal Infirmary. He offered me 50p if I agreed to try a new medication – I agreed and quickly stuffed the coin into my pocket! * I have now taken over 220k units of medication and would be a wealthy man if I had 50p for every time I took my meds. It would certainly improve adherence!

The medication I was prescribed was L-dopa, Sinemet, a drug proven to help elderly patients cope with the on-set of Parkinson's Disease. It worked to an extent, but as I entered my teens I was referred away from the safety net that I had got used to at Booth Hall to a hospital in London that specialised in Movement Disorders.

Under the specialist care of Professor David Marsden and subsequently Professor Niall Quinn, I became the patient of choice in teaching seminars which included invited doctors and students from all over the world. I knew the drill, I knew the questions they were going to ask and I knew the tests they would perform. I actually felt quite smug and wore a huge grin during these seminars, happy in the knowledge that I knew more than them about my condition, that I was the expert.

Any medication that came on the market that my team thought would improve my quality of life I was put forward for.

In the early 2000's after completing a device competency course known as the Apomorphine Challenge whilst an inpatient I began using an Apomorphine pump. A drug delivery system which involved a syringe driver constantly delivering the medication into my system via a tube and canula I inserted into my tummy. It was uncomfortable. It made me feel sick all the time and the drug itself stained everything it touched a dark green colour.

Eighteen months later and with the side effects of extreme startle and Viagra esque effects at unwanted moments becoming unbearable It was time to move to something else.

In 2004, aged 34 and with the amount of medications still rising and other options exhausted, the possibility of having Deep Brain Stimulation surgery was discussed. This was a big deal. It involved having brain surgery whilst you were awake with two holes drilled through your skull and electrodes placed at exactly the right co-ordinates that were determined by an MRI scan. Then once the electrodes were in place a second surgery would take place to attach a stimulation device underneath the collarbone akin to a heart pacemaker. The surgery was new and ground breaking but like any brain surgery not without risk. But I trusted my specialist implicitly, such was the relationship we had built up over my then twenty years of attending the hospital.

Deep Brain Stimulation Surgery

I fainted during the preparation stages of the operation and ended up having both procedures done under general anaesthesia.

The surgery was a success and its effects were life-changing. I was able to get up in the middle of the night and go to the bathroom without crawling on the floor and weeing in a chamber pot. It gave me my dignity back!

Fifteen years on I have now had my stimulator battery replaced twice and now I have a rechargeable battery which means I have to charge my battery everyday… not just when I go on holidays. My oral medication has also been significantly reduced.


Deep Brain Stimulation battery scar

None of this would have been possible without significant investment in Neuro Science research and for this I will always be eternally grateful.

Deep Brain Stimulation is an incredible procedure and the technology is improving exponentially with rechargeable batteries, devices that use AI and machine learning to produce to automatically adjust stimulation settings to achieve the best possible results.

The same techniques which target different areas in the brain have been successful in treating, depression, tourettes, dystonia, cluster headaches and research continues at pace.

Without DBS I would almost certainly be wheelchair bound requiring 24 hour care with it although I still require significant assistance I am able to continue to work and make the most of my life – a positivity activist who can Wingwalk, Zipwire, Tandem Skydive and Absail.

I am Head of Patient Engagement for Havas Lynx Group representing the patient voice for all conditions. I am a global patient champion for Parkinson's and I am the Co-Founder of Parkylife – The Brighter Side of Parkinson's.

www.parkylife.com

I owe a huge debt of gratitude to so many people and now it's my time to give back what I can to science. □

Parkinson's UK, Lambeth Palace 2021

# WHY NEUROSCIENCE MATTERS

Dr Anne Cooke
CE British Neuroscience Association

Professor Tara Spires-Jones
UK Dementia Research Institute
Group Leader and Deputy
Director of the Centre for
Discovery Brain Sciences at the
University of Edinburgh

**World-leading UK neuroscience research can help us meet tomorrow's societal challenges. The science of the nervous system is essential for understanding our humanity, preventing and treating neurological and psychiatric disorders, and keeping the UK at the forefront of cutting-edge research.**

What defines humanity? A question that certainly spans beyond the sciences; however, understanding some of the key features of being human - such as how we think, move, feel, learn and remember - are firmly within the purview of neuroscience.

The brain and wider nervous systems are phenomenally complex organs that bring information from the world into our bodies, interpret these signals from the environment, and generate behaviour. There are over 100 billion neurons connected by 100 trillion synapses in your brain alone. We still do not fully understand how this network functions, which is one of the important remaining frontiers of knowledge for humanity.

In addition to understanding ourselves and advancing knowledge, neuroscience is essential for defeating brain and nervous system disorders. Neurological disorders are one of the leading causes of disability globally and over 1 billion people are living with mental health disorders.[1] This is an enormous burden for people living with these disorders and also for society at large. Brain disorders are estimated to cost over 100 billion pounds per year in the UK alone.[2]

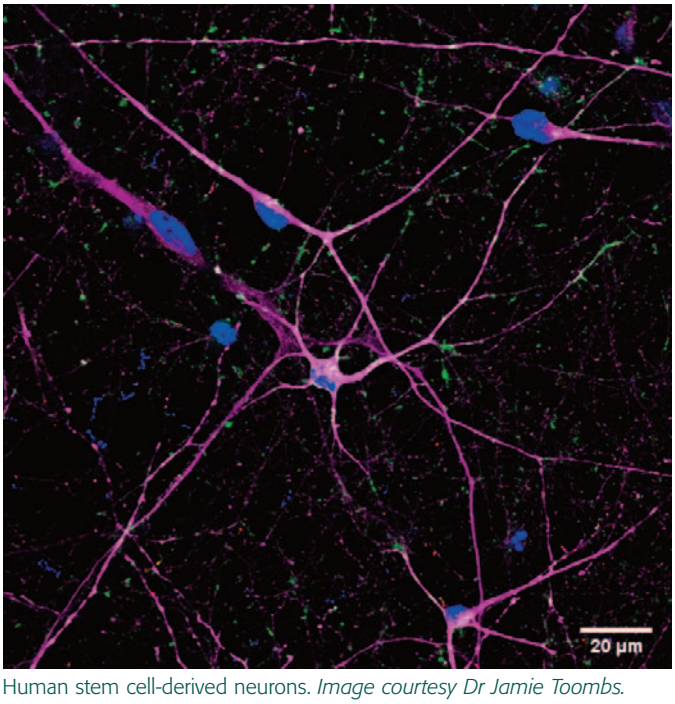
Neuroscience also keeps the UK at the forefront of cutting-edge research in both the biomedical arenas and in technologies. Advances in neurotechnology and artificial intelligence abound in the UK.

One example is the UK Dementia Research Institute's Minder programme[3] that combines smart home technology and artificial intelligence with clinical monitoring. This research is conducted in collaboration with local social care teams, so that neuroscience advances can help people living with dementia today.

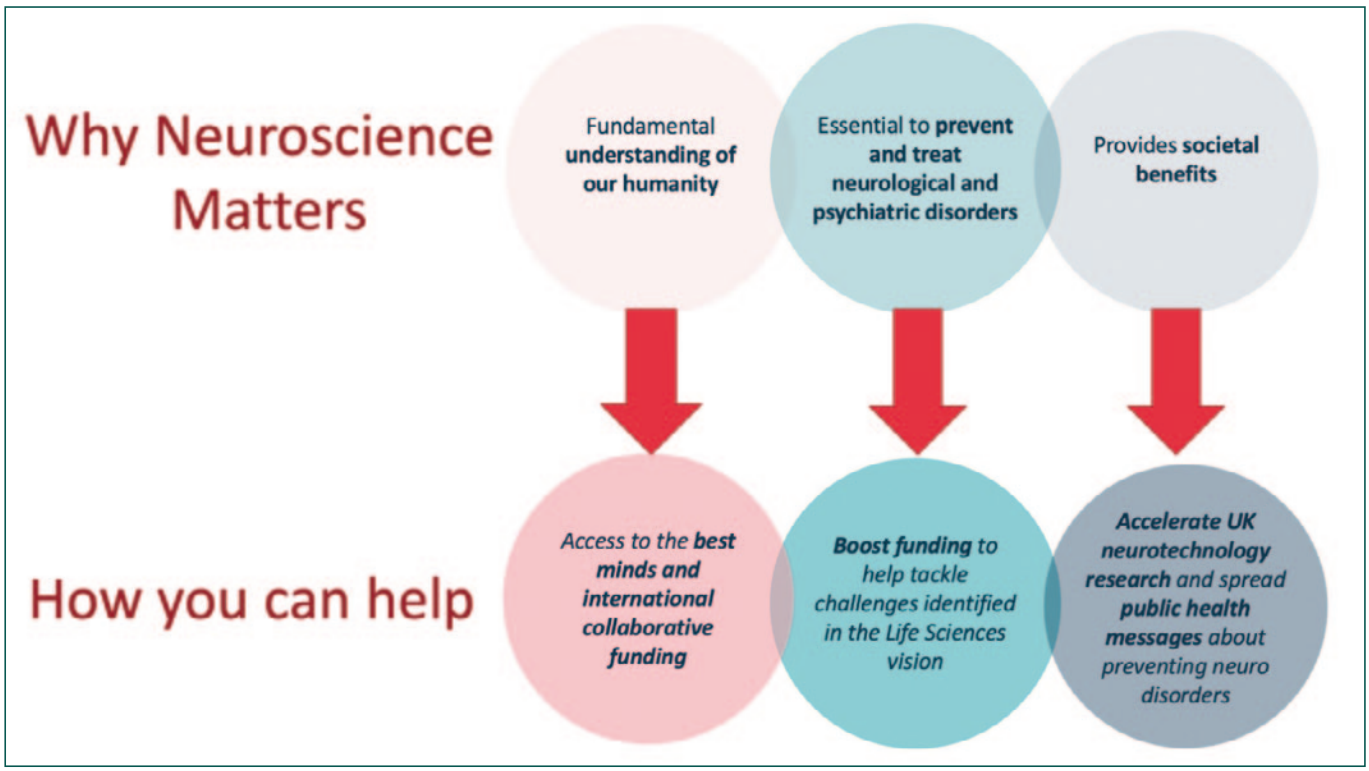
Neuroscientists face several challenges in our goals to understand ourselves and defeat brain disorders.

The complexity of the nervous system makes neuroscience inherently highly challenging. Despite an explosion of knowledge over the last century, we are just scraping the surface when it comes to understanding many of its fundamental functions. To rise to this challenge, we need to drive advances in basic, preclinical, fundamental neuroscience research.

We also face the challenge of communicating neuroscience findings to wider society if we are to harness the results for reducing the burden of brain diseases. Based on neuroscience research over the past few decades, we estimate




Human stem cell-derived neurons. *Image courtesy Dr Jamie Toombs.*




that more than a third of dementia cases could be prevented by modifying lifestyle factors including reducing smoking, keeping active, and staying in higher education. [4, 5]

One of our biggest challenges is that our field is chronically under-funded compared to other biomedical fields. Let's take dementia research as an example. In 2012, for every £10 in health and social care costs for dementia, dementia researchers eceived £0.08 funding; whereas cancer research received £1.08 funding per £10 costs i.e. a funding rate thirteen times higher for cancer than dementia.[6]

Due to this underfunding, neuroscience research in the UK is not as attractive to up-and-coming researchers meaning there is a "brain drain" (pun intended) of talented researchers who pursue their careers in countries with a better funding landscape.

To overcome these challenges, neuroscientists need support. We need government and charities to help to close the funding gap. We need regulatory bodies that are engaged with neuroscientists right from early stages of discovery, so that innovations can be meaningfully assessed with relevant measures and made available to patients without delays. We need immigration policies that are welcoming to the best minds and facilitating international collaboration, and we need help disseminating public health messages that can help people reduce their risks of brain diseases today.

A lynchpin connecting all these stakeholders – neuroscience, government, the general public and more – is the British Neuroscience Association (BNA). This vibrant and progressive community of 2,500 members brings together professional neuroscientists (those practicing neuroscience in research, clinical or commercial settings) and provides critical routes of communication with policymakers, government and wider society.

Examples include the BNA's 'Building Bridges Between: Academia and Industry' initiative, which facilitates greater connection and understanding between sectors which can sometimes feel worlds apart; the 'Credibility in Neuroscience' campaign that engages with policymakers to ensure that the environment in which neuroscientists work supports the best possible neuroscience research; and the 'Bring Your Own Brain' event, enabling members of the public to have two-way conversation with neuroscientists about neuroscience research.

The good news is that neuroscience research **works**.

Despite rapidly growing numbers of people with dementia due to our ageing population, we have already seen a decrease in dementia incidence (that is the risk of any given individual developing dementia)4 likely due to improvements in cardiovascular health, one of the modifiable risk factors discussed earlier.

2021 also saw the first British baby with spinal muscular atrophy treated with a new drug discovered by neuroscientists.[7]

Together, neuroscience researchers, government, charities, clinicians, the commercial sector and wider stakeholders can make an enormous difference to society.

**References**

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2. Fineberg, N. A. et al. The size, burden and cost of disorders of the brain in the UK. J Psychopharmacol 27, 761–770 (2013).
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# HOUSE OF COMMONS SELECT COMMITTEES

## BUSINESS, ENERGY AND INDUSTRIAL STRATEGY COMMITTEE

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

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

**Membership:**

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

**Inquiries:**

- Net zero and UN climate summits - Opened 6 March 2020. Government response published 17th May 2021.
- The impact of coronavirus on businesses and workers - Opened 13 March 2020. Government response published 19th May 2021.
- Delivering audit reform - Opened 18 March 2020.
- Work of the Department and Government Response to coronavirus - Opened 14 April 2020
- Post-pandemic economic growth - Opened 3 June 2020.
- Post-pandemic economic growth: Industrial Strategy – Opened 23rd July 2020. Government response published 24th September 2021.
- Post-pandemic economic growth: Levelling up local and regional structures and the delivery of economic growth – Opened 24th July 2020. Report published 3rd December 2021.
- Forced Labour in UK value chains – Opened 18th September 2020. Government response published 8th July 2021.
- Decarbonising heat in homes – Opened 2nd October. Accepting written evidence until 13th November 2020.
- Business and Brexit preparedness – Opened 17th November 2020.
- Mineworkers' Pension Scheme – Opened 18th March 2021. Government response published 5th July.
- Findings of the Report of Climate Change Assembly UK – Opened 19th April 2021. Government response published 9th September.
- Liberty Steel and the Future of the UK Steel Industry – Opened 27th April 2021. Report published 5th November 2021.
- Net Zero Governance: Opened 23rd June 2021.
- Post-pandemic economic growth: State Aid and Post Brexit Competition Policy. Opened 23rd September.
- Energy National Policy Statements – Opened 3rd November 2021
- Energy Pricing and the future of the Energy Market – Opened 8th December 2021. Written evidence. Deadline 31st January 2022.

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

## ENVIRONMENTAL AUDIT COMMITTEE

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

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

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

**Membership:**

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

**Inquiries**

- Preparation for COP26 - Opened 17 March 2020.
- Greening the post-Covid Recovery - Opened 13 May 2020. Government response published 22nd June 2021.
- Energy Efficiency of Existing Homes - Opened 18 May 2020. Government response published 13th May 2021.
- Biodiversity and Ecosystems – Opened 13th July 2020. Report published 30th September 2021.
- Fixing Fashion follow up – Opened 6th October 2020
- Technological Innovations and Climate Change: Tidal Power –Opened 9th November 2020

- Green Jobs – Opened 17th November 2020. Report published 25th October 2021.
- Water Quality in Rivers – Opened 8th December 2020.
- Technological Innovations and Climate Change: Community Energy – Opened 19th February
- Sustainability of the built environment – Opened 25th March 2021
- Technological Innovations and Climate Change: Supply chain for Battery Electric Vehicles – opened 4th May 2021
- Mapping the path to net zero: Opened 25th June 2021.
- Net zero aviation and shipping: Opened 20th July 2021.
- Carbon border adjustment mechanism: Opened 24th September 2021.
- Technological Innovations and Climate Change: Negative emissions and Technologies – Opened 28th September 2021.
- Aligning the UK's economic goals with environmental sustainability – Opened 29th November 2021.

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).

### Membership:

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

### Inquiries

- UK Science, Research and Technology Capability and Influence in Global Disease Outbreaks. – Opened 20 March 2020. Government response published 14th May 2021.
- The role of technology, research and innovation in the COVID-19 recovery – Opened 24th July 2020.
- Coronavirus – Lessons Learnt – Opened 6th October 2020. Report published 12th October 2021.
- The Role of Hydrogen in Achieving Net Zero – Opened 4th December 2020.
- UK space strategy and UK satellite infrastructure – Opened 23rd April 2021.
- Reproducibility and research integrity. Opened 22nd July 2021. Closed 30th September 2021.
- Diversity in STEM – Opened 22nd November 2021. Written evidence. Deadline 14th January 2022.
- The right to privacy: digital data – Opened 16th December 2021. Written Evidence. Deadline 28th January 2022.

## HEALTH AND SOCIAL CARE COMMITTEE

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

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

### Membership:

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

### Inquiries

- Workforce burnout and resistance in the NHS and social care – Opened 30th July 2020. Published 8th June 2021.
- Coronavirus – Lessons Learnt – Opened 6th October 2020. Report published 8th October 2021.
- Children and young people's mental health – Opened 29th January 2021. Report published 9th December 2021.
- Treatment of autistic people and individuals with learning disabilities – Opened 3rd February 2021. Report published 13th July 2021.
- Supporting those with dementia and their carers – Opened 12th May 2021. Published 29th October 2021.
- Cancer services: Opened 6th July 2021.
- Clearing the backlog caused by the pandemic – Opened 20th July 2021.
- NHS litigation reform: Opened 22nd September 2021.
- The future of general practice – Opened 16th November 2021.
- Workforce: recruitment, training and retention in health and social care – Opened 23rd November 2021.
  Written evidence. Deadline 19th January 2022.
- The impact of body image on physical and mental health – Opened 1st December 2021.
  Written evidence. Deadline 29th January 2022.
- Omicron variant update – Opened 10th December 2021.

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

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# 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.

**Members:**

The Lord Patel KT, Crossbench, Chair
The Baroness Blackwood of North Oxford, Conservative
Viscount Hanworth, Labour
The Lord Holmes of Richmond MBE
The Rt Hon. the Lord Kakkar, Crossbench
The Lord Krebs, Crossbench
The Baroness Manningham-Buller LG DCB, Crossbench
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The Baroness Rock, Conservative
The Lord Sarfraz, Conservative
The Baroness Sheehan, Liberal Democrat
The Baroness Walmsley, Liberal Democrat
The Baroness Warwick of Undercliff, Labour
The Lord Winston, Labour

**Inquiries**

- The science of COVID-19 Opened 7 May 2020.
- The Contribution of Innovation Catapults to Delivering the R&D Roadmap – Opened 11th November 2020. Government response published 6th April 2021.
- Role of batteries and fuel in allowing Net Zero – Opened 3rd March 2021. Report published 27th July 2021. Government response published 27th September 2021.
- Nature-based solutions for climate change: Opened 9th June 2021. Deadline 30th September 2021.

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

# PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

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

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

**POSTnotes produced since September 2021 were:**

659: Upskilling and retraining the adult workforce
658: Conversion Therapy
657: Advances in vaccine technologies
656: Smart Cities

**POSTbriefs are responsive policy briefings based on mini-literature reviews and peer reviews. Those produced since September 2021 were:**

44: reducing the whole life carbon impact of buildings
43: Pesticides and health
42: Sustainable land management: managing land better for environmental benefit

**POST has also continued rapid response articles that summarise the research around COVID-19:**

Long COVID: The long-term health effects of COVID-19
COVID-19: The Omicron Variant
Impact of COVID-19 on Early Childhood Education & Care

**Ongoing and future projects approved by the POST Board:**

## BIOLOGY AND HEALTH

**In production**

Reform of the Mental Health Act impacts on children

Age assessments of children in immigration policy
Parliament-research knowledge exchange mechanisms around the world
Disorders of consciousness
Testosterone and sports performance
Preventing zoonotic diseases

## ENERGY AND ENVIRONMENT

**In production**

Low-carbon hydrogen use
Biodiversity and financial risks
International shipping and emissions
Genome editing and the future of food
Managing soils for carbon and plant productivity
Reducing agricultural pressures on freshwater ecosystems
Geothermal energy resources
Sustainable mining
Peat land restoration

## DIGITAL AND PHYSICAL SCIENCES

**In production**

Sharing public sector data
Energy consumption of computing

## SOCIAL SCIENCES

**In production**

Innovation in adult social care
Invisible disabilities
Remote and flexible working

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

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

**Head of POST**

- Oliver Bennett MBE

## PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY

Houses of Parliament
Westminster
London SW1A 0AA □

# HOUSE OF COMMONS LIBRARY

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

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

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

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

### Coronavirus: Covid-19 booster vaccines frequently asked questions

Published on 14 December 2021, CBP-9332
These briefing addresses commonly asked questions about the roll-out of the Covid-19 booster vaccine.

### National Food Strategy and public health

Published on 14 Dec 2021, CDP-2021-0213
A briefing for a debate in Westminster Hall on 15 December 2021 on the National Food Strategy and public health.

### Abortion in Northern Ireland: recent changes to the legal framework

Published on 8 December 2021, CBP-8909
This briefing provides an overview of how the law on abortion in Northern Ireland has changed in recent years.

### Medical use of cannabis

Published 8 December 2021, CBP-8355
This briefing provides an overview on the change in the law, debate on medicinal cannabis products and the Medical Cannabis (Access) Bill

### Treatment of sickle cell

Published on 06 Dec 2021, CDP-2021-0209
A briefing for a debate in Westminster Hall on 8 December 2021 on treatment of sickle cell.

### Allocations to UK-EU fisheries following the UK's departure from the EU

Published on 29 Nov 2021, CDP-2021-0202
A briefing for a debate in Westminster Hall on 30 November 2021 on allocations to UK-EU fisheries following the UK's departure from the EU.

### Empowering community energy schemes

Published on 29 Nov 2021, CDP-2021-0200
A briefing for a debate in Westminster Hall on 30 November 2021 on empowering community energy schemes

### Environment Bill 2021-22: Lords amendments and "ping pong" stages

Published on 15 Nov 2021, CBP-9345
This briefing looks at how the Bill has changed following Lords stages and ping pong. The Bill has received Royal Assent and is now the Environment Act 2021.

### E-petition debate: ban raw sewage discharges

Published on 12 Nov 2021, CDP-2021-0191
A briefing for a debate in Westminster Hall on 15 November 2021 relating to sewage discharges

### Green Belt

Published on 29 Oct 2021, SN00934
This briefing examines some of the concern and controversy about the Green Belt and discusses how the white paper Planning for the Future treats it. It applies only to England.

### Tackling the digital divide

Published on 29 Oct 2021, CDP-2021-0175
A briefing for a debate in Westminster Hall on 4 November 2021 on tackling the digital divide.

### UK's Climate Progress: the Committee on Climate Change's 2021 Progress Report

Published on 19 Oct 2021, CDP-2021-0164
A briefing for a general debate in Westminster Hall on 21 October 2021 on the UK's Climate Progress: the Committee on Climate Change's 2021 Progress Report

### Animal Welfare (Kept Animals) Bill

Published on 19 Oct 2021, CBP-9229
This briefing provides an overview of the proposed measures in the Animal Welfare (Kept Animals) Bill, along with background on the issues it aims to address.

### The energy price crunch 2021

Published on 13 Oct 2021, CBP-9340
This paper sets out the causes of the price rise, impacts in the UK, and possible implications for UK energy policy.

### Climate change: an overview

Published on 12 Oct 2021, CBP-8666
A collection of overarching climate change-related parliamentary briefings and publications. □

## UK Research and Innovation

Contact: Roxy Squire
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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

Contact: Audrey Yvernault
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Website: www.abpi.org.uk

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

Contact: Dr Jane Gate, Executive Director
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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.

Contact:
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07895 162 896 for all queries whether for membership or assistance.
Branch Office Address:
Merchant Quay,
Salford Quays, Salford
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Website: www.amps-tradeunion.com

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

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

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

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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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Twitter: @BESPolicy

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

## British In Vitro Diagnostics Association (BIVDA)

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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.

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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.

## British Society for immunology

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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.

## BRITISH SOCIETY OF SOIL SCIENCE

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

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

## Brunel University London

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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

UNIVERSITY OF CAMBRIDGE

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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

## Chartered Institute of Ergonomics & Human Factors

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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.

## The Cosmetic Toiletry & Perfumery Association | ctpa

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www.thefactsabout.co.uk

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

## CLIFTON SCIENTIFIC Trust

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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
- internationally to build global awareness and experience science as a cultural bridge
- to build transferable skills for employability and citizenship

Two powerful Exemplars

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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

## The Council for the Mathematical Sciences

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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

## THE FRANCIS CRICK INSTITUTE

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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.

# SCIENCE DIRECTORY

## Daphne Jackson Trust

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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.

## energy institute

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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.

## EngineeringUK

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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.

## fera

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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.

## First Group

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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.

## GAMBICA

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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.

## The Geological Society

*serving science, profession & society*

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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.

## IBMS Institute of Biomedical Science

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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 ifst

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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.

## Institute of Measurement and Control

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Reg Charity number: 269815

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

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

## IOP Institute of Physics

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

## IET The Institution of Engineering and Technology

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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.

## LGC

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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.

## L'ORÉAL UK AND IRELAND

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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.

## The Linnean Society of London

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

*A Forum for Natural History*

## Marine Biological Association

Est. 1884
Incorporated by Royal Charter 2013

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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.

## Institution of Mechanical Engineers

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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.

## Met Office

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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.

## Microbiology Society

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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.

## NPL National Physical Laboratory

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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.

## Natural History Museum

Advancing the science of nature

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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.

## University of Northampton

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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.

## The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

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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.

## THE NUTRITION SOCIETY
Advancing Nutritional Science

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www.nutritionsociety.org

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

## The Physiological Society

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

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

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

## prospect

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Deputy General Secretary,
Senior Management Team
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www.prospect.org.uk

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

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

## QUADRUM INSTITUTE

Quadram Institute
Science • Health • Food • Innovation

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Website: www.quadram.ac.uk

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

## Royal Academy of Engineering

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

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

## Kew
ROYAL BOTANIC GARDENS

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

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

Kew's strategic priorities for science are:

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

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

## Ri The Royal Institution
Science Lives Here

Contact: Dr Gail Cardew
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www.richannel.org
Twitter: ri_science

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.

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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.

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

## Society for Underwater Technology

Society for Underwater Technology
Contact: David Liddle, Business Development Executive
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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

Contact: Sharon Todd
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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

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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.

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

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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.

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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.

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W www.essex.ac.uk/business

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

## Universities Federation for Animal Welfare

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Email: ufaw@ufaw.org.uk
Website: www.ufaw.org.uk
Registered in England Charity No: 207996

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

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

## The Welding Institute

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Website: www.twi-global.com

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

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

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

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

# SCIENCE DIARY

## PARLIAMENTARY AND SCIENTIFIC COMMITTEE – ALL-PARTY PARLIAMENTARY GROUP

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

## FORTHCOMING DISCUSSION AND OTHER MEETINGS

Monday 17th January
**Discussion Meeting**
'Climate change and health: Surviving rising global temperatures'
In partnership with the Physiological Society
5.30pm to 7.00pm

Monday 21st February
**Discussion Meeting**
'Rising Seas: the impact of changing climate on coastal communities'
In cooperation with the National Oceanography Centre
5.30pm to 7.00pm

Monday 7th March
**STEM for Britain 2022**
Houses of Parliament

Monday 14th March
**Discussion Meeting**
10.30am to 12.00pm

Monday 28th March,
**Discussion Meeting**
5.30pm to 7.00pm

Monday 6th June
**Discussion Meeting**
5.30pm to 7.00pm

Monday 4th July
**Discussion Meeting**
Online discusion 10.30am to 12.00

Tuesday 5th July
**Annual Luncheon**
12.30pm to 2.00pm
House of Lords

## 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 Laura Bellingan at events@rsb.org

## ROYAL SOCIETY OF CHEMISTRY

For further details please contact Events@rsc.org






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The Parliamentary & Scientific Committee's

# STEM for BRITAIN

## 2021 AWARDS

Following the online competition in March, we were finally able to meet and congratulate our 2021 winners at a ceremony held at Portcullis House, Houses of Parliament, on Monday 6th December. The successful early-career researchers were welcomed by Stephen Metcalfe MP, Chairman of the Parliamentary & Scientific Committee, who also thanked our sponsors and the Learned Societies for their generous support.

## THE WINNERS!

### BIOLOGICAL AND BIOMEDICAL SCIENCES

L-R **Amber Bozward**, University of Birmingham, winner the Nutrition Society Prize; **Nikita Mayur Patel**, Queen Mary University London, GOLD, and The Physiological Society Prize; **Sian Morgan**, Cardiff University, BRONZE.

Unfortunately **Paula Martin Gonzalez** (inset) was unable to be with us on the day but we hope there will be an opportunity for Paula to receive her SILVER award in person.

### Biosciences Supporters and Sponsor representatives

Dr Laura Bellingan, Director of Policy and Public Affairs, **Royal Society of Biology** (supporter)

Professor Julie Lovegrove, President, **Nutrition Society** (Prize sponsor)

Dr Lucy Green, Trustee, **The Physiological Society** (Prize sponsor)

David Wells, CEO, **Institute of Biomedical Science** (Gold and Silver sponsor)

Dr Derry Mercer, **Biochemical Society** (Bronze sponsor)

### CHEMISTRY

L-R **Rachel Irlam**, Newcastle University, SILVER; **Ben Lewis**, Imperial College London, GOLD; **David Brossault**, University of Cambridge, BRONZE

Dr Robert Parker, Chemistry Ambassador to Europe and the Commonwealth, **Royal Society of Chemistry** (supporter)

Rory Duncan, Director of Talent & Skills, UKRI, sponsor of the medals and certificates, addressing the event

All photographs John Deehan Photography

## ENGINEERING


L-R **Joseph van Batenberg-Sherwood**, Imperial College London, BRONZE; **Marlini Simoes**, University of Cambridge, SILVER; **Bernard Cooper**, University of Glasgow, GOLD; **Andrew Creagh**, University of Oxford, BRONZE

Professor Constantinos Soutis, **Royal Academy of Engineering** (supporter)

## PHYSICS

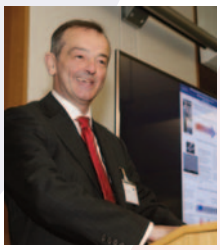

L-R **Vicky Fawcett**, Durham University, SILVER; **Ben Fernando**, University of Oxford, GOLD; **Heidi Thiemann**, The Open University, BRONZE

Professor Paul Hardaker, CEO, **Institute of Physics** (supporter)

## MATHEMATICS


L-R **Gioia Boschi**, Kings College, London, BRONZE; **Scott Harper**, University of Bristol, GOLD; **Georgia Brennan**, University of Oxford, SILVER

Professor Helen Wilson, **Council for the Mathematical Sciences** (supporter)



Professor Martin Bridson, President, **Clay Mathematics Institute** (Gold and Silver supporter)

Professor Geoffrey Grimmett, Chair, **Heilbronn Institute for Mathematical Research** (Bronze sponsor)

## THE WESTMINSTER MEDAL


L-R **Lucinda Bruce-Gardyne**, SCI; **Susan Grayef**, SCI; **Sue Wharton**, STEM for BRITAIN Organising Committee; **Ben Fernando**, Winner, The Westminster Medal; **Dr Andrew H Parton**, SCI.

Lucinda Bruce-Gardyne, Trustee **Society of Chemical Industry** (sponsor)

The Parliamentary & Scientific Committee's

**STEM for BRITAIN**

2021 AWARDS

All photographs John Deehan Photography