The Journal of the Parliamentary and Scientific Committee

SCIENCE IN PARLIAMENT

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AUTUMN 2018

Boosting the UK Space Economy

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Stephen Metcalfe MP, Chairman, Parliamentary and Scientific Committee

Welcome to the autumn 2018 edition of Science in Parliament. I hope you will enjoy the plethora of topics presented in this issue. The wide range of articles it contains – ranging literally from the Deep Ocean to Space – reflects both the range of topics covered by the Committee, as well as how the many advances in science and technology will transform our lives and the planet we inhabit.

The opening article on Space Science and Industrial Strategy was the first of the fascinating presentations at the Committee's September meeting, and the others will feature in our next edition, along with articles based on the meetings we will be holding in October and November.

The December meeting of the Committee will be about Brexit and its implications for science and research.

Inevitably, much of the focus within Parliament lately has been on the Brexit negotiations, and this will only intensify as the date for the UK's departure approaches, along with speculation on what sort of deal will finally be reached. I know the prospect of a 'no-deal' outcome is troubling many in the scientific community. It was helpful then, that one of the first debates when Parliament resumed after its summer recess was on Brexit, Science and Innovation. Several members of the Parliamentary and Scientific Committee spoke, including myself. Despite the different views on Brexit itself, there was strong cross-party consensus about the importance of science and innovation, and ensuring that the UK remains a world class player and contributor. It was gratifying to hear the Minister say "we are determined to be a top collaborator with the EU and the world in future" and that "there is an appetite on their side as well to continue the EU's long-established relationship with the UK."

I should like to draw your attention to the reports in this edition about the impressive amount of work that the Select Committees of both Houses are doing in relation to science and technology matters. As expected, much of this work is being undertaken by the Science and Technology Select Committees, on one of which I'm privileged to serve, but there is also much relevant work being done by other Select Committees. Their perceptive, analytical reports show how Parliament is holding the Government to account in matters involving science and technology.

Finally, I should like to thank Dr Isabel Spence for the work she did for the Committee while she was our Executive Secretary. Her time in that role was much shorter than we would all have wished. Although she stood down in May, I'm pleased she is willing to continue to support the work of the Committee in other ways. I'm also particularly grateful to Karen Smith for ably 'keeping the show on the road' while we consider the longer-term staffing and financing requirements of the Committee.

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The Journal of the Parliamentary and Scientific Committee.
The Parliamentary and Scientific Committee is an All-Party Parliamentary Group of members of both Houses of Parliament and British members of the European Parliament, representatives of scientific and technical institutions, industrial organisations and universities.

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

Front cover image: The Mid Infrared Instrument (MIRI) for the NASA/ESA/Canada James Webb Space Telescope. MIRI is a UK-led contribution, with the University of Leicester responsible for the mechanical and thermal design. Photo ©NASA.

BOOSTING THE UK SPACE ECONOMY

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Chief Executive Officer
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The Government's Industrial Strategy[1] highlighted the importance of "Space" to the UK economy. This was amplified at the recent Farnborough Air Show, when the Prime Minister visited the UK Space Zone following her opening address, the first time any PM has done so.

Separate Ministerial visits followed from Greg Clark, Sam Gyimah, Chris Grayling and Liam Fox, representing business, science, transport and trade respectively, reflecting the breadth of economic and societal contributions from the space industry. Greg Clark's announcement of the UK's first commercial space port and promise of a "Space Sector Deal" was an amazing boost to the Air Show, creating a buzz that lasted all that week and which continues beyond as the sector responds to these opportunities. Coupled with the announcement that Virgin Orbit will operate horizontal launch services in Cornwall, UK space activity has a strengthened sense of purpose with this emerging independent launch capability and the need to develop the supply chains that will service it. Brexit, and the recent challenges around Galileo, adds impetus to enhance UK capacity to make, launch and collect data from satellites for security and broader economic reasons. The development of new markets in high volume, low cost satellite systems are extremely attractive, but speed is of the essence to allow the UK to compete and capture the targeted 10% share of the global market by 2030.

The space business is changing. Manufacturing is a bespoke production process, where satellites and instruments are mostly hand-built by teams of engineers, technicians and scientists. The largest British-based satellite manufacturer, Airbus, specialises in multi-tonne spacecraft for telecoms, remote sensing and space exploration. Surrey Satellite Technology (part of Airbus) has pioneered the development and use of small to medium satellites (100 to a few 100 kg) for specialist applications and built a thriving international business around these. International companies such as Thales Alenia Space and Lockheed Martin have established growing commercial operations in the UK.

These companies (and others) in the "upstream" space sector make important contributions to the UK economy, but significant value also lies in "downstream" applications of remote sensing data obtained from space systems.[2] Early examples are satellite navigation, logistics, climate and weather monitoring, smarter agriculture and disaster/incident management, but the list is growing and extending into parts of the economy not normally thought of as "space", such as insurance. The Space Growth Partnership highlights a £20bn UK market opportunity in Earth information services.

Increased demand for data will result in a greatly expanded need for space platforms to provide it, which the current space business models are unable to meet. There is a growing need for continuous coverage of particular locations and high time resolution monitoring, requiring fleets of small to medium-sized satellites ("constellations") hosting dedicated instruments. A first step has been taken with the creation of launch services in the UK, but the ability to rapidly construct satellites to fulfil the downstream sector needs does not yet exist. There is a queue of companies wanting to provide data services, but these are hindered by the lack of current satellite capability and cost-effective manufacturing capacity. There is a huge opportunity therefore for the UK to integrate "downstream" business demand with rapid "upstream" manufacturing supply of low-cost satellite constellations. Many countries are looking at this and we need to respond quickly to make the UK an attractive home for "new space" companies.

Lowering the time and cost of access to space is a key challenge that the spaceports will fulfil in part. However, this needs to be matched by satellite manufacturing moving from the traditional approach towards "industry 4.0" production line approaches. The UK has invested significantly in

modernising manufacturing techniques, but there is much research and development to be done to apply these to complex, sensitive and often fragile spacecraft. An important element will be the modularisation of spacecraft and systems to create multi-purpose platforms from common, pre-tested and validated elements that are amenable to robotic assembly. Overall, the cost of satellites should be reduced significantly, further benefiting competitiveness of downstream companies.

The majority of current space manufacturing exists in the SE corner of the UK. However, there exist complementary clusters of expertise in other regions that are ready to grow. Furthermore, the Government has already recognised the need for economic growth in all sectors across the regions to help rebalance the economy.[3] Space, as one of the most productive sectors, is well placed to deliver this aspiration. There are also advantages in developing growth in less crowded and stressed regional infrastructures. A prime example of how regional growth could drive the UK Space economy is the Space Park Leicester (SPL) development, which is currently underway.

SPL is a collaboration between the University of Leicester, Leicester City Council and the Leicester & Leicestershire Enterprise Partnership (LLEP), and is located next to the National Space Centre (NSC), the UK's only dedicated space-related visitor centre. SPL is envisaged as a world-leading hub for space and space-enabled industry and will be a globally leading centre for the translation of space research and Earth Observation (EO) data into commercial applications, services and businesses. The Space Park will provide research and manufacturing innovation, alongside industrial production. It will draw on the University's space research and innovation strengths - there has been a Leicester-built instrument in orbit every year since 1967 - together with the Midlands industrial base (350,000 employees) and Advanced Manufacturing prowess. The development is creating a regional cluster, supported by the UK Space Agency and Satellite Applications Catapult, which will support delivery of UK ambitions on productivity and jobs growth (aiming for 10% of the global space market and 100,000 new jobs by 2030), in addition to helping deliver the Government's ambition of 2.4% national expenditure on R&I. Realising the potential of SPL is therefore an important priority for the Midlands Engine as part of its ambition to increase productivity, create jobs and grow the Midlands and UK economies by £54 billion by 2030.

In summary, SPL will be:

- A collaborative community of businesses, start-ups, researchers & students;
- A cluster integrating downstream data customers with upstream satellite manufacturing capability;
- Home to the NERC National Centre for Earth Observation; Centre for Earth Observation Instrumentation; UKSA Space Business Incubators; Leicester Institute for Space and Earth Observation; and the East Midlands Centre of Excellence in Satellite Applications, supported by the Satellite Applications Catapult & UKSA;
- An educational centre of excellence, providing much needed skills, training & talent to support skills needs of the sector from apprenticeships and CPD. The University of Leicester and the National Space Centre collaboration already underpins the National Space Academy;
- A venue for public engagement, in partnership with the NSC.

This first phase of SPL, focused on downstream applications, opens in 2020, with activity developing rapidly to create a globally competitive cluster of space and space enabled businesses. Future phases are the subject of active funding bids. If successful, these will house an enhanced suite of Space Research and industry facilities to develop and test the approach to low cost satellite manufacturing and to apply artificial intelligence to the analysis, interpretation and application of space data. There are also well-progressed plans to construct a Low-Cost Access to Space (LoCAS) factory, which will provide manufacture, assembly, integration and verification capability and test facilities for high throughput spacecraft production. It will create a flexible environment for space primes and emerging space businesses (including inward investors) to develop their constellations of spacecraft, hosted payloads and link as required with launch system providers. The LoCAS factory has been identified as a Midlands Engine and Leicester and Leicestershire LLEP priority. Delivering the vision for SPL will lead to over 2,500 new jobs, with enhanced GVA of £715m.

Leicester isn't alone in being a regional focus of specialist expertise that can contribute to the National Space Infrastructure. There are several regional centres of expertise outside the national facilities at Harwell. Significant investment is being made in all these. The Goonhilly Earth Station in Cornwall is being redeveloped for an essential deep space communication role in support of launch and satellite operation services. Strathclyde University and AAC Clyde (formerly Clyde Space) are experts in space electronics and nanosat systems. Surrey Space Centre have expertise in small/medium spacecraft, space robotics and imaging systems. There are also developing activities in the North East of England and Wales, besides investment from space companies in Northern Ireland.

SPL and the regional clusters support the new model of space manufacturing and applications targeting opportunities in excess of £75bn.[4] Some investments have already been made from Government growth funds, universities and private capital. However, more is needed quickly for the UK to lead this new industrial frontier. Capital and operational support for regional clusters from the eagerly awaited Space Sector Deal would be an effective and timely vehicle to boost the UK space economy.

References

1 https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future

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THE UK HAS A SUPER POWER HELPING TO SOLVE 21ST CENTURY CHALLENGES

DIAMOND LIGHT SOURCE, THE UK'S NATIONAL SYNCHROTRON

The super bright light created by Diamond Light Source, the UK's national synchrotron, is keeping UK science at the forefront of global scientific research and discovery. In the south of Oxfordshire, on the Harwell Campus, Diamond is enabling scientists to break new science frontiers by making the invisible visible using its light 10 billion time brighter than the sun. Since beginning operations in 2007, experiments at Diamond have resulted in the publication of over 7000 scientific papers detailing important and many groundbreaking new discoveries.

With a half kilometre circumference, and a similar footprint to Wembley Stadium, Diamond is a huge scientific machine. It works like a giant microscope, harnessing the power of electrons to produce light, which is channeled into 32 laboratories known as 'beamlines'. These very intense beams of X-rays, infrared and ultraviolet light can be used to support an astonishing variety of research. Scientists use the light to study everything from fossils and historical artefacts to new medicines and treatments for disease, pollution and climate change to innovative engineering, new energy sources and cutting-edge technology.

MAKING THE INVISIBLE VISIBLE

For centuries, scientists have used microscopes to study things that are too small to see with the naked eye. However, microscopes are limited by the visible light that they use. Optical microscopes can be used to study objects that are a few microns (0.001mm) in size, about the size of cells. To study smaller objects like molecules and atoms, scientists need to use the special light generated by the synchrotron. So whether it is fragments of ancient paintings or unknown virus structures, at Diamond, scientists can study their samples using a machine that is 10,000 times more powerful than a traditional microscope.

One of the most advanced scientific facilities in the world, Diamond is run as a not-for-profit limited company and funded as a joint venture by the UK Government through the Science & Technology Facilities Council (STFC) in partnership with the Wellcome Trust. The synchrotron is free at the point of access through a competitive application process, provided that the results are in the public domain. Over 7000 researchers from both academia and industry use Diamond to conduct experiments, assisted by approximately 600 staff.

SCIENCE CASE STUDIES

Environmental Pollution: Tackling plastic pollution – engineering a plastic-digesting enzyme

Plastic pollution is one of the world's biggest environmental and health problems. However, an international team of scientists working with Diamond have recently made a discovery that could result in a recycling solution for millions of tonnes of plastic bottles, made of polyethylene terephthalate, or PET, which currently persists for hundreds of years in the environment.

The scientists from the University of Portsmouth, the National Renewable Energy Laboratory in Colorado, the University of South Florida, the University of Campinas in Sao Paulo and Diamond Light Source have engineered an enzyme which can digest some of our most commonly polluting plastics, providing a potential solution to this global issue.

Their research published in *Proceedings of the National Academy of Sciences (PNAS)* was led by Professor John McGeehan at the University of Portsmouth and Dr Gregg Beckham at NREL. The team

determined the 3D structure of PETase (a recently discovered natural enzyme that digests PET) using three of Diamond's Macromolecular Crystallography (MX) beamlines. They used this information to understand how it works and inadvertently engineered an enzyme that is even better at degrading the plastic than the one that evolved in nature.

further to allow it to be used industrially to break down plastics in a fraction of the time. The researchers found that the PETase mutant was better than the natural PETase in degrading PET. Significantly, the enzyme can also degrade polyethylene furandicarboxylate, or PEF, a bio-based substitute for PET plastics that is being hailed as a replacement for glass beer bottles.

Plastic pollution in oceans. © David Jones

Professor McGeehan said: "Diamond recently created one of the most advanced X-ray beamlines in the world and having access to this facility allowed us to see the 3D atomic structure of PETase in incredible detail. Being able to see the inner workings of this biological catalyst provided us with the blueprints to engineer a faster and more efficient enzyme."

The researchers are now working on improving the enzyme

This research demonstrates how international collaboration can help make significant scientific breakthroughs. The results achieved will be invaluable in tailoring the enzyme for use in large-scale industrial recycling processes. The impact of such an innovative solution to plastic waste would be global.

Cultural Heritage: Henry V111th's "Balls" – Ironshot from the Mary Rose

Humans have been using iron to make weapons, tools and ceremonial items for more than 20,000 years, but once these objects have been excavated they are at risk from corrosion, which can be accelerated by the presence of chlorine. Each recovered artefact has to be conserved to prevent it from deteriorating in the presence of air and water. Until now, a comparison of the effectiveness of different conservation methods has been hampered by the variable nature of the artefacts found, and the environments in which they were buried.

When King Henry VIII's flagship, the *Mary Rose*, sank off Portsmouth in 1545, it took with it 1248 iron cannonballs. Since the excavation of the shipwreck, the cannonballs have been conserved in different ways, offering a unique opportunity to study different conservation methods.

At Diamond, researchers used a combination of X-ray powder diffraction, absorption spectroscopy and fluorescence to characterise the effect of the different conservation techniques on the iron, and the

Cannon Ball from Mary Rose with Henry Tudor 'stamp'.
© The Mary Rose Trust

Coroded iron shot
© The Mary Rose Trust

Shot in drawer. © The Mary Rose Trust

Plastic washed ashore. © David Jones

distribution of chlorine in the artefacts.

Synchrotron X-ray techniques can differentiate iron corrosion products formed during treatments, even years later, giving us an unprecedented insight into the effects of conversation techniques on iron corrosion. This new information will play an important role in future conservation developments concerning archaeological iron worldwide.

NEW ENERGY EFFICIENCIES: INVESTIGATING BATTERY FAILURE

From mobile phones to electric vehicles, lithium ion (Li-ion) batteries are ubiquitous in today's society. However, these devices have been known to fail, sometimes in spectacular fashion, as seen recently in the Samsung Galaxy Note 7 smartphone recall. A team of researchers have investigated the nature of this failure in an effort to improve safety and reliability of Li-ion batteries.

As battery failure takes place in millisecond time frames they used high speed X-ray imaging at Diamond Light Source and the European Synchrotron Radiation Facility to track how failure propagates through Li-ion batteries. They used a NASA and National Renewable Energy Laboratory-developed device to induce short circuits in Li-ion batteries at a specific and pre-determined time and location.

Their work has enabled them to look inside the 'black box' of commercial Li-ion batteries and determine why failure happens. They now plan to investigate different safety devices to determine which work best. Ultimately, they hope their work will help to develop new safety devices and materials for batteries in the future.

DIAMOND: INSPIRING YOUNG ENGINEERS AND SCIENTISTS

As one of the most exciting places in the country to be a scientist or engineer, Diamond sees it as part of its mission to share this excitement with young people. This is why it showcases at every opportunity the incredible possibilities and opportunities available to students choosing science, technology, engineering, and mathematics (STEM) subjects and careers. Diamond has worked in schools for over 15 years, inspiring tens of thousands of young people with visits, participating in festivals, and in the classroom.

Training and learning at Diamond extend from schools to post-doctoral education. It welcomes over 4000 visitors to the site every year through school, undergraduate, and post-graduate visits, and through a programme of workshops and conferences. 23 School and 25 Public Open Days have been held since 2012 welcoming more than 1800 visitors each year. All play a key role in developing awareness of Diamond's techniques and capabilities at every stage in a scientific career.

100 UK schools took part in Diamond's largest citizen science experiment, Project M, and Science in Schools had 200 female participants, aged 14-16, to encourage more girls into science. More than 1000 students and visitors every year attend masterclasses and public Stargazing events jointly organised with STFC. Additionally, nearly 30 students per year become immersed in Diamond for a week at the Work Experience Academy.

DANGER OF STEM SKILLS SHORTAGE TO UK SCIENCE

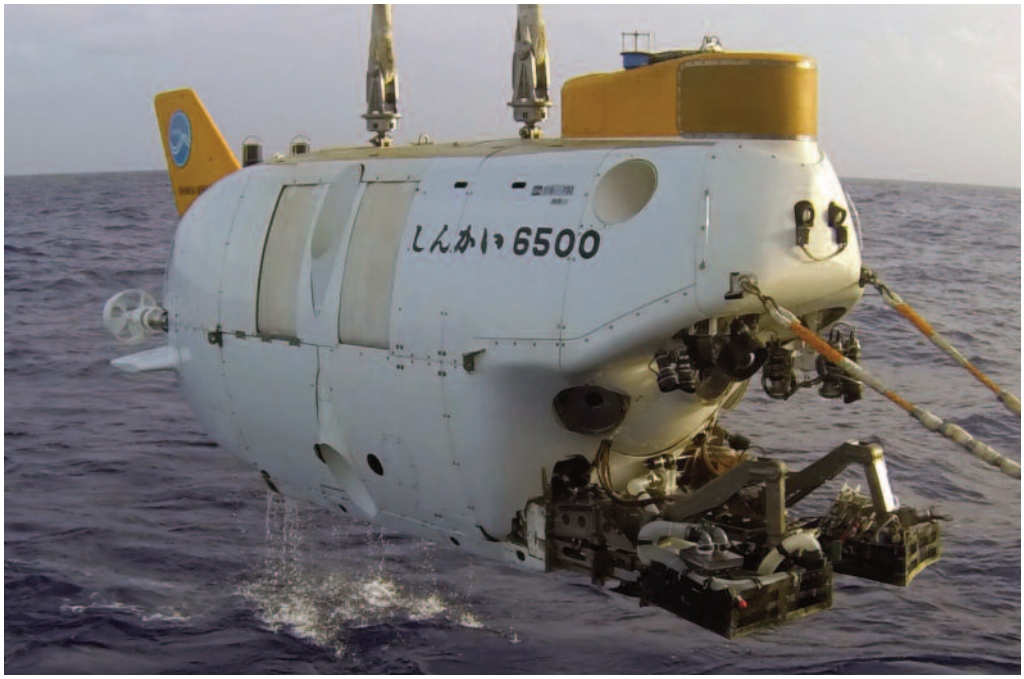
The skills shortage in STEM has the potential to jeopardise Diamond's future success. The skilled scientists and engineers needed to run and develop the synchrotron may not be available if current trends continue. New generations of scientists are needed to research solutions to global problems and create the technological advancements that are the lifeblood of a modern economy.

Diamond is currently co-hosting over 90 PhD students (of which 21 new students started in 2017) across many areas of science and technology, providing a key link between the user community and the facility. Diamond also provides over 20 undergraduate student placements each year (including 12 week and a year in industry placements). It also provides new apprenticeships in mechanical and electrical engineering. As well as providing direct learning opportunities, Diamond's diverse range of workshops and conferences provide academics from around the world with the opportunity to discuss ideas and remain at the forefront of thinking in their fields.

If you would like further information on Diamond, or to arrange a visit, please contact the Head of Communications, Isabelle Boscaro-Clarke: isabelle.boscaro-clarke@diamond.ac.uk

OPPORTUNITIES AND CHALLENGES OF THE DEEP OCEAN: A CHOICE FOR OUR FUTURE

Dr Jonathan Copley BSc(Hons), MSc, PhD is the first British "bathynaut' to dive more than 5km deep in the ocean, and Associate Professor of Ocean Exploration & Public Engagement at the University of Southampton.



When Pliny the Elder wrote his *Naturalis Historia* around 77 CE, he listed "*the names of all the animals that exist in the sea, one hundred and seventy-six in number*" and boldly claimed "*by Hercules! in the sea and in the Ocean, vast as it is, there exists nothing that is unknown to us*". Pliny was rather premature in declaring "mission accomplished" for exploring the oceans, and today is a great time to be an ocean explorer, because for the first time in history we have the capability to reach the furthest recesses of our blue planet. But the choice now is what to do with that capability: do we explore the ocean to learn from the ingenuity of nature beneath the waves, or to exploit its other resources for short-term gain?

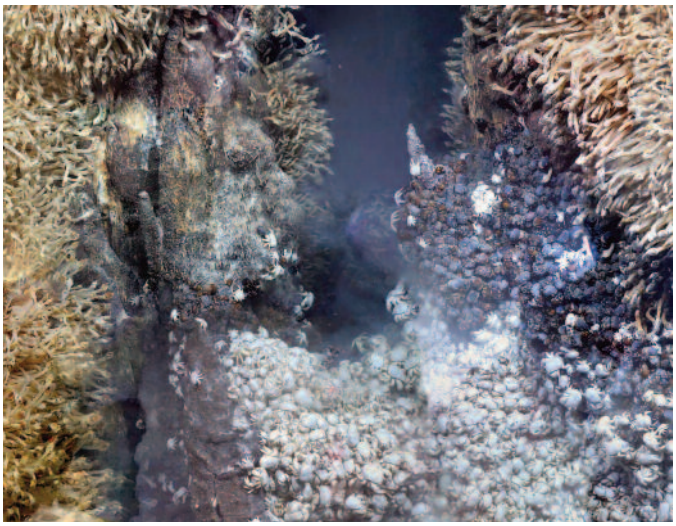
It is not true that "we know more about Mars or the Moon than the deep ocean", as we sometimes hear. We have more detailed maps of the surface of Mars and the Moon than the deep ocean floor, because seawater acts like a veil to block radar from satellites, but having a map is not really the same as knowing or understanding. The amount of rocks that have been collected and analysed from the Moon to understand its geology is just over 500 kilograms. Thousands of times more samples have been collected and analysed from the ocean floor to understand the processes that shape it, along with vast volumes of other data, so we know far more about the geology and biology of the deep ocean than other places in the Solar System.

But of course there is still plenty still to discover in the half of our planet that is covered by water more than 2 kilometres deep. And I think that there are three steps in exploring the ocean. The first is "mapping and monitoring", and the scale of the oceans has made that a daunting step until now. Fortunately we have a new generation of autonomous underwater vehicles (AUVs) to help us -- essentially robots that are not connected to a ship, or remote controlled at all. We are starting to send these autonomous vehicles out to survey the ocean on their own, replacing research ships for some tasks and giving us greater coverage than the world's research fleet can provide.

Making a map is an important first step in exploring our oceans, but it is only a first step. Mapping and monitoring tell us where there are things happening that challenge our current understanding of how the oceans work. So the second step in exploring the ocean is "human-directed investigation" of the anomalies found by mapping and monitoring, and this involves a different type of undersea technology. Robots cannot do this second step for us: it is really the "science" part, testing our hypotheses, and we need to be able to collect very specific samples and measurements as we develop new ideas from what we are seeing and finding. Robots can help us get to this step more quickly, and use human-directed vehicles more efficiently -- but we must not lose sight of this step, and the technology we need to complete it.

The technology for this step comes in two types of undersea vehicles. We have "human-occupied vehicles" (HOVs): minisubmarines that can carry people into the deep ocean, such as the ones that I used with BBC colleagues to make the first dives to 1 kilometre deep in the Antarctic for the filming of the *Blue Planet II*

television series. Literally immersing yourself in the unknown is an effective way to explore it; during a dive we can decide exactly where to make measurements on the basis of what we are seeing, or exactly what to pick as samples the vehicle's mechanical arms. No autonomous underwater vehicle has ever collected a specimen of a deep-sea animal from the ocean floor to analyse ashore and identify as a new species, and robots are not able to decide when to stop and film what might be a previously unseen behaviour of a deep-sea animal.



Vent Life

But human-occupied vehicles for the deep ocean are expensive to build and operate. So we also have remotely operated vehicles (ROVs), like the UK's *Isis* ROV for science, which is about the size of a car and can reach 6 kilometres deep. Remotely operated vehicles are connected to a ship by a cable and thereby under our direct control, allowing us to send our minds, if not our bodies, to the ocean floor. And they send live, high-definition video to us via their cable -- again, not something that an autonomous underwater vehicle can do. The video from remotely operated vehicles can then be broadcast from ship to shore via satellite, and then shared live with people all around the world on the internet. The US Ocean Exploration Program recently used the live-streaming facility to broadcast from expeditions exploring their new Marine Protected Areas in the Pacific, allowing members of the public to join in discovering what lives there. I hope that UK research ships will be equipped with the hardware to do that too in future.

With these tools, the first two steps of ocean exploration have already revealed deep-sea wonders aplenty in the UK's own seafloor territory, which is 27 times larger than our land area when we include seafloor around UK Overseas Territories. For example, my colleagues and I found the world's deepest known hydrothermal vents - hot springs on the ocean floor - five kilometres beneath the waves near the Cayman Islands, with several new species of animals thriving around them, including swarms of a shrimp that grows bacteria on its mouthparts to eat.

The final step in exploring the oceans is "using our understanding", which is where Parliamentarians in particular are involved. The choices involved in using our understanding are perhaps exemplified by a snail that one of my PhD students described as a new species from 2.8 kilometres deep in the Indian Ocean. The "scaly foot" snail (*Chrysomallon squamiferum*) is unlike any other snail on land or in the sea because its fleshy foot is covered by metal plates, which is how the snail copes with the metal-rich fluids gushing out of undersea hot springs where it lives.

Scaly foot snail

Its shell has an unusual layered structure that enables it to "self-heal" when damaged, which has inspired materials scientists to pursue new designs for better crash helmets and body armour. So the "scaly foot" snail is just one example of how we can learn from the ingenuity of nature beneath the waves to benefit our everyday lives. But the hot springs where this snail lives also harbour rich deposits of copper on the ocean floor, which are now being targeted for possible seafloor mining to meet the demands of our modern lives for metals. So far we have only found the "scaly foot" snail living at four places on the ocean floor, each the size of a few football pitches, and all in areas that the United Nations International Seabed Authority has already licensed for mineral exploration.

Deep-sea vents are one of three types of seafloor habitat now being targeted for future mining. There are also seamounts with deposits of cobalt, currently needed for electric car batteries, and manganese nodules on abyssal plains, which contain Rare Earth Elements used in many modern devices. Each of those deep-sea habitats is very different in scale, in the biodiversity that lives there, and how it is likely to respond to disturbances from mining. Earlier this year, the European Parliament called for a moratorium on new mineral exploration licences in the deep ocean until the impacts of mining have been investigated, but that will require a major coordinated research effort.

So here is the challenge for our future: as we explore the deep oceans, can we preserve their biodiversity to learn from the ingenuity of nature? Or will we rush to exploit the other resources we find there at the risk of losing that biodiversity? With the possible exception of the Antarctic Treaty, there seems to be little historical precedent for achieving a balance between those two: from the deforestation of Easter Island that led to the decline of the Rapa Nui, to the extinction of the North America Bison for fertiliser from their ground-down skulls, and the modern cutting of rainforests for cattle ranching. But if we believe we are better than that, that we have grown in wisdom as well as in technology, then the immediate future of the deep ocean offers a chance to prove it, through the legislation that we create.

INTO THE DEEP – DISCOVERING OUR OCEANS

Sarah Miles, External Affairs Officer, Natural Environment Research Council

As new research and innovation pushes the frontiers of exploration of the deep ocean and opens up new possibilities, what challenges do we face? And how can we responsibly seize these new opportunities?

These were just some of the topics covered at the Parliamentary and Scientific Committee discussion meeting and reception on Monday 23rd April, held in partnership with the Natural Environment Research Council (NERC), part of UK Research and Innovation, and chaired by Stephen Metcalfe MP.

The regulation of our oceans is a key challenge, made more complex by their inherently international nature. Lowri Mai Griffiths, Head of the Maritime Policy Unit at the Foreign and Commonwealth Office, shared her experiences of international negotiations to ensure conservation of the high seas, highlighting the key role of scientific evidence in new international arrangements.

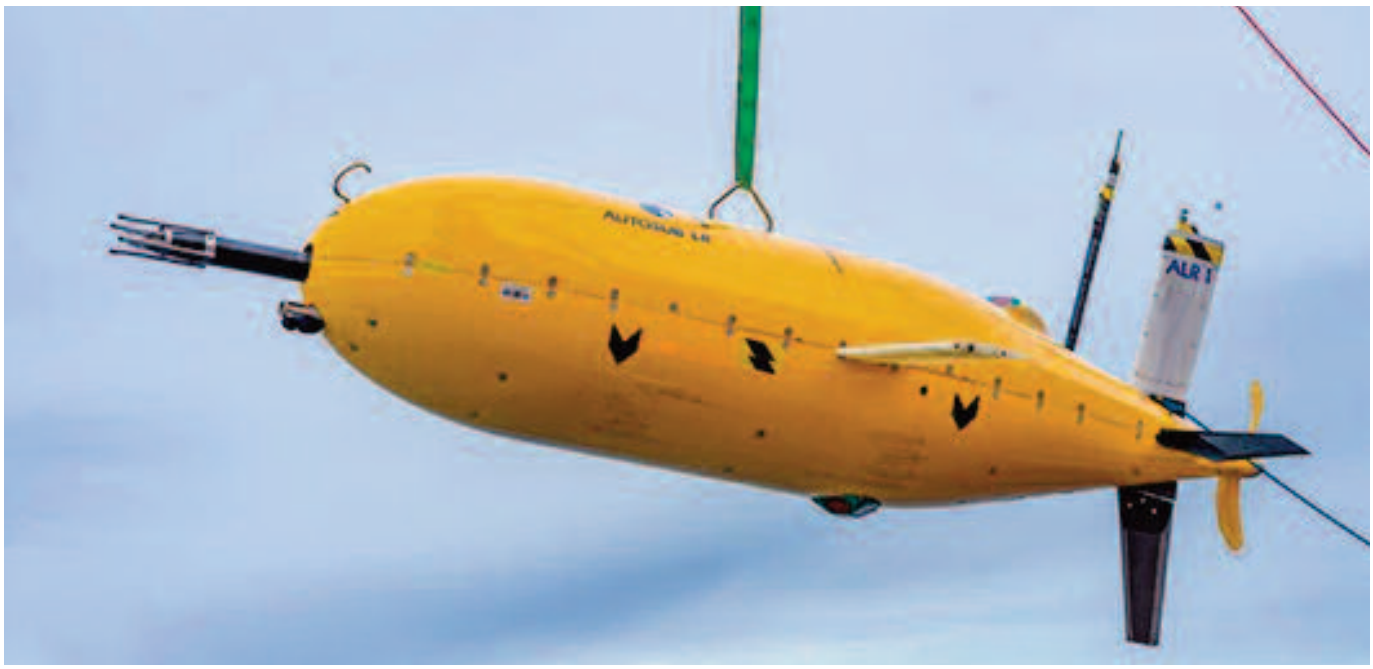
The Biodiversity Beyond National Jurisdiction (BBNJ) process has been ongoing since 2004. Lowri highlighted some of the factors being considered, such as how the UN Sustainable Development Goals can be met while at the same time increasing Marine Protected Areas, referencing the most recent UK Government commitment to the BBNJ in the 25-Year Environment Plan.

One of the issues for consideration is marine noise. There is no doubt the ocean is becoming an increasingly noisy place, with human activities such as shipping, hydrocarbon exploration and military sonar all contributing. However, the ocean has never been silent, with waves, underwater eruptions and echo locating marine mammals all contributing to the natural soundscape.

Professor Russell Wynn, Associate Director at NERC's National Oceanography Centre and Chief Scientist of Marine Autonomous and Robotic Systems, showcased new and innovative technologies being developed to monitor marine noises. The aim for research in the future is to explore areas where the noise is likely to get louder, for example Antarctica and the Arctic, and investigate the impact of increased marine noise in these areas.

Marine mining in the deep ocean is a hotly-debated opportunity. Dr Tracy Shimmield, Co-Director of the Lyell Centre of NERC's British Geological Survey, highlighted the increasing global demand for metals and minerals that could be met through deep sea mining. She also outlined the importance of identifying the many potential environmental impacts on the marine environment. For example, these depend on how deep into the ocean you go. The impacts at the surface could include light, noise, pipe failures and routine discharges; deeper down, they could include disturbed habitats, suspended particulate material, and light and noise.

Tracy highlighted that it is unlikely that recycling can meet the increasing demand for cobalt and nickel for use in technologies such as smartphones, which can be



The National Oceanography Centre's Boaty McBoatface is one of NERC's Autonomous Underwater Vehicles

mined from the deep ocean floor. UK and EU institutions are currently at the forefront of independent research to understand the environment, habitats and resources that could be affected by an increase in marine mining.

The UK sea floor ocean territory is 27 times larger than our land territory, and most of that is deep ocean, more than 1km deep. Dr Jon Copley, Associate Professor of Ocean Exploration and Public Engagement at the University of Southampton explained how scientists are exploring this vast expanse, using a new generation of autonomous underwater vehicles (AUVs) to reach new depths of the ocean and cover large areas without being connected to a ship. He emphasized the current need to continue human-directed investigations, in occupied or remotely operated vehicles, and highlighted the importance of using this understanding to inform policy. Jon argued that we can make a choice for our oceans' future.

The speakers inspired wide-ranging discussions, including how to regulate and solve the issue of plastics as a key pollutant of our seas, which has gained high public awareness recently. The Commonwealth Heads of Government Meeting, held just before this event, saw countries across the Commonwealth pledge to eliminate single use plastic, in an ambitious bid to clean up our world's oceans.

Into the Deep – Discovering Our Oceans, asked how can we inspire public engagement with broader challenges facing our seas to inspire further positive action?

Stephen Metcalfe ended the meeting by highlighting the connection to a forthcoming Committee meeting on behavioral science, reinforcing the interconnected nature of the solutions to the challenges facing our oceans today.

OUR FUTURE METAL RESOURCES AND THE ROLE OF THE NATURAL HISTORY MUSEUM

Robin Armstrong
Mining Consultancy Leader,
Natural History Museum

Richard Herrington
Head of Earth Sciences Department,
Natural History Museum

Metals are intrinsic parts of minerals found in the rocks that surround us and support the ground under our feet. In specific parts of the earth's crust, metals are found in concentrations high enough for the rock to be referred to as 'ore'. Ore is not a geological definition; it is an economic term that describes minerals from which metals and non-metals can be extracted, at a profit. These ores are found in mineral deposits which often represent locations on earth with high degrees of mineralogical diversity. Our societal need for earth materials has defined the ages of our technological advancement from the stone-age through to the current industrial age with our dependency on iron, copper, aluminium and concrete. Yet now, arguably like our supermarkets, we are entering an age when in addition to those infrastructure materials we demand the more exotic, rarer 'ingredients'. The metal equivalents of mangoes and quinoa are indium (for touch screens), and lithium and cobalt for rechargeable batteries. This demand for the 'E-elements' is driven by consumer demand for ever more sophisticated personal electronics and the realization that renewable electricity generation and electric vehicles are required to stop our cities from driving to disaster. And, if we return to our supermarket of elements, we are also entering an age, where at least in the case of some elements, the consumers of metals are ever more aware of the ethical concerns around the origins of these resources.

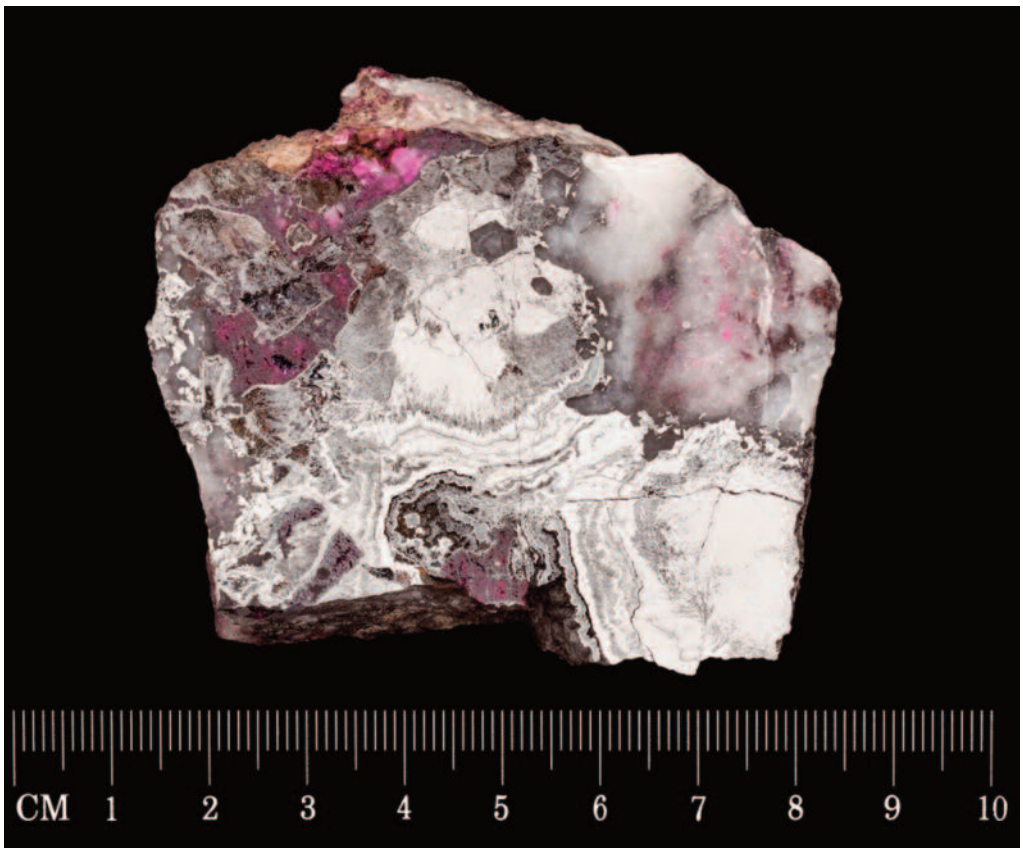
The Natural History Museum's (NHM), London, Ores Collection dates to the Museum of Practical Geology founded in 1838 by Henry de la Bêche and currently numbers over 30,000 specimens from more than 2,600 localities in 108 countries. In addition, the NHM also hosts one of the world's top three systematic Mineral Collections from a diverse range of settings around the world which, together with the Ores and Petrology Collections, form an unrivalled resource for benchmarking studies of natural minerals. On the back of these collections the NHM has built a unique world class scientific expertise in the study of mineral deposits that encompasses the identification of these minerals of interest, the location of these deposits in geological time and space within the earth's crust and perhaps more pertinent to our thirst for resources - the expertise to 'win' the elements of interest from these often complex minerals in the most energy efficient manner. These questions demand that we as an institution engage with all the stakeholders in these processes, whether the governments of the countries where these deposits are found, the companies that explore and mine these metals, or the general public who ultimately consume these metals in their everyday lives and interact with the Museum. The NHM is uniquely placed to address questions of the societal need for natural resources and the impact this demand has upon the wider natural environment. The work at the NHM regarding mineral deposits can be viewed through the Oil and Gas industry terminology of 'Upstream' and 'Downstream' where upstream is the exploration of and development for resources, and the downstream where the resource is extracted and refined.

RESEARCHING THE 'UPSTREAM'

LODE & FAMOS: 'Green rocks' as vectors to ore and the assessing the ore-forming potential of magmatic arcs

We are now entering an age where the discovery of large economic resources at surface is becoming more difficult and one of the challenges for the mineral exploration industry is to identify sub-surface, deep deposits in efficient and less-invasive ways. This requires remote sensing of the deep earth in the first instance through geophysical techniques that measure the density, the magnetism and electrical conductivity of sub-surface. These methods, though effective, do create false-positives. These anomalies must then be drilled to establish the nature of the mineralization, the size of the anomaly and whether or not the resource is economic to extract. Porphyry Copper Deposits account for 70% of the world's current copper production, forming large tonnage low grade deposits associated with specific magmatic rocks. Though the

potential economic mineralization encompasses a large volume of rock, the halo of hydrothermal mineralization can be much larger. This large halo of altered rocks, if interpreted correctly, can be used to vector to the potential ore. The LODE laboratory at the NHM is a mining industry sponsored facility that provides a mineral indicator service (that through the measurement of trace elements in the alteration minerals formed during the mineralization process) can be used to direct drilling programs towards ore bodies thus reducing initial drilling costs in the proving of geophysical anomalies *(https://www.researchgate.net/publication/322357295_Porphyry_indicator_minerals_and_their_mineral_chemistry_as_vectoring_and_fertility_tools)*. The LODE team are also active in the development of new techniques to establish which of these granite-type rocks have the potential to form these porphyry copper systems. This is exemplified through the NERC funded FAMOS project which seeks to develop a fundamental scientific understanding that lead to the creation of these deposits in geological space and time. This work will ultimately allow the explorers to generate inclusion and exclusion criteria for the identification of 'fertile' tracts of earth's crust.



BM.2013,OR5(3) - Large mass of silver-white skutterudite, a cobalt arsenide mineral, from the Bou Azzer mine in Morocco. Bou-Azzer is presently the only mining district in the world to produce cobalt as a primary commodity from arsenide ores.

MOVING 'DOWNSTREAM'

New Metal Resources in Old Mines

The UK and Europe has a long legacy of old mines and metal production with these old mining districts frequently being associated with a narrow range of commodities. Past processing technologies, a poor understanding of the metal distribution in these mineral deposits and emerging uses for the minor and rarer metals have often lead to the full economic potential of these deposits not being realized. Through the EC funded Horizon 2020 program, NHM is engaged with 17 partners consisting of universities, geological surveys and SMEs from across Europe in the FAME project to investigate the potential of some of these older deposits. The role of the NHM is to characterise the mineralogical diversity within these often complex ores and account for the distribution of the key technological elements of Li, Sn, W, Rare Earth Elements and In. The NHM's comprehensive and world class mineral characterisation facilities have allowed the team to develop workflows that can inform and help refine the new processing technologies being developed by other partners *(http://www.nhm.ac.uk/our-science/our-work/sustainability/fame-and-fortune.html)*. This approach means that co-production of multi-element suites will now be possible from these older deposits thus potentially making them economic once more. Furthermore, these deposits are in Europe, and therefore addresses the issues of security of supply for some of the E-elements essential for the UK and Europe's high technology industries.

COBALT: A TECHNOLOGY ENABLING MINOR METAL

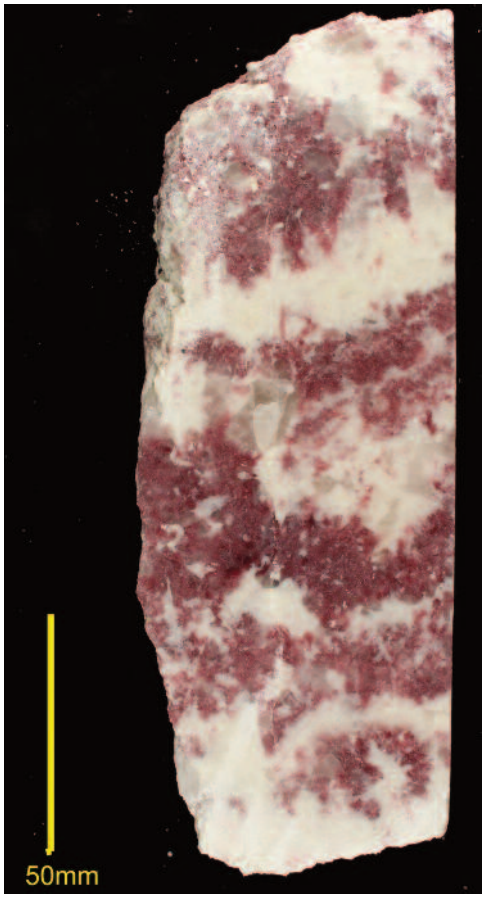
Cobalt has long been in demand as a minor metal in the 'superalloys' that have driven technological developments from the early 20th Century. More recently the metal has hit the headlines as demand for it doubled, coupled with a near three-fold price rise in part due to its use in high-performing rechargeable Li-ion batteries for electric vehicles. The UK government has recognised the need to address the challenge of providing for the appetite of future generations (for electric vehicles and rechargeable batteries), through 'The Faraday Challenge'. *(https://innovateuk.blog.gov.uk/2017/07/24/the-faraday-challenge-part-of-the-industrial-strategy-challenge-fund/)*. Cobalt will undoubtedly form an important part of the cocktail of metals in rechargeable batteries for the foreseeable future. Cobalt is currently largely sourced from central Africa where questions concerning ethical supply are regularly raised. The NHM's ore and mineral collections have been an invaluable 'library' source of information for the discovery of other more secure places that this minor metal might be found hidden away in the earth's crust.

CoG^3 AND CROCODILE

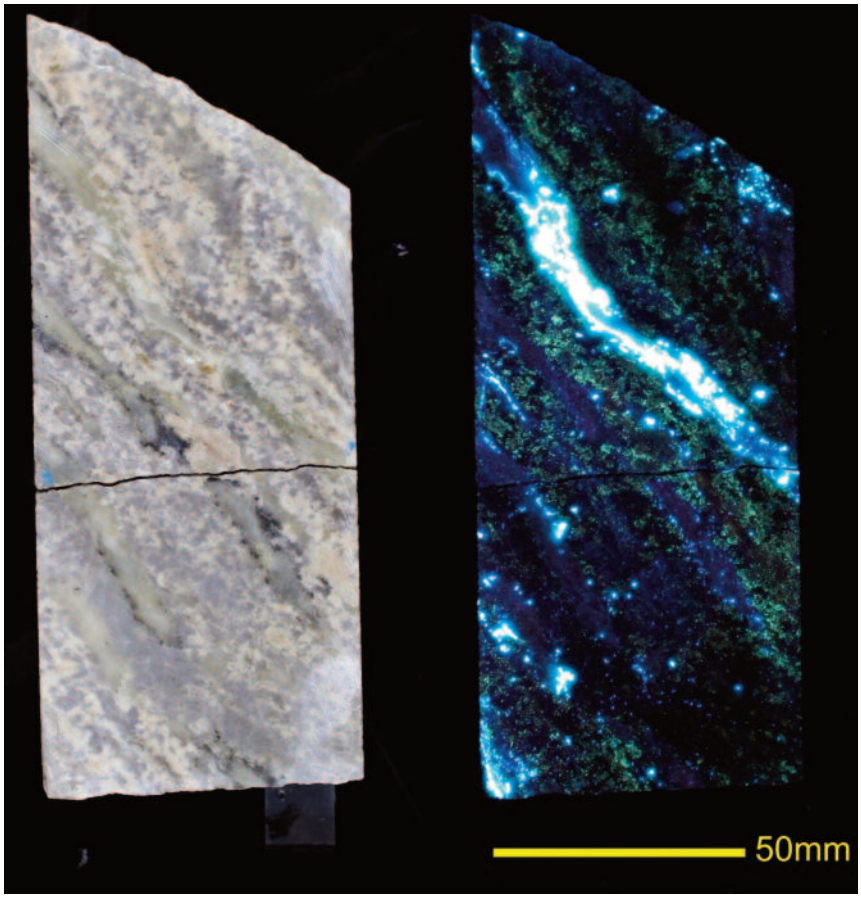
The NHM already leads a £2.5 million UK Research Council-funded project called CoG^3 *(http://www.nhm.ac.uk/our-science/our-work/sustainability/cog3-cobalt-project.html)* that investigates the diversity of geological sources of cobalt as well as researching novel ways to improve the metal's recovery from these and existing resources. Working with other UK and international colleagues, novel bioleaching technologies are utilising the power of nature to unlock cobalt from minerals in a greener form of mining that seeks to cut the energy costs whilst leaving a more sustainable footprint to mineral production. The NHM team is now part of a recently successful European Horizon 2020 project 'CROCODILE' *(http://h2020-crocodile.eu)* that has been awarded € 12 million to help develop strategies for cobalt recovery from European primary (mining) and secondary (recycling) sources. CROCODILE has the bold aim of unlocking around 10,000 tonnes of cobalt metal per year (currently 50% of EU needs) from indigenous primary and secondary sources.

METALS FOR A SUSTAINABLE FUTURE?

There is an old adage, 'if it can't be grown, it has to be mined'. In the past, our understanding of the fate of mined resources has been less than perfect but we are getting increasingly better at tracking material flows and implementing recycling to minimise the extraction of newly mined minerals. However, the unavoidable reality is that the world is growing both in population and increasing technological complexity; all of this growth fuels a hunger for increasing volumes of a larger range of metals from the periodic table. What we need are efforts focused at maximising the efficiency of this resource usage, minimising energy and environmental costs of production, and ensuring that the metals are reused and recycled in a circular fashion. NHM collections and science are both helping to work towards this. The NHM is also in a unique position to be able educate the public about the life-cycle of mined metals, empowering them to help make better choices about the use of non-renewable Earth resources.



GON-9b. An image of a cut slab of a potential lithium ore from the Goncalo pegmatite field, Portugal. The pink mineral is lepidolite mica, the target ore mineral which in this instance which contains up to 3 weight percent Lithium. This sample was collected as part of the FAME project funded by the EU H2020 program.



A sample of drill core from the Sao Pedro Das Aguias Skarn, Tabuaço, Portugal. The left hand image was photographed under visible light conditions whereas the right hand image was photographed under ultraviolet light. The electric blue domains indicated the presence of scheelite, a tungsten-bearing mineral and the target ore mineral at this project. This sample was collected as part of the FAME project funded by the EU H2020 program.

CAN WE ELIMINATE INTESTINAL WORMS?

The Natural History Museum is driving life-saving research into Neglected Tropical Diseases

Dr Tom Littlewood

A community health worker travels around households in a town in Benin, in West Africa. A large-scale awareness campaign to showcase the causes and treatments of intestinal worms has resulted in encouraging engagement with local families and health officials. The health worker is hopeful that she can deliver deworming medication to the community as part of a new trial to investigate how the disease could be eliminated.

The town is in an area that is endemic for soil-transmitted helminths, also known as intestinal worms, due to a lack of adequate sanitation allowing persistent transmission of worm eggs through contaminated soil and water.

Recent modelling research has shown that it may be possible to break the transmission of intestinal worms by treating an entire community twice a year with albendazole, in the hope that reinfection rates will decrease and in turn the life cycle of the worm will be interrupted.

This approach is being tested as part of a pioneering trial called DeWorm3 led by the Natural History Museum in London which works together with partner organisations to engage with local communities to tackle the potentially debilitating soil-transmitted helminth infections and attempt to eliminate this Neglected Tropical Disease as a public health problem.

THE LONDON DECLARATION ON NEGLECTED TROPICAL DISEASES AS A TURNING POINT

In 2012, pharmaceutical companies, private donors, endemic countries and non-government organisations signed a pledge to control or eliminate 10 Neglected Tropical Diseases (NTDs) by 2020 - the London Declaration on Neglected Tropical Diseases. These diseases affect over 1 billion people globally,

DeWorm3 community health workers provide the medication 'albendazole' to families in trial areas in Benin, Malawi and India. The change in prevalence of infection is also analysed throughout the trial. © NHM

particularly in conditions of poverty and without adequate sanitation in both low- and middle-income countries. The human, economic and societal impacts of NTDs are significant and result in disabling chronic conditions, delayed growth and cognitive development, severe social stigma, and loss of economic productivity.

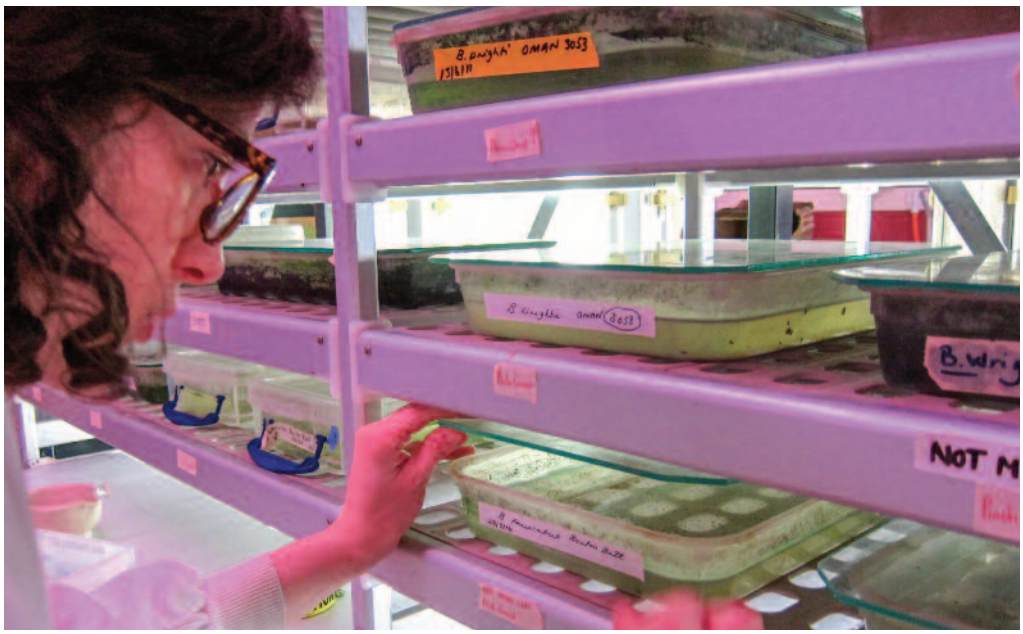
Intervention involving mass drug administration; improvements in sanitation and hygiene; and control of disease transmitting organisms has the potential to increase the feasibility of eliminating or controlling the diseases that form such a heavy burden on affected populations.

NTD programmes target the fulfilment of the UN's Sustainable Development Goals (SDG) of the 2030 Agenda for Sustainable Development calling for action to promote good health and wellbeing while also playing a role in reducing the financial burden of health care and providing clean water and sanitation amongst others.

THE MUSEUM WITHIN THE NTD LANDSCAPE

The momentum for beating NTDs has never been greater and the Natural History Museum's expertise in taxonomy, systematics, parasitology, field trials and treatment programmes is driving life-saving research into NTDs.

In the basement of the museum, a genetic archive of parasite and snail samples provides a key resource to support ground-breaking research into the NTD 'schistosomiasis'. The disease is caused by parasitic flatworms which infect specific types of freshwater snail. Inside the snail the parasites multiply and then emerge back into the freshwater to find and bury through a person's skin. Infections cause a chronic, debilitating disease that hampers learning and productivity, and damages organs. This can lead to dangerous outcomes such as organ failure, breathing difficulties, and reproductive problems - especially for girls and women.



Snails of the genera Bulinus and Biomphalaria, intermediate hosts of schistosome parasites, are preserved and archived in the museum's molecular collection facility. We also keep some live snails which enjoy a climate-controlled environment in the Wolfson Wellcome labs where they are served regular meals of dried lettuce, fish food and algae.

Within the NHM an array of freezers preserves the freshwater snails, with the most fragile of specimens stored at -180°C in giant liquid nitrogen vapour vats. Tissue samples collected by museum researchers in Tanzania, Niger, Senegal, Cote d'Ivoire, Uganda and Ethiopia are stored on cards that stabilise DNA at room temperature. Tracking the genetic diversity and structure of parasite populations over time allows researchers to monitor how parasites respond to various treatment strategies. It also allows parasite material collected from current outbreaks to be compared to archival material stored to track the origins and spread of infections. The Museum is designated a World Health Organization (WHO) collaborating centre for the identification and characterisation of schistosomes and their snail hosts.

The NHM's NTD collection is not all snails and worms. Assembled over a period of 150 years, the Museum holds a collection of insects that transmit the pathogens that cause a wide range of NTDs. Over 1.3 million specimens of insects – including mosquitoes, sand flies, black flies, tsetse flies and horse flies – are in the collection. A nearly completed project on UK mosquitoes will aid in monitoring for the spread of mosquito populations and serve as a platform for DNA-based diagnostics and monitoring.

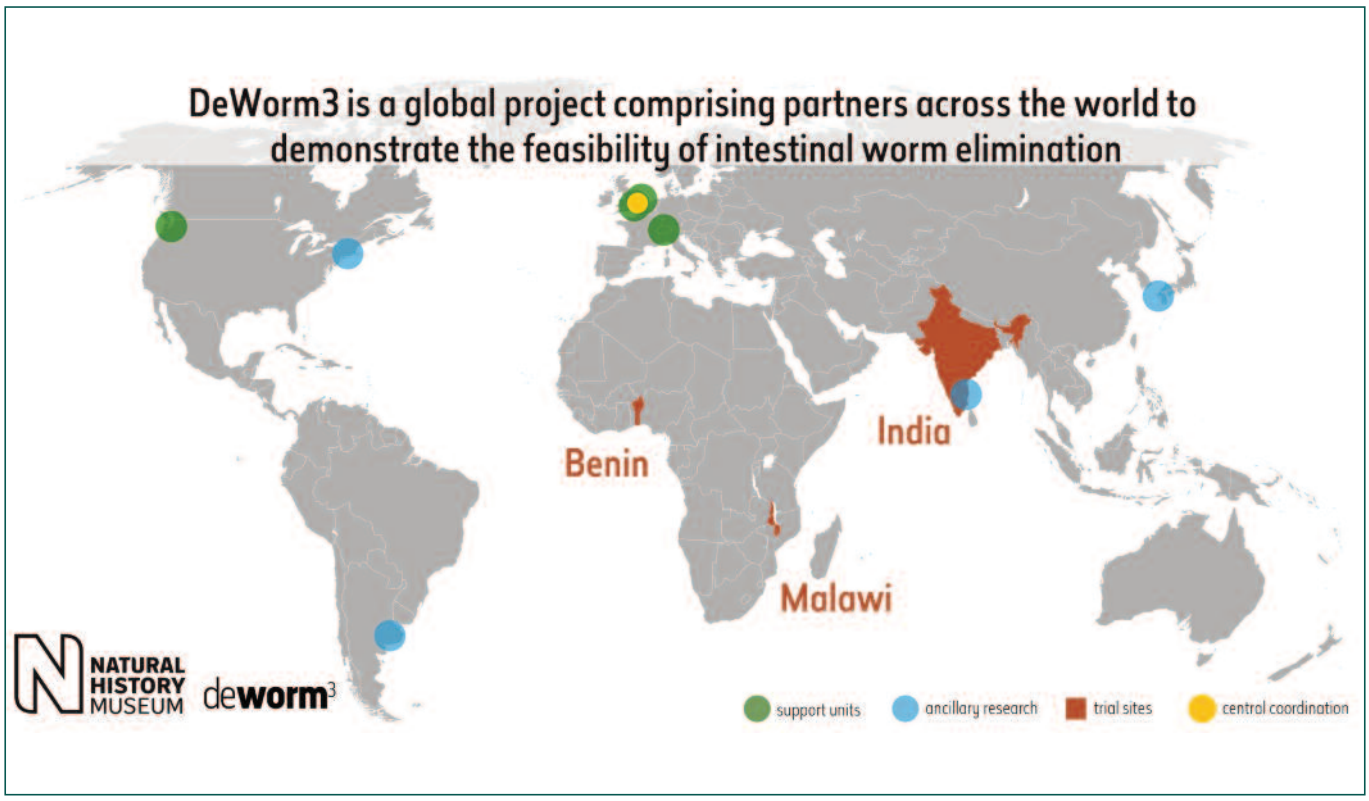
These collections provide a unique opportunity to travel back in time, to study how geographic distributions and the genetic composition have changed in relation to factors that are vitally important to present day control efforts, such as drug and pesticide resistance genes. Such long-term changes cannot be evaluated by using modern laboratory strains.

The collections are being made available not only for researchers to tackle current questions, but are being developed for future researchers to tackle new questions.

Global access for scientists to these collections, and the information they contain, is being facilitated by an accelerating programme of specimen digitisation. New visualisation methodologies have the potential to deliver previously inconceivable insights into the interaction between parasites and vectors – for instance the lancet liver fluke lodging itself into the brain of an ant to manipulate its behaviour and enhance the chances of disease transmission to the final host.

THE REACH OF THE MUSEUM EXTENDS BEYOND THE BUILDINGS

In the fight to eliminate intestinal worms, the UK's Natural History Museum is leading a major international push - DeWorm3 - funded by the Bill and Melinda Gates Foundation. The Museum is prominent in UK research in NTDs, winning significant grant funding and acting as a founding partner of the London Centre for Neglected Tropical Disease Research (LCNTDR). The Museum provides the central operations hub and scientific



46 of the 53 Commonwealth countries are endemic for at least one NTD.

support for DeWorm3, particularly with the development and application of molecular techniques.

DeWorm3 brings together expertise from research centres across the globe to provide the evidence base to test if community-wide deworming can stop the transmission of soil-transmitted helminths compared to school-based deworming. With over 350,000 people across trial areas in Benin, India and Malawi, the trial is an immense undertaking comprising field visits, lab processing and comprehensive logistics. Each country trial is led by local partners in conjunction with the country level Ministry of Health. Detailed work on understanding the readiness and barriers for country-level change to transition to community-wide mass drug administration is also being undertaken to develop a programme that is sustainable and scalable in soil-transmitted helminth endemic areas. After 5 years a recommendation will be made to the World Health Organisation on the future of STH elimination.

More and more countries are announcing the elimination of various NTDs as a public health problem – the success of partnerships globally. With the announcement in March 2018 that Kenya is now Guinea worm free, the disease has now been eliminated in all Commonwealth countries. An immense achievement - 30 years ago, Guinea worm afflicted more than 3 million people in 20 countries.

Over 840 million people in 46 endemic Commonwealth countries are estimated to need treatment for at least one NTD that can be treated through drug delivery – and the good news is that 66% received that treatment in 2016 - however there remain over 280 million people who are yet to be reached.

At the NTD Summit in Geneva in April 2017 the UK government announced that £360 million would be invested on treatments and preventions to tackle NTDs between 2017-18 and 2021-22, more than double the average annual expenditure on NTD implementation. In addition, a further £88 million would be spent on research programmes looking for new drugs, diagnostics and better treatment programmes. A year later at the Commonwealth Heads of Government Meeting 2018, an extra £20 million of funding was committed to contribute to eliminating trachoma by providing vital sight-saving treatment.

THE PUSH TOWARDS CONTROL AND ELIMINATION

The gains since the signing of the London Declaration are made possible by the strong commitment of governments in countries where NTDs are endemic and by the front-line health workers involved in country programmes. The UK's contribution has also been remarkable, providing funding to reach communities affected by these diseases and to lead research innovation to prevent, detect and treat NTDs. The All-Party Group on Malaria and NTDs and the debates held in the House of Lords show committed and active engagement.

Maintaining commitments towards implementation and research is crucial in the fight to beat NTDs. Major progress is being made, and the future looks bright as we come together to address the neglected disease burden in some of the world's hardest to reach areas.

By Dr Tim Littlewood and Catherine Wheller, DeWorm3
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SCIENCE AND RESEARCH PARTNERSHIPS BETWEEN THE UK AND LATIN AMERICA ARE HELPING TO TACKLE GLOBAL DEVELOPMENT CHALLENGES

Dr Dan Korbel, Global Head of Science, British Council

Dr Sarah Honour, Head of Science and Innovation Strategy and ODA, Department for Business, Energy and Industrial Strategy

The authors would like to thank Mark Gardner, Kate Kilner, Dr Stephanie Renforth, Dr Conor Snowden and Emma Baker for their contributions.

More information about the Newton Fund and to view the 2018 Newton Prize shortlist, visit www.newtonfund.ac.uk

The Newton Fund was set up in 2014 by the UK's Department for Business, Energy and Industrial Strategy (BEIS). It uses science and innovation partnerships to tackle global development challenges such as extreme poverty, climate change and food security. It also set out to improve the research capacity of developing countries.

The Newton Fund allows UK researchers to work in partnership with counterparts in 17 countries around the world. It's one of the main ways (along with the Global Challenges Research Fund and the International Climate Fund) that BEIS contributes to the international development agenda. Money spent on development research with these countries contributes to the 0.7% of gross domestic income the UK government has committed to spend each year on official development assistance, and also contributes to the 2.4% target for UK research and development spending by 2027.

While BEIS manages the fund, independent and expert research funders known as 'delivery partners' develop and run projects and funding calls, and allocate and manage the money they receive as part of the Newton Fund.

What makes the Newton Fund unique is that each country is an equal partner in the fund, putting in matched funding or resources for every project. Partner countries also shape the strategic direction of the work, which means development is tailored and targeted at addressing research and development priorities. Equal partnership is a real strength of the fund and is cited by researchers as a valuable and innovative way to lead research design as well as achieving value for money for the UK taxpayer.

NEWTON FUND IN LATIN AMERICA

Latin America – generally defined as countries in the Americas where Spanish or Portuguese is the national language – has a wealth of excellent researchers and a human and natural diversity that enables an unparalleled range of high quality research. It boasts unique urban environments, high altitude deserts, and remote jungles allowing for research collaborations under the Newton Fund on themes as diverse as post conflict studies, biodiversity, health, renewable energy and earth observation.

There are five countries in Latin America engaged with the UK through the Newton Fund. They are: Brazil, Chile[1], Colombia, Mexico – these countries have been part of Newton since 2014 and Peru, which joined in 2017.

DELIVERY IN FOCUS: BRITISH COUNCIL

As a delivery partner under the Newton Fund, the British Council supports research and innovation partnerships between the UK and Latin America to address global challenges such as access to safe drinking water, dealing with the effects of climate change or limiting infectious diseases. Since 2014, awards made to Newton Fund grantees under the British Council Institutional Links programme have received £2.6 million in match funding and have leveraged additional funding of £1.6 million.

Impact: Safe water

The growing mining industry in Colombia is causing heavy metal pollution in lakes and rivers. Illegal mining alone is estimated to account for 63 per cent of the total mining activities and has led to the pollution of 19 rivers. This threatens local communities who are living along the river banks and whose livelihood and health depend on fishing and agriculture.

1 Chile recently graduated from the OECD DAC list, which means it was a high income country for three years running and is no longer eligible to receive official development assistance. The Newton Fund is now working with Chile to develop the science and innovation relationship, moving away from Chilean development challenges to focus on joint working to address global development challenges.

Researchers from University of Bath and Universidad de los Andes, supported by British Council via a Newton Fund grant, have developed a portable, cost-effective and user-friendly device that allows the effective monitoring of water. The device measures parameters such as pH and temperature and can detect heavy metals including mercury which is often used in gold mining. The data is sentto a web-based platform and made available to the public worldwide.

Local communities can use the device to instantly check if their water is safe to use. It allows them to measure pollution effectively and raise concerns with Colombian authorities and policy-makers to ensure that vulnerable ecosystems are protected. The new technology will not only benefit Colombia. People around the world will be able to use it to minimise environmental impacts and protect public health.

"The only real way to prevent the use of contaminated water is to give the tool to the communities themselves so that they can check whether the water that they are using on a daily basis is safe to consume or not." Dr Mirella Di Lorenzo, University of Bath.

Impact: Fighting Dengue Fever

Dengue fever is the most rapidly spreading mosquito-borne viral disease in the world. Estimates indicate 390 million people are infected every year, with Mexico accounting for 6.3 percent of all cases. A group of researchers from Oxford and several partner universities in Mexico have set out to find a pioneering universal vaccine against the disease.

Led by Professor Reyes-Sandoval, the group secured funding from the Newton Fund via the British Council's Institutional Links programme to conduct research in Mexico where the virus is particularly prevalent. The funding bought vital equipment and enabled scientists from both countries to work face-to-face and share their expertise. It also supported the mobility of 10 scientists from Mexico to Oxford to further build their capacity in the field. The group have now secured funding to transfer their research to industry, with a UK patent pending.

The study indicated that nearly everyone tested responded to the vaccine antigen. And, if taken into production, the vaccine could be essential for travellers going overseas. The work also helped to establish a growing consortium of scientists in Mexico and the UK with a common interest in studying viruses, further fostering collaboration and relationships between the two countries.

"The funding brought me closer to scientists in Mexico and also to people that were interested in supporting the vaccine development." - Professor Arturo Reyes-Sandoval

Impact: Communicating in a disaster

Other programmes, such as the Leaders in Innovation Fellowships (LIF) run by the Royal Academy of Engineering, build the capacity of researchers for entrepreneurship and commercialisation of their research. Among LIF alumni is Chilean engineer, Barbarita Lara, who has developed a quick, reliable and low-cost solution to communicate emergency information during natural disasters. Barbarita was recently named one of Massachusetts Institute of Technology Technology Review's Innovators Under 35 Latin America.

Impact: Understanding Climate Change

The Climate Science for Service Partnership (CSSP) Brazil – is a research project between the UK's Met Office and key Brazilian scientific institutes, which is facilitating the development of services to strengthen the resilience of vulnerable communities to weather and climate variability. Combining UK and Brazilian expertise allows us to understand the risks and causes of climate related extreme weather, inform decision making and contribute to disaster risk reduction in Brazil, the UK and around the world.

Supporting peace and security

Official Development Assistance research and innovation plays a valuable role in delivering the government's foreign policy and national security objectives, supporting peace and security and improving diplomatic relations. The Newton Fund has created nine government to government partnerships, paving the way for 23 other funding agreements between delivery partners.

A total of £152m of Newton funding will be invested with these countries until 2021 and this is matched by the partner countries. The meaningful partnerships built through the Newton Fund act as catalysts to unlock opportunities for wider collaboration beyond development. They also help secure the UK's position as the international research partner of choice.

Colombia is one example of the Fund's ability to deliver science diplomatic results. The UK was recently guest of honour at FIMA, Colombia's international environment fair attended by President Santos and his Minister of the Environment, Luis Gilberto Murillo. At FIMA the Colombia BIO programme, which is supported by the Newton Fund, was praised as being a major contributing factor to strengthening the relations between the UK and Colombia. The Newton Fund is also a key element of the 2018/19 UK-Brazil Year of Science and Innovation, a joint initiative led by the UK and Brazilian governments. It builds on the long history of joint, world class partnerships between the two nations and the significant results achieved. The Year of Science and Innovation provides an opportunity for scientists, entrepreneurs and British and Brazilian companies to celebrate existing and new joint research in light of the key global challenges we face and supports the UK's Industrial Strategy.

The Newton Fund is only four years old but has already been recognised as demonstrating impact in the research community, and in society more widely. This year, Latin American partner countries are playing host to the Newton Prize, a £1m fund which will advance the work of the best projects funded through the Fund. The prize is designed to showcase research excellence and will involve a series of events and public engagement in the UK and Latin America and will be overseen by Professor Sir Venki Ramakrishnan, Nobel Prize winner, President of the Royal Society and chair of the Newton Prize committee.

The world-class research base that we have in the UK needs to have international reach, and perhaps it because of its international reach that we have a world-class research base. This is the virtuous circle of international research collaboration. The Newton Fund gives our scientists and researchers access and opportunity to address the most important global challenges of our time with research teams and local knowledge and resources from partner countries.

DIGITAL PATHOLOGY – FUTURE PROOFING CANCER DIAGNOSTIC SERVICES

Dr Bethany Williams, PhD Fellow in Digital Pathology, Leeds Teaching Hospitals NHS Trust and the University of Leeds

Digital pathology is a technology which has the potential to revolutionise the way in which pathology services are delivered, offering a flexible platform for safety, quality and efficiency improvements in cancer diagnostics, while future-proofing an increasingly pressured medical specialty. Leeds Teaching Hospitals NHS Trust and the University of Leeds, in collaboration with Leica Biosystems, have completed an innovative pilot project to utilise digital diagnostic images, and are now in the process of a large scale clinical digitisation.

In conventional pathology workflows, tissue is taken from a patient, examined and dissected by a pathologist, mounted on glass slides and stained for a pathologist to view it down a microscope and make a diagnosis. (Figure 1). This pathway hasn't changed dramatically in 100 years. In digital pathology, an extra step is added to the pathway. Glass slides are scanned at high resolution using a microscope lens, and the acquired image is compressed and stored. The digital slide is then streamed to a pathologist, who can view the image using specialist software on a computer screen and make their diagnosis. The process of scanning a slide to create a diagnostic image is known as whole slide imaging. (Figure 2)

So why would we want to use digital pathology? We are facing what Cancer Research UK have called "testing times". Diagnostic pathology services face the challenge of an increasing workload, both in terms of volume and data complexity of cancer specimens and pressure to maintain or improve on diagnostic turnaround times. In the UK, year on year, the volume of cellular pathology requests received by laboratories has increased by an average of 4.5%.[1]

The drive to identify pre-cancers and early stage cancers adds to the complexity of histopathological assessment, when morphology can be harder, and more time consuming to interpret. Pathologists are required to identify subtler pathologies in smaller diagnostic specimens. In addition to an increase in specimen requests, the pathologist is required to take more blocks and make more slides for each cancer specimen. Increased demand has resulted in a negative impact on turnaround times, with data for England showing that the number of patients waiting more than 6 weeks for diagnostics in pathology has been increasing at approximately 17% per year since 2010–2011, with the majority of delays waiting for histopathology.[2] Data from the Royal College of Pathologists

Figure 1: Conventional light microscopy. Image courtesy of Alex Wright, University of Leeds.

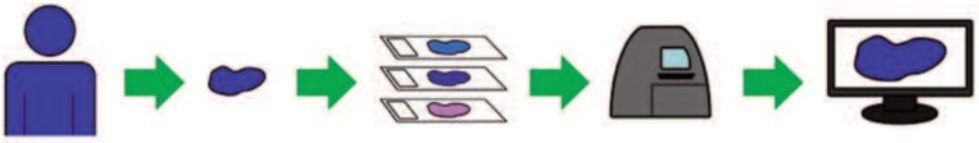

Figure 2: Digital microscopy. Image courtesy of Alex Wright, University of Leeds.

show that 32% of cellular pathologists are over the age of 55 (615 people), and are expected to retire in the next 5 years. [1] Meanwhile, from August 2015 to June 2016, only 52 trainees in histopathology were recommended to the General Medical Council for completion of training.

Cancer Research UK highlights the need to ensure pathology services maximise efficiency, with networking and consolidation of pathology services prioritised. In light of increasing costs for staff overtime and outsourcing, optimisation of the pathology workforce is vital. Improved retention of near-retirement consultants, and increased efforts to drive recruitment in medical schools have been proposed, but these measures are not sufficient to solve the problem. The report recommends that departments and trusts should invest in infrastructure to support digital pathology, and that on-screen examination of histological slides should be used to enable more efficient networked services. This sentiment is echoed in the Nuffield Trust's publication—'The Future of Pathology' which states that 'without change it will be difficult to maintain an adequately skilled workforce in many areas of the country'. [3]

Given this perfect storm, how can we best future proof our cancer diagnostic services? At least part of the answer may lie in digital pathology.

Digital pathology has the potential to alleviate some of the pressures faced by the modern diagnostic departments, offering a flexible platform for safety, quality and efficiency improvements, whilst future-proofing pathology services and allowing closer matching of reporting capacity and demand. The principal benefits of a digitized reporting service can be broadly divided into four categories: improvements in patient safety, improvements in diagnostic workflow, improvements in workforce factors, and improvements in over-all service quality.

The flexibility and agility of digital pathology systems allows for a number of improvements to the diagnostic workflow, including the ability to manipulate workload allocations by pushing and pulling of cases to respond to fluctuations in workload or case mix in a department. Rapid case tracking, archiving and retrieval, and faster case transfer times between the laboratory and primary pathologist, and the pathologist and internal or external second opinion pathologists should streamline turnaround times and diagnostic pathways. Given the strategic context outlined above, improvements in workforce factors are some of the key benefits service managers seek to capitalise on in a digital deployment. The innate flexibility of the digital diagnosis offers the potential for diverse and appealing patterns of work, freeing the diagnostician from geographical and temporal constraints on where and when they work. Digital reporting can enable optimisation of the workforce, supporting those that work less than full time to maximise the hours they can offer, and providing an incentive for those considering retirement to continue to offer their services on more flexible terms. Working arrangements more conducive to "work - life balance" are likely to appeal to the next generation of pathologists, and drive recruitment of medical graduates into the specialty.

Improvements in service quality are likely to follow from the myriad workflow and workforce improvements already outlined. Improved information sharing and collaboration, in particular streamlined double reporting and rapid access to second opinion can lead to better quality diagnosis, and accuracy and convenience of the recording of cancer staging parameters could drive up the quality and reproducibility of cancer dataset reporting.

Finally, we should consider patient safety, surely the cornerstone of clinical decision making. Use of an integrated digital pathology system offers obvious advantages, with paperless transmission of digital slides directly to the pathologist lessening the possibility of a misidentification or transposition error at multiple points in the diagnostic workflow. Furthermore, digital slides offer a readily portable, instantaneously transmissible diagnostic image which is not subject to the physical limitations frailties and risks of glass slides and their transport.

The benefits of a histopathology laboratory digitisation can be felt at multiple levels – from the patient who stands to benefit from patient safety improvements and faster time to diagnosis, to the pathologist who can benefit from a streamlined workflow, the institution which can reap efficiency savings. And the broader regional network which can benefit from pooling of reporting expertise and capacity.

So why aren't we all digital pathologists already? There are 3 major challenges which stand as barriers to widespread adoption.

1. Significant investment is needed to develop digital pathology networks.
2. IT networks that support digital pathology will have to have sufficient capacity and storage to accommodate large files containing digital images and be robust enough to ensure the patient confidentiality is protected.
3. Pathologists are medical professionals, who may have 10, 20 or 30 years' experience with the light microscope. The switch to digital pathology requires them to modify their practice and become familiar with the subtle differences between digital images and light microscopy. Pathologists need opportunities to engage with digital reporting, train in the use of microscope software, and modify their reporting practice, without compromising patient safety.

The Royal College of Pathologists has a newly appointed lead for digital pathology, Dr Darren Treanor, and has developed a strategy and guideline for digital pathology adoption in the UK,[4 5] which hopes to address some of these barriers to adoption, and encourage best standards in digital reporting. The College recognises the need for digital pathology and its potential utility in benefitting patients, and supports the safe adoption of the technology in the NHS. It has recently published detailed guidelines for pathologists seeking to use digital pathology to make diagnoses, including practical steps for "validation" to ensure that patient safety is maintained. In addition to replacing the light microscope with the digital microscope, use of digital images in routine diagnostics opens the door for the development and use of augmented intelligence/ computer assisted diagnosis, which could free the pathologist from some of the more onerous and repetitive tasks (e.g. counting and quantifying

parameters) and allow them to concentrate on the more intellectual facets of complex pathological interpretation.

In conclusion, digital pathology offers the flexibility to redesign and improve pathology diagnostic services in the NHS.

- Digital pathology benefits patients by improving safety, streamlining access to expert opinion and dual reporting.
- It improves the workflow and connectivity of laboratories and increases flexibility and efficiency of the workforce.
- Investment is needed in infrastructure, including IT systems, staffing and training.
- The NHS is positioned to lead the world in patient safety focused, evidence based clinical digital pathology deployment.

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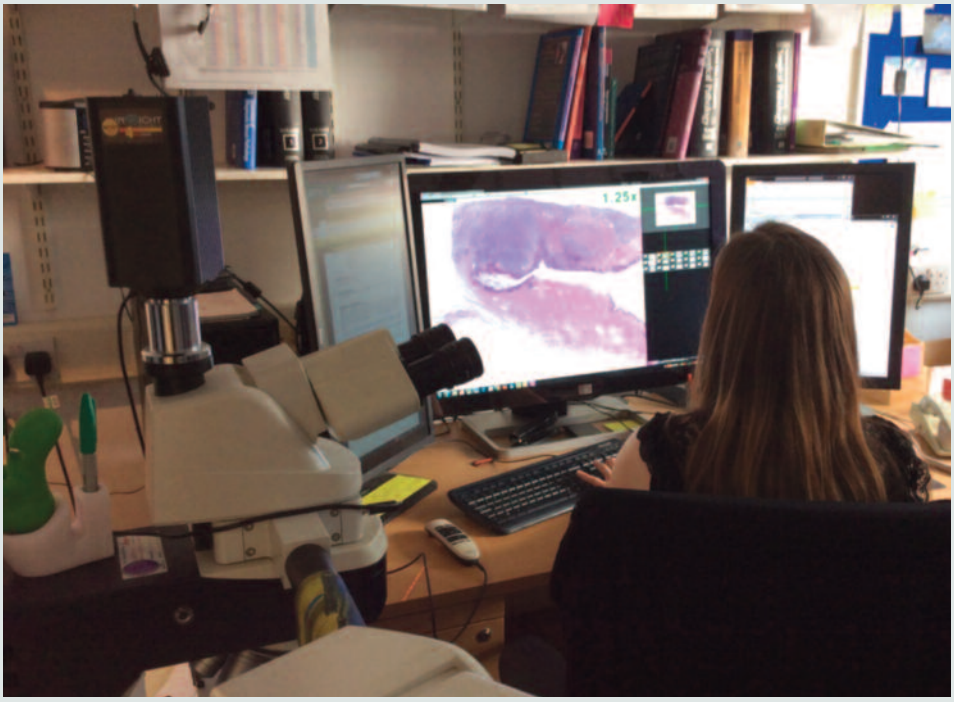
LEEDS TEACHING HOSPITALS NHS AND DIGITAL PATHOLOGY

We are the most long established digital pathology project in Europe, with a proven track record in delivering quality digital pathology research and innovations – including our free access website, http://www.virtualpathology.leeds.ac.uk/, where public and professionals alike can access our digital slide library, educational and research materials.

Leeds Teaching Hospitals NHS Trust has a collaborative partnership with Leica Biosystems for a 100% digital pathology clinical deployment. Our experienced digital pathology research team is capturing data on the benefits of clinical digitisation, developing deployment tools and protocols to aid the transition of over departments to digital practice. As part of this partnership, we have already digitized our breast and neuropathology diagnostic services, and this year we will continue to roll out digital pathology sub-specialty by sub-specialty, and start using digital slides for our multidiscliplinary team and cancer review meetings.

We currently scan 30% of our slide output for primary digital diagnosis – which represent the entirety of our breast and neuropathology workload. Cases are viewed by our pathologists on custom workstations with high resolution, medical grade monitors.

At Leeds, we are passionate about evidence based practice, and want to ensure that the benefits of digital pathology are harnessed without compromising patient safety, or our own professional standards. In line with this, we are the first team to systematically analyse the evidence base, to investigate the patient safety implications, and to design the world's first evidence based training and validation protocol to help pathologists transition to digital reporting.



Dr Millican Slater, consultant pathologist at Leeds Teaching Hospitals NHS Trust, at her digital pathology workstation.

We hold regular free workshops in Leeds, where we offer advice and hands on experience of digital reporting. These attract attendees from Europe and the United States, and we are invited to travel the world to share our knowledge and experience.

In our work we have demonstrated, that when given access to a quality training and self-validation programme, our pathologists are able to make 99% of their diagnoses on the digital microscope, meaning that in our department, the light microscope will soon be for emergency use only. [6]

To find out more about our project, refer to our website, or contact Dr Bethany Williams Bethany.williams2@nhs.net

THESE 10 GREEN CHEMICALS COULD GIVE UK INDUSTRY A BRIGHT FUTURE AND HELP MEET ENVIRONMENTAL TARGETS

Simon McQueen-Mason, Network Director of The Lignocellulosic Biorefinery Network (LBNet), part of The Biotechnology and Biological Sciences Research Council Network (BBSRC)

The UK once had the world's leading chemicals industry, and even now employs 105,000 people, generating a gross added value of £9bn per year.

But this industry is changing. Many existing chemicals – derived from petroleum - will gradually fall out of favour, and new bio-based chemicals will replace many of them. This will be driven by inevitable global trends, rising costs of petroleum, consumer demand for sustainably produced products, and ethical and regulatory drivers pushing companies to reduce emissions and landfill.

The UK has world-leading expertise – in our universities, startups, and corporate R&D departments - in the science that will underpin the bio-based chemicals of the future. To ensure this translates into commercial advantage, and to ensure the value stays in the UK, we need policy support to advance existing chemicals and find ways to produce them competitively at commercial scale.

A recent report commissioned by LBNet carried out a rigorous analysis of the industry's strengths and weaknesses to date and recommended a way forward. Our recommended approach – based partly on a successful US policy – is to focus on ten bio-based chemicals (Figure 1) where the UK stands the best chance to lead the world.

These ten chemicals – identified by the report – all present a long-term business opportunities for the UK, driven by real demand, and where the UK already has strong foundations and infrastructure to commercialise them. With the right support, these chemicals are expected to create short-term advantage from areas where we already have a global lead, whilst creating the infrastructure and networks to allow other early stage bio-based chemicals to be developed.

01	**LACTIC ACID:** Used to make PolyLactic Acid (PLA), which can form biodegradable plastics
02	**2,5-FURANDICARBOXYLIC ACID (FDCA):** Can be used to make polymers such as PEF, a stronger alternative to PET, which is a fibre used to make plastic bottles, food packaging and carpets
03	**LEVOGLUCOSENONE:** A safer alternative to harmful solvents used in pharmaceutical manufacturing, and also used in flavours and fragrances.
04	**5 HYDROXYMETHYL FURFURAL (HMF):** A versatile chemical with potential to replace chemicals used in plastics and polyesters, and for producing high energy biofuel
05	**MUCONIC ACID:** Derivatives could replace non-sustainable chemicals used in the production of PET and nylon fibres
06	**ITACONIC ACID:** A replacement for petroleum-based acrylic acid, used to make absorbent materials for nappies; and resins used in high-performance marine and automotive components
07	**1,3-BUTANEDIOL (1,3-BDO):** A building block for many high value products including pheromones, fragrances, insecticides, antibiotics and synthetic rubber
08	**GLUCARIC ACID:** Prevents deposits of limescale and dirt on fabric or dishes, providing a green replacement for phosphate-based detergents
09	**LEVULINIC ACID:** Used in the production of environmentally friendly herbicides, fruity flavour and fragrance ingredients, skin creams and degreasers
10	**N-BUTANOL:** Used in a wide range of polymers and plastics, as a solvent in a wide variety of chemical and textile processes and as a paint thinner

Figure 1

WHAT ARE BIO-BASED CHEMICALS AND WHY DO WE NEED THEM?

The chemical industry has traditionally obtained chemicals

from materials dug out of the ground, liberating carbon that was sequested millions of years ago. Most polymers, plastics, textiles, pharmaceuticals and cosmetics are largely derived from oil and gas fossil fuels. Manufacturing clothes, plastics, pharmaceuticals, etc, involves multiple chemical steps to turn that oil and gas into useful chemicals, and to combine them to create a commercial product.

Bio-based chemicals on the other hand are obtained from plant- or animal-based feedstocks, including sugar, starch, oils and fats, or biomass from crops and organic waste. They are chemicals derived from carbon which has been recently taken out of the air.

Chemicals from sustainably grown crops could replace chemicals from oil and gas

Many similar useful chemicals could be produced from bio-based sources instead of fossil fuels. A different set chemical steps are required - but the resulting bio-based chemicals can have similar or improved properties compared with fossil fuel-derived chemicals. And they have the advantage of being produced in a low-carbon, sustainable way.

WHERE DOES THE UK STAND NOW?

The UK is already ahead of the game in this disruptive industry. We have world leading bio-based chemicals research in our universities, startups and corporate R&D. And we have established supply chains to buyers of these chemicals at home and abroad - innovative manufacturers in clothing, automotive, aerospace, and packaging to name just a few – who want new bio-based chemicals to replace fossil fuel-based ones.

We now need to bridge this gap, scaling up promising R&D to produce commercially affordable chemicals to meet a growing demand. The ten chemicals identified represent the best opportunities to do this, with many UK companies and research groups already showing huge potential.

Biome Bioplastics is one UK biochemistry success story. Alongside academic partners, Biome is currently producing FDCA from natural sugars. First, the bio-based chemical HMF is produced from a sugar dehydration process, then this is turned into FDCA by bio-oxidation. Finally, the FDCA is polymerised to produce a polyester co-polymer that can be used in biodegradable food packaging. Biome is now scaling elements of this process up. Biodegradable plastics such as these will be critical to achieving the government's goal of zero avoidable plastic waste by 2042.

Biome is one of the UK's more advanced bio-based chemical companies. Its success so far owes a large part to being able to access academic expertise and facilities.

Another promising application of a Top Ten chemical comes from Chester-based Itaconix, which has patented a process for making ingredients from itaconic acid. These are sold to personal care and homecare manufacturers for laundry and dishwasher powders, and hair products.

Itaconix already makes sales where sustainability or functionality provide competitive advantage. Competing on price with petroleum-derived chemicals would open a multi-billion-dollar global market, something Itaconix believes will happen eventually as crude oil prices rise and production costs go down. But it could happen much sooner with the right policy support, such as investment in UK science, and incentives for companies to build fermentation and processing plants.

Any bold vision for a future industry must look beyond our borders to attract expertise and investment from abroad. We have already shown we are capable of this in bio- based chemicals. Australian company **Circa**, which produces levoglucosenone from waste wood, recently decided to establish strategic assets in the UK and recruit locally.

This stemmed from a collaboration with The University of York, which showed Circa's levoglucosenone could be used to produce a solvent – subsequently patented as Cyrene™ - with applications in manufacturing processes, water filtration, batteries, and even graffiti removal.

In being interviewed for our report, Fabien Deswarte of Circa, emphasised the strong incentive

FDCA can offer a sustainable alternative to chemicals widely used in food packaging

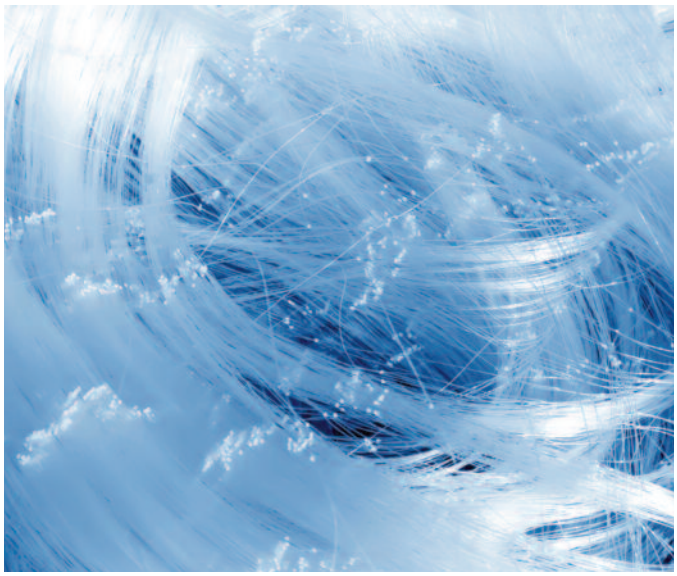
for international companies to invest in teams and facilities here, noting our world class academic expertise and praising the UK government's focus on bringing together industry and academia.

HOW SHOULD GOVERNMENT SUPPORT THE UK'S BIO-BASED CHEMICALS INDUSTRY

The above show just three examples of where we are already succeeding, and the potential we have to do more

Right now, most UK activities are early stage. Moving from research and lab-scale tests to commercial products is an area where the UK traditionally falls down. To ensure that we lead the disruption – rather than have our research commercialised abroad - we need to focus and play to our strengths. To harness this opportunity, we call on the government to take the following steps:

1. **Focus:** The UKBiochem10 list has been compiled by experts to represent the gold standard in opportunities for the UK's chemical industry. It should be the starting point for focusing resources on exploiting value from bio-based chemicals.
2. **Increased support for academic-business collaborations:** Good partnerships and interactions between SMEs and universities are critical in moving chemicals from the lab into manufacturing. Existing networks which facilitate these relationships should continue to be supported by government, industry and academia, particularly through BBSRC and EPSRC.
3. **Support UK science capability:** Research funding should include a focus on developing cost-effective ways to produce these chemicals and their derivativities, and on ways to scale them up to commercial products.
4. **Build UK scale up and testing capabilities:** There needs to be further investment in developing easy-access test and scale up services, including open access piloting and demonstration facilities, for researchers and startups. Technology advances in feedstock pre-treatment and the supply of low cost renewable sugars will also be an important enabler for the development of bio-based chemicals.
5. **Incentivise use of bio-based materials:** Policy should incentivise use of bio-based chemicals to accelerate market uptake. For example, in 2017 France mandated compostable materials for supermarket bags and packaging, leading to growth in its biomaterials industry. The UK should investigate and implement similar policies designed to promote the bio-based chemicals in this report.



Muconic acid derived polymers could replace non-sustainable chemicals used in nylon fibres

Bio-based chemicals represent a dynamic area of innovation in the UK, one that can create growth, trade, investment, and jobs. Such support would contribute to the sustainable growth of the UK chemical industry and could generate significant value to the UK economy.

Just as fossil fuels underpinned the development of now ubiquitous plastics, textiles, pharmaceuticals and cosmetics in the last century, bio-based chemicals could do the same in the next century. Investment and policy support for R&D and scale up will allow the UK to be a leader in this important emerging field.

The full report can be viewed here: https://lb-net.net/wp-content/uploads/2018/05/UKBioChem10_Report.pdf

To discuss the opportunities presented, contact Simon McQueen Mason: simon.mcqueenmason@york.ac.uk

Glucaric acid could replace 4.5 million tonnes of environmentally damaging phosphate based detergent chemicals

PARLIAMENTARY LINKS DAY 2018

To say it was standing room only at this year's Parliamentary Links Day on 26 June would be an understatement.

The Attlee Suite was packed to capacity for this 30th Annual Parliamentary Links Day organised once again on behalf of the science and engineering community by the Royal Society of Biology [RSB]. This year's theme was Science and the Industrial Strategy.

Parliamentary Links Day – which is the annual meeting of scientists and MPs – is the largest science event in the annual Parliamentary calendar and for the tenth consecutive time it was launched by Mr Speaker. Organised by the RSB the event allows hundreds of scientists and representatives from the science and engineering community to engage with MPs, peers and policy-makers in the Houses of Parliament.

It featured keynote speakers from Parliament, Government and the science community including the new Government Chief Scientific Adviser, Dr Patrick Vallance, who was making his first appearance at a Links Day.

Commenting on the most well-attended Links Day on record the Speaker of the House of Commons Rt Hon John Bercow MP observed that he had "never seen so many people" in the Attlee Suite and the Shadow Minister for Industrial Strategy Chi Onwurah MP later said that it was "standing room only for science".

This year's event saw two panel discussions with sector leaders discussing challenges facing the science sector, including the Industrial Strategy and its delivery, the uptake and retention of science for school pupils, increasing diversity and accessibility and the potential

Panel A with Carol Monaghan MP (last on right)

Chi Onwurah MP

Rt Hon Norman Lamb MP

landscape of the sector post-Brexit.

The first panel, chaired by the BBC's science correspondent Pallab Ghosh, discussed "The Target" of the Industrial Strategy, with audience members invited to pose their own questions to the sector leaders.

As part of the event, the Cabinet-level Minister for Business, Energy and Industrial Strategy Rt Hon Claire Perry MP gave a keynote address on the Government's Industrial Strategy, published in November last year. She said the proposals represented a "profound statement" of the Government's long-term commitment to science and that the target to increase R&D spending by up to £80bn over the next 10 years was the largest funding boost the sector had seen in 40 years.

Perry said an Independent Industrial Strategy Council was being set up to ensure the Government was delivering on the strategy's aims for innovation, productivity and excellence in various locations across the country.

The Chair of the Commons Science and Technology Select Committee, Rt Hon Norman

Lamb MP, told delegates that the Committee will soon be publishing a blueprint on how to make the post-Brexit immigration system supportive of a skilled research and innovation workforce. The committee is also likely to launch an inquiry into how the Government's promised £80bn increase in R&D spending is distributed and how value for money could be guaranteed, said Lamb.

Rt Hon Clare Perry MP

Chi Onwurah MP told delegates that Labour would aim to create an "innovation nation, with science as part of our DNA". She said the party would aim to leverage more funding from the private sector and raise R&D spending to 3% of GDP, with further improvements to country-wide innovation backed by a £250bn transformation fund and the establishment of a national education service. "Our pledge is to democratise science and technology so that they benefit everybody," she said. Onwurah also said Labour would take action to improve diversity in science after years of slow progress.

Dr Patrick Vallance, the Government Chief Scientific Advisor, described how communicating science in an accessible way was key to informing good policy-making, highlighting the example of former UN Secretary-General Kofi Annan, whose understanding of African economies was transformed by data visualisation.

Dr Vallance also spoke of the importance of bringing the

Patrick Vallance CSA


Dr Hayaatun Sillem and Dr Sarah Main

Panel B

commercial sector into discussions about innovation strategy – noting that 165,000 people are employed in private sector R&D and more money is spent in this sector than on publicly-funded R&D.

The second panel discussion, also chaired by Pallab Ghosh, looked to cover "The Target" of the Industrial Strategy, and discussions touched on the delivery of the increased funding for R&D, and the future of STEM-based industries in the UK.

Closing the event, former Science and Technology Select Committee Chair Stephen Metcalfe MP read out a special message from the Prime Minister Theresa May welcoming "the presence in the House today of so many distinguished scientists and engineers from such a wide range of the UK's most prominent scientific societies." In her message the Prime Minister recognised the concerns that many scientists have about the impact of Brexit on attracting the best scientists to their institutions.

"I know how deeply British scientists value their collaboration with colleagues in other countries through EU-organised programmes...," May wrote. "That is why I have made clear that it is in the mutual interest of the UK and the EU for the UK to have the option to fully associate ourselves with the excellence-based European science and innovation programmes."

One of the most significant remarks of the morning was made at the start by Mr Speaker who has offered to host a "Science Lecture" as part of his Speakership's lecture series held in the State Apartments. This will be a fitting tribute to 30 consecutive years of Parliamentary Links Day.

Following the morning session the formal Links Day luncheon for 140 people was held in the House of Lords where over a dozen societies engaged with members of both Houses

Stephen Benn

Dr Stephen Benn and Mr Speaker

PARLIAMENTARY CO-SPONSORS:

Rt Hon Norman Lamb MP
Stephen Metcalfe MP
Carol Monaghan MP
Chi Onwurah MP

LINKS DAY KEYNOTE SPEAKERS:

Stephen Metcalfe MP, Member of the Science & Technology Select Committee and Chair of the All-Party Parliamentary & Scientific Committee

Rt Hon Claire Perry MP, Minister for Business, Energy and Industrial Strategy

Chi Onwurah MP, Shadow Minister for Industrial Strategy

Dr Patrick Vallance, Government Chief Scientific Advisor

Rebecca Endean, UKRI

Rt Hon Norman Lamb MP, Chair of the House of Commons Science and Technology Select Committee

PANEL SESSION A: THE MISSION

Jonathan Flint, Institute of Physics

John McGagh, Institution of Chemical Engineers

Professor Dame Carol Robinson, Royal Society of Chemistry

Dr Hetan Shah, Royal Statistical Society

Carol Monaghan MP

PANEL SESSION B: THE TARGET

Professor Peter Bruce, The Royal Society

Dr Louise Leong FRSB, Royal Society of Biology

Dr Sarah Main FRSB, Campaign for Science and Engineering

Dr Hayaatun Sillem, Royal Academy of Engineering

Professor Iain Gray, Royal Society of Edinburgh

Stephen Metcalfe MP

CAN WE END THE THREAT OF ANTI-MICROBIAL RESISTANCE ONCE AND FOR ALL?

Timothy Leighton FRS, FREng, FMedSci., Professor of Ultrasonics and Underwater Acoustics
Chair, NAMRIP (Network for AntiMicrobial Resistance and Infection Prevention)
Chair, HEFUA (Health Effects of Ultrasound in Air)
Institute of Sound and Vibration Research, University of Southampton, Southampton SO17 1BJ UK

WHAT IS ANTI-MICROBIAL RESISTANCE?

Microbes that exhibit Anti-Microbial Resistance (AMR) are resistant to existing disinfection cleaning or antimicrobial medication. Specifically, that is when bacteria, viruses, fungi and parasites (of, for example, the type that cause malaria) becoming respectively resistant to antibiotics, antivirals, anti-fungals, and anti-parasite drugs (the four categories of anti-microbial medication).

The inexorable increase of AMR threatens us as a society because (i) our increased expectations from healthcare (e.g. we expect treatments that would not be possible without effective antibiotics) and (ii) our overuse and in appropriate use of antimicrobial medication causes us increasingly to see more infections exhibiting AMR.

For thousands of years we relied on our skin to be our shield to protect us from the billions of microbes in our fields, food, and water. Infections did of course occur, usually when microbes got past the skin barrier via wounds and penetration, or when ingested or carried (often on dirty hands) to natural openings in our body (eyes, nose etc.). Prior to the second half of the 20th century, our use of antimicrobials was not on an industrial scale, so that whilst treatment affected the microbes present at the site of infection, it did not significantly affect the resistance of the billions of microbes in the reservoirs from which the infection usually originated (fields and forests, water supplies, sewage, food sources, people and animals etc.). Indeed, it could be argued that some bacteria already had some antibiotic resistance characteristics because of millions of years co-habiting with and fighting antibiotic-producing fungi, or surviving in environments that contained dilute forms of the agents we now use to kill microbes, and that the mechanisms they have to remove such chemicals from their cells coincidentally remove antibiotics as well.

Now, however, modern treatment has exacerbated the development of resistance in that reservoir, as a consequence of natural selection. When we inject or swallow anti-microbials, or use them routinely to wash hands and food etc., a dilute form of the chemical is urinated or washed into the water and sewage systems. From there it passes out into the vast reservoir of microbes in the wider world. There, the microbes that are susceptible to that drug or disinfectant are killed, shifting the balance of the surviving reservoir population so that a greater proportion are resistant to that agent, ready to cause future infections. Over time we therefore see an increased occurrence of AMR in infections that originate in that reservoir. (There are other routes by which a species can develop AMR, including direct transfer of genetic material, but here we will focus on the one outlined above because it is the a sufficient springboard for the arguments that follow and, in many ways, an engine that makes these other routes so much more devastating to society).

WHAT ARE THE IMPLICATIONS OF AMR?

Government-sponsored studies showed that, unless Anti-Microbial Resistance is tackled, it will by 2050 be causing more deaths than cancer and have cost the world economy more than the current size of the global economy [1].

In my opinion the most important word in the above paragraph is '*unless*'. One view of 'unless' is optimistic, containing a tacit assumption that scientists will find new antibiotics etc., then pharmaceutical companies will roll these out to billions of people and animals in an affordable way, and when resistance to these develops (as it will, being prone to natural selection as described above), scientists will again find another antimicrobial drug. Note that treatment must be global, since

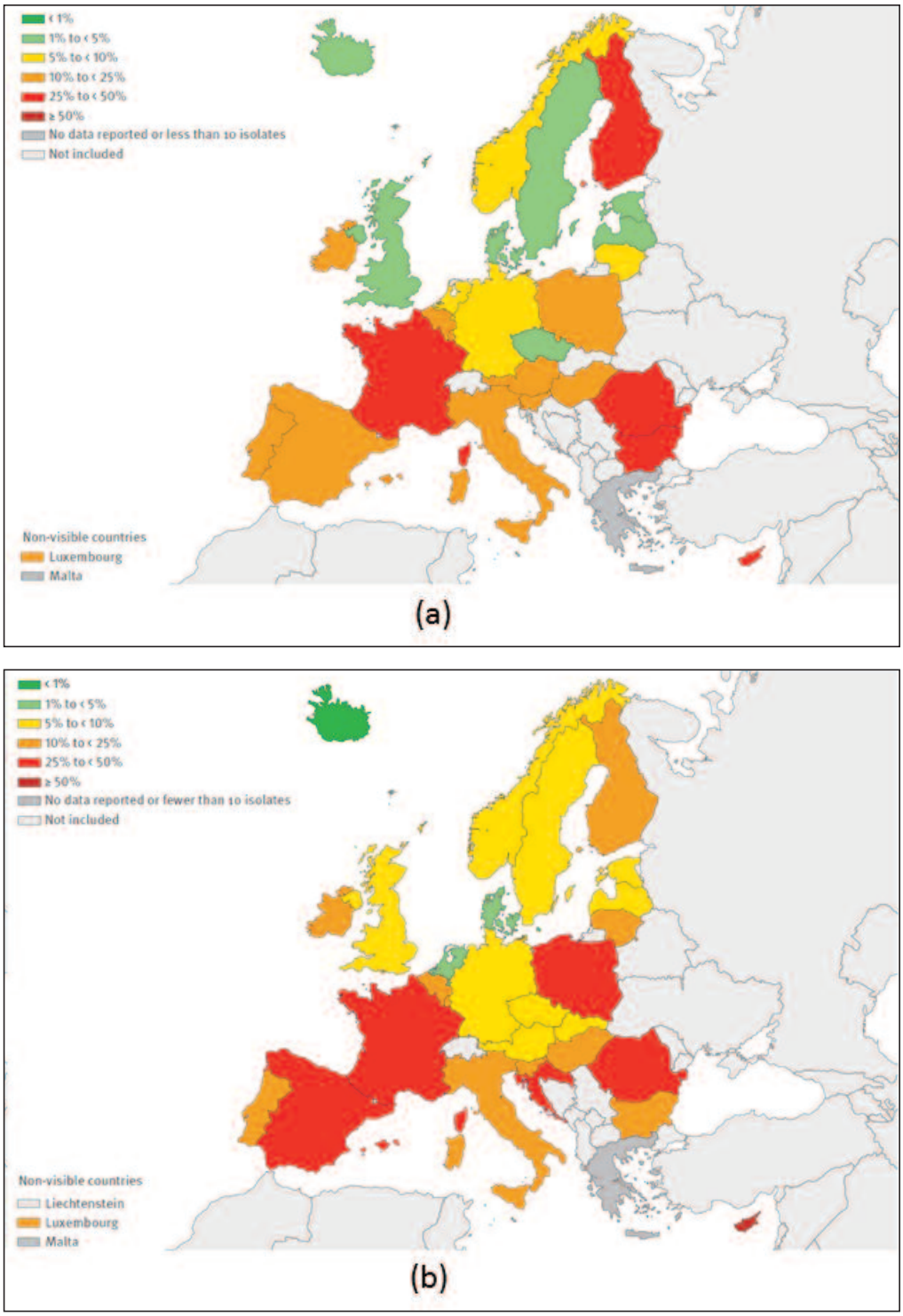


Figure 1. Maps showing increasing occurrence of resistance to the macrolide class on antibiotic as seen in samples of Streptococcus pneumoniae. The maps show the percentage (%) of invasive isolates non-susceptible to macrolides, by EU/EEA country, in (a) 2009 (from [3]) and (b) in 2016 (from [2]).

(with for example increased air travel) your next serious infection could have originated from elsewhere on the planet [2] (Figure 1).

Therefore, the yet-to-be-made discovery of a future new antibiotic (and news stories of such discoveries tend to be exaggerated) is only the start of the problem: the delivery of this new antibiotic on a global scale faces challenges, and if all this is accomplished, it might shift the 2050 date of the apocalypse on to perhaps 2065. As we approach this apocalypse, the political choices become particularly unpalatable: whilst it is excellent practice to avoid the unnecessary use of anti-microbials (to reduce the amount going into the wider world and promoting AMR through the natural selection process outlined above), as the apocalypse looms, logic raises horrific choices that cannot be forever postponed: do we ban the use of anti-microbials for pets? for farming and aquaculture? do some procedures for some patients become unsupported? Whilst logic produces these options, they are ethically appalling.

CAN WE AVOID THE APOCALYPSE?

It is not enough simply to throw money at chemists and pharmaceutical companies, trusting in the optimistic interpretation of 'unless' outlined above. We must address the fact that the 32 years to the 2050 apocalypse is close on the timescale for scientific discovery and global roll-out: and indeed in 10 years the pain of climbing the foothills of the AMR mountain will be obvious to all. After all, it is not the case that the alarm bell has just been rung, so scientists can quickly marshal solutions: on his acceptance of the Nobel Prize for discovering penicillin, the first antibiotic, in 1945, Fleming spelled out the threat of AMR, saying '*The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant*' [4]. Despite that warning 73 years ago, we have no solution, and indeed have discovered we promote AMR in other ways. Taking examples only from resistance to antibiotics, we promote AMR through use of antibiotics against viruses, and against bacteria that are not sensitive to that particular antibiotic; by using antibiotics as growth promoters in livestock and aquaculture and any changes in behaviour to circumvent rules against this [5]. Behaviour, and the social, cultural and financial pressures that drive this, underpin these drivers.

One way to hinder the development of AMR via natural selection is to prevent dilute forms of the agent that kills the microbes from reaching the reservoir population in the wider world. Whilst established internalized infections require drug treatment, one invention, StarStream, is aimed at preventing microbes from passing through our 'skin shield' by cleaning food, skin, surgical instruments and open wounds before those infections can become established, without the use of chemicals that act as 'smoking guns' in run-off that promote resistance developing in the wider world. StarStream is a handheld device (Figure 2) that sends microscopic air bubbles in a gentle stream of water, onto surfaces we wish to clean [6].

Figure 2. Professor Leighton demonstrates his invention by washing his hands with cold water and no soap.

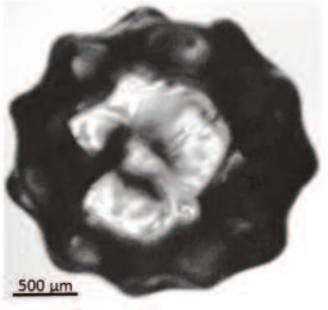


Figure 3. A bubble containing ultrasonically-induced surface waves which move rapidly over the bubble surface, 'scrubbing' the surroundings

It is currently being used in an NIHR-funded trial for gently decontaminating surgical instruments and endoscopes without the need for aggressive chemicals. Sound, produced in the handheld unit, is projected down StarStream's stream of water. That sound converts the spherical microbubbles into spiky, shimmering micro-scrubbing machines (Figure 3) which actively seek out the cracks and crevices that are particularly difficult to clean with chemicals, brushes and wipes. The scrubbing action of the bubbles removes the microbes and dirt from these crevices. StarStream's air, water and sound are active only when combined at the tip of the water stream, when it reaches the surface to be cleaned. By the time they reach the drain, they have reconverted back to simply air and water (with no sound) so that no 'smoking gun' clues go down the drains to drive natural selection in the wider world's microbe reservoir, and therefore no Anti-Microbial Resistance can develop.

The automatic response to, say, a bacterium, is to think about killing it, but we are in fact used to thinking in terms of beneficial bacteria in the gut, and know that our gut will not work perfectly if we harm these through, for example, taking oral antibiotics. A large proportion of our skin is also made up of beneficial bacteria, and if we harm these our skin will suffer, and we could (ironically) become more open to infection. We are working on ultrasonic devices which preserve these beneficial bacteria, whilst dislodging harmful ones from our skin.

Another device, StarHealer, not only cleans wounds, but also causes skin to grow over the wound very much more rapidly than would normally occur, restoring the 'skin shield' and so preventing infection. Equipped with a StarHealer nozzle that can attach to any bottle of drinking water, an army medic, rescue worker, rural healthcare worker or first responder could not only clean a wound prior to transportation to hospital, but promote rapid regrowth of skin over it, preventing further infection (Figure 4). This would reduce the likelihood of sepsis setting in in the time between injury and transportation to hospital (500,000 patients with severe sepsis are treated annually in US emergency departments [7], 100,000 of which are children [8,9]).

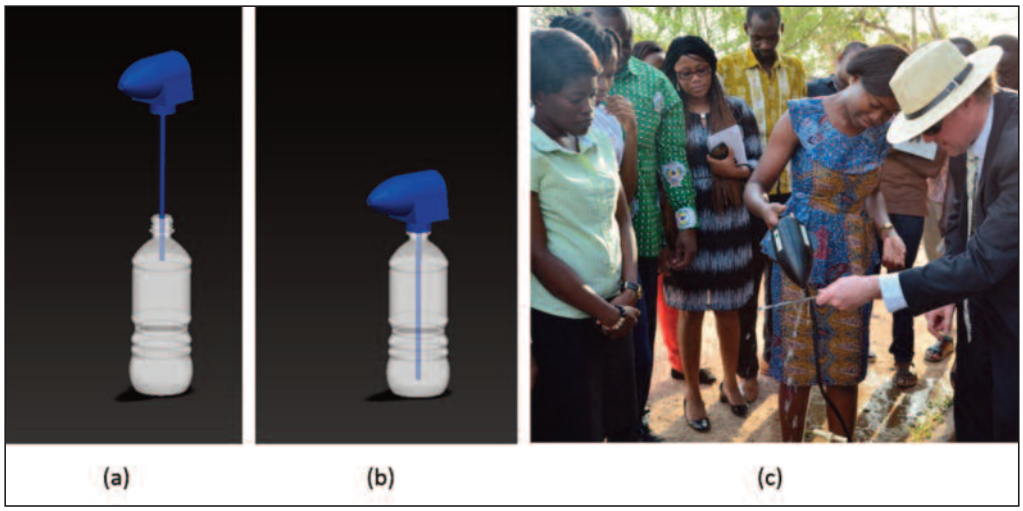


Figure 4. (a,b) Concept for a battery-powered solar-charged UAS device that can fit onto any bottled drinking water unit. For the video see https://youtu.be/o903Yey71L4 (c) Professor Leighton in rural Ghana in March 2018 demonstrating to healthcare and demographic surveillance staff how his technology can clean using just cold water.

These examples, all of which focus on infection prevention to avoid treatment of an established infection, illustrate that there are sometimes options to the use of anti-microbials, options that reduce the risk of resistance developing. However, to enable research breakthroughs to benefit society, they need to be designed to be easy-to-use by the end-user, cost-effective, and amenable for manufacturing on a large scale in the form of reliable products. Conducting game-changing research and translating it to benefit society are at the core of NAMRIP, the Network for Anti-Microbial Resistance and Infection Prevention [10], a network of over 200 researchers including engineers, chemists, microbiologists, environmental scientists, veterinary and human medics, clinicians, experts in food, ethics and law, crucially networked with economists, geographers, health scientists and experts from other social sciences. Our members also include people from hospitals, veterinarian practices, industries, charities and policy-making bodies, because of the imperative to translate research as well as conduct and publish it. Membership has spread across the UK, and one year ago we formed Global-NAMRIP [11], with members across four continents. NAMRIP builds the right multidisciplinary consortium to identify (with end user input) the real problem, and design an

Figure 5. The public play 'The Most Dangerous Game in the World' at the Science Museum to learn about AMR.

effective solution that is not going to be unusable because of end user constraints in terms of training, infrastructure, economics, scalability, culture, social mores etc.

In NAMRIP, we have an award-winning programme for engagement with the Public and Policymakers, which includes a permanent exhibition that was mentioned by Steve Brine MP, the Under-Secretary of State for Health [12,13] (Figure 5). Dialogue with the public is vital because many people outside of science have been poorly educated to believe AMR is the development of resistance to antibiotics by humans. This is not only incorrect, but encourages the very behaviour that promotes the growth of AMR. We have not learned the lesson Fleming gave us, more than 70 years ago, in his 1945 Nobel Prize acceptance speech.

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MEDICAL DETECTION DOGS

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Medical Detection Dogs

The association between humans and dogs is long and close. Throughout history, dogs have fulfilled a whole range of different functions and the number and diversity is continually expanding. Whilst traditionally dogs have been trained to hunt, herd and guard, more recently canine roles have grown to a range of medical support and disease detection tasks.

As medical usage expands, it is imperative that the value of these dogs is objectively assessed, their potential capabilities are optimised and we use these abilities to further our understanding of the diseases in question. Medical Detection Dogs (MDD) is the world leader at training dogs for this purpose, pioneering both medical assistance and disease detection. The charity is committed to carrying out empirical research to improve training and to inform future medical technologies.

To further this aim, MDD is currently working on a range of NHS approved clinical trials, exploring dogs' ability to locate urological cancers – with a promising prostate cancer trial ongoing, and colorectal cancer. MDD is also researching the volatile detection of the malaria parasite and Parkinson's disease. The other arm of MDD, Medical Alert Assistance Dogs, uses olfactory alerting ability for day to day support for people living with chronic conditions.

OUR WORK

There is growing evidence that elevated levels of a 'signature' of volatile organic compounds (VOCs) are associated with disease growth. Our research has shown dogs can be trained to detect these odours and identify the signature associated with cancer. We have been at the forefront of canine olfaction work for nearly 15 years and were responsible for the world's first study of canine detection of bladder cancer, published in the BMJ in September 2004. Our 2014 research indicated that our dogs were capable of detecting odours down to parts per trillion, the equivalent of a teaspoon of

sugar diluted in two Olympic-size swimming pools of water.

Medical Detection Dogs is now working on two NHS approved clinical trials. Our urological cancer study with Milton Keynes University Hospital NHS Foundation Trust focuses on detecting the VOCs associated with prostate cancer, the biggest killer of men.

The current prostate-specific Antigen (PSA) test has a 75% false positive rate, meaning that 3 in 4 men given an initial diagnosis of cancer after this test do not in fact have the disease. We have trained dogs up to an accuracy of 93%, virtually eliminating a false positive result. Together with existing diagnostic methods, canine olfaction would dramatically reduce instances of unnecessary invasive procedures and increase the reliability of early screening.

Our colorectal cancer study in partnership with Hull and East Yorkshire Hospitals NHS Trust, is investigating the potential of dogs to detect colorectal cancer accurately from urine samples. Colorectal cancer is the fourth most common form of cancer in the UK. Due to the invasive nature of the current screening process, only just over half of those offered will take it up. A non-invasive method that can detect the cancer at an early stage could both increase uptake of the screening and improve health outcomes.

THE MICROBIOME

We are starting to explore how changes to a person's microbiome might be linked to the development of cancer tumours and how our dogs can detect changes at an early stage. Indications are that the microbiome is linked to an individual's genetic footprint and hence plays a role in the determination of our unique DNA.

There is growing evidence of the role of the microbiome in human health. Changes or damage to our microbiome can result in significant deterioration in health. Research could provide information that alters the future of diagnostics and treatments for many diseases.

Our data indicates that dogs can assess the human microbiome by odour and we believe that dogs can detect individual changes. Our dogs will accelerate the knowledge of the role of the microbiome in human health and will assist in answering crucial questions about its influence on disease process, diagnostics and recovery.

Understanding the microbiome, human, animal and environmental is as important to our future as the human genome. It influences all major health conditions including cancer, neurology and immunity and we believe will play a crucial part in future diagnostics.

THE POTENTIAL

We are on the threshold of delivering an accurate, rapid and non-invasive test to diagnose cancer at an early stage, a test that would be offered to clinicians to use alongside existing diagnostic methods.

An increase in the aging population, along with widespread PSA screening has, notwithstanding the limitations of the PSA test, contributed to a rise in diagnoses of early-stage prostate cancer. The majority of these newly diagnosed cancers are slow-growing and require no treatment. In fact unnecessary investigative procedures on such

cancers can do more harm that good. Identifying the aggressive ones remains a major challenge for clinicians.

Biomarkers could be used to distinguish between aggressive prostate cancer and indolent tumours, which could identify patients who will benefit from treatment or active surveillance, thereby avoiding overtreatment with invasive tests and therapies.

HOW WE ARE TAKING THIS FORWARD

Whilst we all 'know' what coffee smells like, this complex odour which contains over 100, component molecules, would be impossible to describe to anyone who has never smelt it. How can the dogs communicate to technology what the 'cancery' smell is?

Together with the Open University, we are developing new technology that allows our dogs to communicate their degree of certainty when screening a sample.

Researchers at the Animal Computer Interaction (ACI) Lab, in Milton Keynes, have worked with us to design a sensor which enhances the dog's ability to communicate whether they can detect disease when confronted with samples.

Bio Detection Dogs work on a carousel or stand system that consists of metal pads installed on top of sample tubes which the dog sniffs. If disease is present, the dog indicates this to their handler by sitting in front of the sample. The new technology incorporates a sensor that records the level of pressure the dog exerts whilst sniffing. With training, dogs will apply greater pressure on the pad when they are certain the disease is present.

Therefore, pressure indicates the level of certainty that the dog has, helping to reduce human. Capturing this data provides us with pressure readouts (Figure 1) and will be vital to developing a future screening method. This will be used to educate experts about the strength of the biomarkers that the dog uses to make his decision.

THE FUTURE

In a ground breaking collaboration with the world-famous Massachusetts Institute of Technology (MIT), we are working with a quantum physicist to develop advanced technologies which will harness the power of the dog's nose in a handheld bio-electronic nose.

Dr Andreas Mershin, research scientist at the MIT Center for Bits and Atoms, in Cambridge, Massachusetts was inspired by our study showing dogs could sniff out cancer and plans to use their olfactory ability to develop an easy-to-use electronic nose that can be brought into every doctors' surgery.

Dr Mershin is relying on cancer detection dog, Florin, to teach his prototype device, which uses the latest artificial intelligence (AI) technology, to recognise the odour of prostate cancer.

The device, no bigger than a mobile phone, has been developed to the point where its sensitivity matches the power of a dog's nose – it too can detect parts per trillion – but it is unable to replicate the dogs' powers of cognition, which allows them to spot a 'cancery smell' even though no two humans' cancer smells exactly alike.

Harnessing new AI technology, the machine will 'learn' to detect this 'cancery smell' rather than rely on being programmed with every possible molecular combination.

Dr Mershin explained: "When it comes to the earliest, least invasive, most precise cancer detection, the ability of the trained canine far surpasses our best analytical laboratory tests.

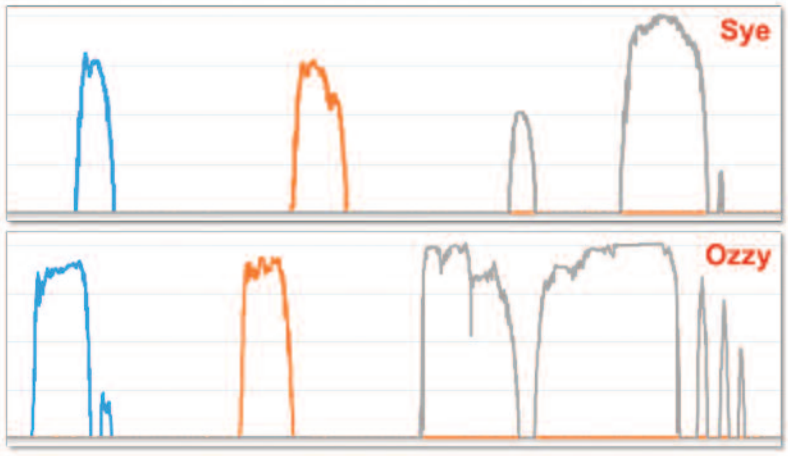
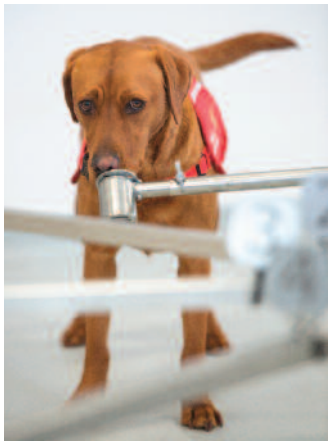


Figure 1

grey = interaction with positive sample (concentration 1/20million).



"Dogs trained on urine samples from bladder cancer patients may also detect prostate, skin and breast cancers. As far as we know, these four cancers share no common volatile molecular signature and yet the dogs can generalise a 'cancery scent character' without molecular analytics."

How the dogs do this and how we can train machine scent detectors to do same or better than dogs are the questions we will be addressing during our collaboration.

Professor Karol Sikora, world respected oncologist and campaigner for better universal cancer treatment, and an adviser to MDD has said that "this collaboration between MDD and MIT could knock cancer off the top killer diseases list."

This project is a fantastic example of how humans and dogs can work together to save lives. The expertise developed during this collaboration will result in a team of canine and electronic experts that could produce bio-electronic noses for all the diseases that currently require increasingly vital role in our work of the dog's nose into every doctor's consulting room.

We believe that dogs are capable of detecting all disease. Our vision for the future is to answer the power of canine olfaction, to speed the early diagnosis of cancer, neurological conditions such as Parkinsons and motor neuron disease and by doing so other researchers will discover more effective treatments and, hopefully, cures.

THE GUT MICROBIOME AND PERSONALISED HEALTHCARE

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Systems biology describes the computational or mathematical analysis of complex, interacting biological systems.[1] One of the most important outcomes from this field of research has been the rediscovery of the importance of bacteria to human health. [2] The microbiome describes the combined genomic composition of the bacteria, viruses, fungi and parasites within a defined ecosystem (figure 1).

human genome. The small intestine contains a very different abundance and composition of bacteria, and it shows much more dynamic variation compared to the colon. [4]

The gut microbiome is highly individualised, and it varies through age and between human populations. [5] In humans, the gut microbiome adopts an adult ecological structure by the age of three,

This is important as the gut microbiome is increasingly associated with a remarkably large variety of chronic health conditions ranging from cancer, obesity and diabetes, through autoimmune diseases and neuropsychiatric disorders [6]. However, establishing causation has been more problematic. This is in part because gut microbiome science is relatively young, the gut microbiome is hard to access, animal models

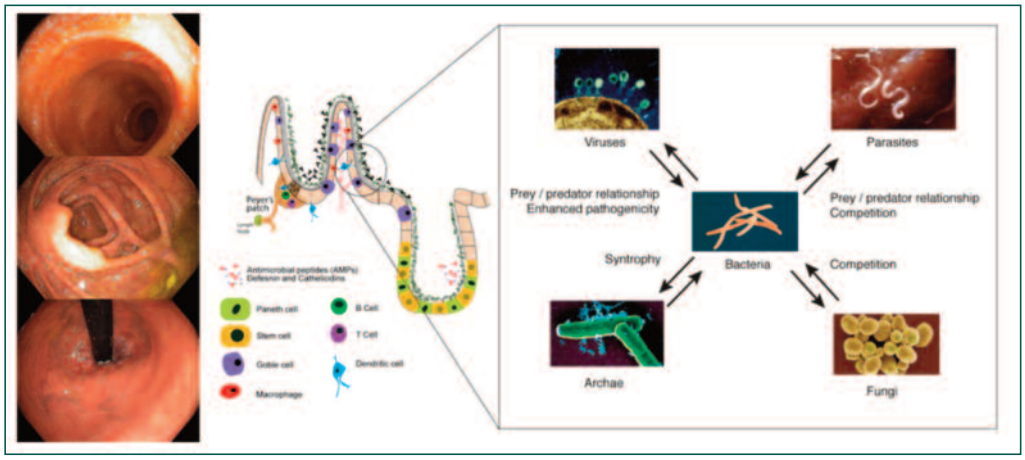

Figure 1. An overview of the common organisms distributed within the gut and the gut microbiome, and the components of the immune system they interact with at a microscopic level. The gut microbiome is geographically discrete, and niche specific. What is present in the caecum will vary to what is in the rectum. In the ageing gut complex changes occur with a reduction in biodiversity, which is a vital part of the intestinal defence mechanism; once depleted the intestine is vulnerable to the detrimental effects of pathological bacteria.

Several large-scale projects, have investigated the microbiota of a variety of niches across the human body, including the skin as well as the oral, vaginal and nasal cavities. [3] Currently the majority of microbiome research is focused on the gut microbiota, since this is where the greatest density and numbers of bacteria are found, with most of the data being derived from faecal samples as the source of biological material, and, to a lesser extent, on mucosal biopsies. The gut microbiome is vast, and it contains over 1000 different species containing 20 to 30 million genes, dwarfing the

although it is unclear how changes in its early development influence the risk of disease later in life. In adult humans the gut microbiota comprises up to 1 Kg of bacteria, the majority of which are obligate anaerobes from the genera *Bacteriodes, Clostridium, Lactobacillus, Escherichia and Bifidobacteria* together with an assortment of yeasts and other microorganisms, to say nothing of the many viruses. These microbes provide benefits to the host via enhanced energy recovery from undigested food, defence against pathogens and interactions with both immune and nervous systems.

are not representative of the human gut and we lack robust longitudinal studies. Moreover, we have yet to establish a clear definition of causation. This is because current definitions such as Koch's postulates define the relationship between a single infecting organism and a specific disease state. In reality, many chronic diseases share common pathways and result from interactions across thousands of host genes and interacting commensal and pathogenic organisms. i.e. chronic disease results from a network effect of interacting organisms, and both the structure and function of the

gut ecology causes disease.

THE GUT MICROBIOME AND CANCER

A good exemplar of this challenge is sporadic colorectal cancer, which is the third commonest cause of cancer-related death worldwide and its global incidence is increasing. [7] Whilst there is strong epidemiological evidence to suggest that diet (high in red meat and fat and low in fiber) is a significant risk factor that may explain this trend, [8] the interaction between the colon and its environment is complex and subject to personalized variation and dynamic xeno-metabolite interactions. Data now exists to support the hypothesis that one of the most important environmental drivers of CRC risk is the colonic microbiota and the metabolites its creates (known as its metabonome). [9 10] For example, it has been demonstrated that the metabolic function of the colonic microbiota directly influences cancer risk through its modulation of dietary fibre, an increase of which leads to profound changes in the ecological co-occurrence networks with resulting upregulation of butyrate metabolism and a reduction in the metabolism of secondary bile acids. [9] Several competing theories regarding the microbial regulation of CRC have now emerged to explain the function and importance of the CRC-associated metagenome. [11 12] However, the 'driver passenger' model is now increasingly accepted, which states that a 'first hit' caused by indigenous intestinal bacteria drives epithelial DNA damage which in turn contributes to the initiation of CRC (termed bacterial drivers). [13] Tumorigenesis induces intestinal niche alterations that favour the proliferation of opportunistic bacteria (termed bacterial passengers). Pathobionts are commensal organisms that can cause disease when specific genetic or environmental conditions are altered in the host. It may be that colonic pathobionts are able to influence host pathogenesis through a large and complex number of chemical and molecular signaling pathways, but whether they create a specific mucosal metabolic microenvironment that potentiates tumour growth and how the mucosal metabonome evolves with cancer progression remain unclear. The significance of this is that they can be targeted as new biomarkers for colon cancer or as novel therapeutic targets to treat cancer.

GUT BRAIN AND SYSTEMIC MICROBIOME INTERACTIONS

Host genes in concert with the gut microbiota, diet and other environmental stressors determine the metabolic and disease phenotypes of individuals and populations. Within this complexity there are specific lines or axes of interaction that couple particular microbiological activities to particular host pathways and compartments, the gut, liver and brain being particularly involved in the communication networks (Figure 2). This has lead to the description of many newly recognised inter-kingdom axes of communication such as the gut:liver axis, the gut:brain axis and the gut:brain:skin axis. [14] It is useful to classify these axes functionally although they are highly metabolically

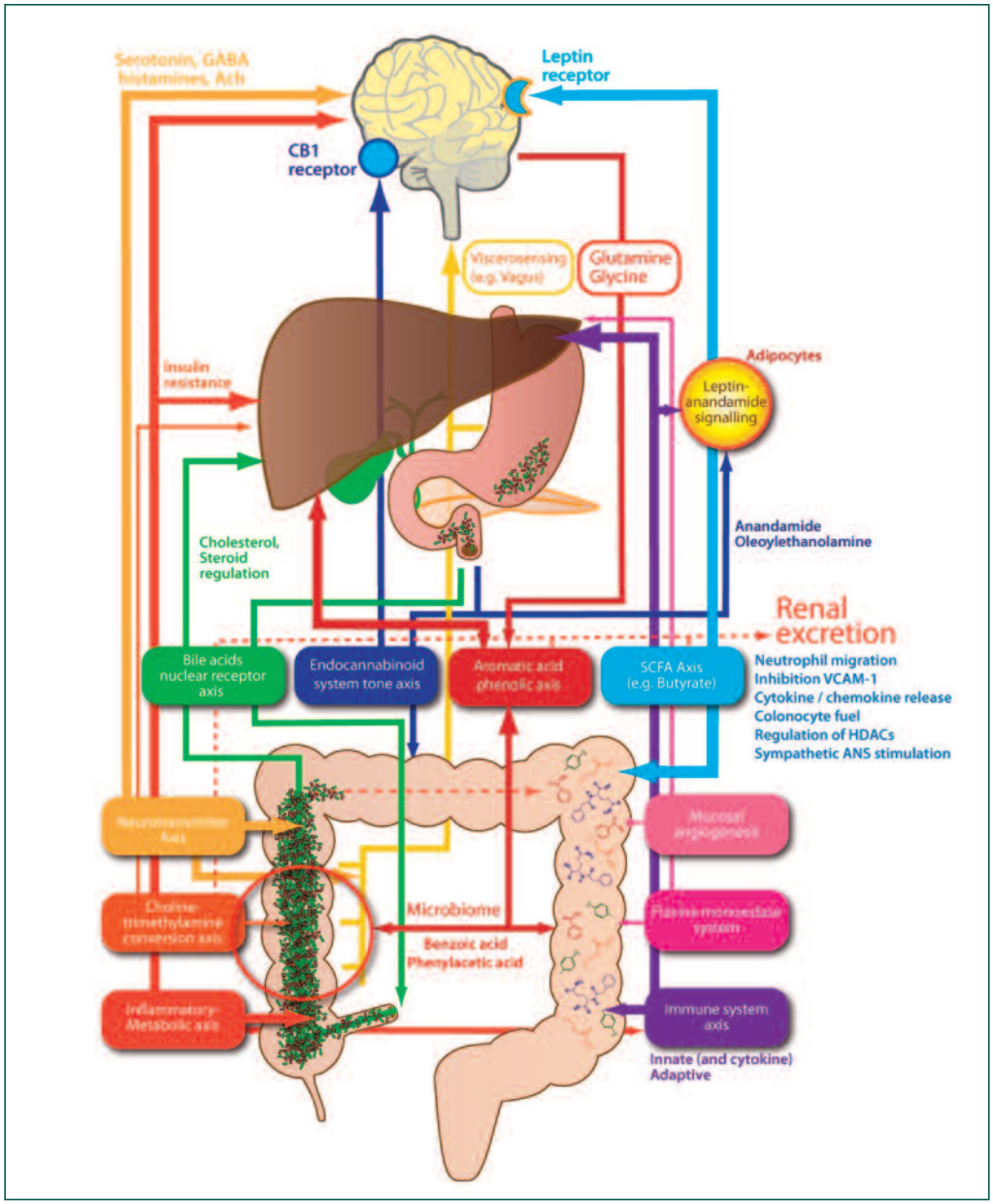

Figure 2. A summary of microbiome-host-gut-liver-brain metabolic signalling axes and pathways. The coordinated activities of the microbiota (under dietary stimuli) appear to be highly interactive based on community and ecological networks at different gut levels. Thus multiple diverse therapeutic options are available ranging from highly specific antibiotics and drugs targeted to microbial pathways through to probiotic and prebiotic interventions as well as the development of designer ecologies via synthetic biology and ecological engineering.

interconnected and vary in relative activity throughout development and human life as well as varying in relation to the lifestyle and diet of the host. The gut microbiome has therefore been intimately linked to conditions such as atopy and allergy, asthma, autism, Alzheimer's and even depression. [5, 15-19] This implies that these conditions could in fact be prevented by maintaining an optimising gut microbiome symbiosis both in early development and throughout old age.

PHARMACOMICROBIOMICS AND DRUG DISCOVERY

There is an increasing appreciation that the microbiome represents a "drugable target" in itself. There is potential for altering both the composition, and therefore the metabolic capability, of the microbiome using a range of approaches. Drug metabolism by intestinal organisms has been well recognised since the 1960s, [20] for example, microbiome-driven drug metabolism is essential for the activation of certain azo prodrugs such as prontosil and neoprontosil, and can effect drug disposition [21] and toxicity [22]. However, recent advances in high throughput sequencing and other 'omics' platforms, has led to the concept of 'pharma-comicrobiomics', and the importance of the gut microbiome for chemotherapeutic drug modulation and for drug discovery is now being increasingly recognised. [23] In fact, the gut microbiota plays a significant role in defining the efficacy and toxicity of a broad range of drugs. [24,25] The gut microbiome modulates these chemotherapeutic agents through key mechanisms, structured as the '**TIMER**' mechanistic framework; namely **T**ranslocation, **I**mmunomodulation, **M**etabolism, **E**nzymatic degradation, and **R**educed diversity and ecological variation. [26] Despite this, we are still lacking a complete map of microbiome-host-drug interactions in cancer, and biological complexity remains a considerable obstacle to the development of these 'precision' therapies. The gut microbiome can now therefore be targeted to improve efficacy and reduce the toxicity of current chemotherapy agents. Engineering the microbiota for human health is a formidable challenge that will require a deeper knowledge of co-metabolic regulation and ecological properties of the microbes to be effective.

CONCLUSIONS

Tthe gut microbiome is not simply an idle passenger in the host, but it serves as an active driver of host biological functions. Because the gut microbiome is so highly personalised, it therefore follows that the vision of personalised healthcare can only be delivered if we are able to account for the important role that these organisms plays in determining our risk of disease and the chance that it will respond to therapy. In this respect, the gut microbiome serves as one of the most important discoveries in medicine of the last decade, and it offers a completely novel target for solving some of the world's greatest health challenges.

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HOUSE OF COMMONS LIBRARY

The Science and Environment Section (SES) is one of eight teams in the Research Service in the House of Commons Library. The Library provides confidential, impartial and bespoke briefing to Members of the House of Commons and their offices on a daily basis supporting the full range of parliamentary work, from policy development to constituency issues. We also produce a series of briefing papers on topical issues, published on the internet and available in hard copy around the Parliamentary Estate.

The Library continues to produce material around the debate on Brexit. For example we have produced briefings on What if there's no Brexit deal? We have also published a reading list of post-EU Referendum publications by Parliament and the Devolved Assemblies and on specific issues such as Brexit and energy and climate change

We have also published, and continue to update, briefings on issues such as

- Distributed Ledger Technology
- In Vitro Fertilisation: 40th Anniversary
- Full-fibre networks in the UK
- NHS and Healthcare Data
- Security of UK Telecommunications
- Automated and Electric Vehicles Act 2018
- Animal Sentience and Brexit
- Leaving the EU: Antimicrobial Resistance
- Antimicrobial Resistance and Immunisation
- Small Modular Nuclear Reactors
- Biometric Technologies

We would be pleased to hear from anyone who wants to know more about how the Library works or how we can help with Parliamentary duties. Please contact Ed Potton (pottone@parliament.uk) in the first instance. If you want to keep up to date with what we are up to, you can follow us @CommonsLibrary or visit www.commonslibrary.parliament.uk.

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST)

POST is Parliament's in-house source of independent, balanced and accessible analysis of public policy issues related to science and technology. It is an office of both Houses of Parliament, overseen by a Board of MPs, Peers and external experts.

POST delivers a number of key services for Parliament:

ADVICE

POST provides advice on research evidence relating to public policy issues.

ANALYSIS

POST provides impartial summaries of academic and other rigorous research, placing findings in a policy context for parliamentary use. These often take the form of POSTnotes, which are submitted to peer review from academia, industry, government and the third sector.

BUILDING CONNECTIONS

POST holds a number of events each year that connect parliamentarians to leading experts from the research community and other sectors. POST helps identify experts for Members, library research services and select committees, for example, upon starting a new inquiry.

PROFESSIONAL DEVELOPMENT

POST works with people in Parliament who want to develop their skills in using research evidence, and with members of the research community who are keen to learn more about policy in general, and Parliament in particular.

FELLOWSHIPS

POST manages a Fellowship Programme for PhD students and academics at any stage post-PhD, in collaboration with research funders and professional societies. These schemes bring researchers into Parliament to support and learn about the activities of POST, the committee offices and the libraries.

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.

Those produced so far in 2018 are:

584 - Security of UK Telecommunications
583 - Developing Non-Academic Skills
582 - Unpaid Care
581 - Antimicrobial Resistance and Immunisation
580 - Small Modular Nuclear Reactors
579 - Persistent Chemical Pollutants
578 - Biometric Technologies
577 - Age of Criminal Responsibility
576 - Relationships and Sex Education
575 - Fire Safety of Construction Products
574 - The Microbiome and Human Health
573 - Health in Private-Rented Housing
572 - UK Fisheries Management
571 - The Ageing Process and Health
570 - Parental Alcohol Misuse
569 - Overseas Electricity Interconnection
568 - Science Diplomacy

The following is a list of POSTnotes currently being worked on, and the section responsible for the work.

Biological Sciences and Health

- Causes of Obesity
- Gambling
- Sleep, Sleep Deprivation and Health

Physical Sciences and ICT

- Distributed Ledger Technology

Social Sciences

- Comparing Economic and Behavioural Interventions

PLANNED WORK

POST carries out horizon-scanning to anticipate issues of science and technology that are likely to impact on policy.

At Board meetings, POST advisers present a shortlist of topics for discussion. The following projects were approved by the POST board but work has not yet started. If you would like to contribute or find out more at this stage please email POST

Biological sciences and health

- Influence of industry on public health policy
- Links of antimicrobial use in animals and antimicrobial resistance in human pathogens
- Outward medical tourism

Environment and energy

- Mitigation and adaptation in agriculture
- Assessing and restoring soil microbiomes
- Environmental gain

Physical sciences and ICT

- Cyber security of consumer products

Social sciences

- Approaches to reducing violent crime, focusing on early interventions
- Robotics in social care

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HOUSE OF COMMONS SELECT COMMITTEES

Current work and Inquiries

SCIENCE & TECHNOLOGY COMMITTEE

RECENT REPORTS

E-cigarettes

Inquiry announced 25 October 2017 into the health impacts and role of e-cigarettes as a smoking cessation tool.

Report published on 17 August 2018. This attracted considerable media coverage.

A Commons Statement on the report by the Chair on 6 September clarified some of its recommendations, including those that had not been accurately reported in the media.

Government response awaited

An immigration system that works for science and innovation

Inquiry announced on 16 May following disappointing Government response (published on 21 March) to the Select Committee's report on Brexit, Science and Innovation.

Report published on 19 July. This was favourably referred to during a Commons debate on 6 September on Brexit, Science and Innovation

Government response awaited.

Research integrity

Inquiry on fraud, misconduct and mistakes in research, and the publication of research announced 13 September 2017.

Report published on 11 June 2018.

Government response awaited.

Biometric Strategy and Forensic Services

Inquiry announced 01 February 2018 into the reasons for the delay in producing a Biometric Strategy, the use of facial imaging technology, and developments affecting the Forensic Services.

Report published on 25 May. The Home Office published its long-awaited Biometrics Strategy on 28 June. This was disappointing and described by the Select Committee Chair, Norman Lamb MP, as 'simply not good enough … and does not do justice to the critical issues involved.'

Government response awaited.

Algorithms in decision-making

Inquiry announced 14 September 2017 into the increasing use of algorithms in public and business decision making

Report published on 23 May 2018

Government response published on 12 September 2018

Genomics and Gene editing in the NHS

Inquiry announced on 14 September into of the mainstreaming of genomic medicine in the NHS

Report published on 17 April 2018

Government response published in July 2018. This addresses each of the Committee's recommendations and outlines the UK Governments plans to work with partners and stakeholders to create an ambitious vision for genomic medicine.

WORK IN PROGRESS

Flu vaccination programme

Inquiry announced 1 March 2018 into the planning for the flu vaccination programme how advice is formulated, and cost-effectiveness issues are addressed, the reasons for different types of vaccines for different groups of the population, the effectiveness and take-up of the vaccination programme, and any plans for adjustments for the next flu season in terms of the vaccines uses and groups targeted.

Energy drinks

Inquiry announced 8 March 2018 on the consumption of energy drinks. A study conducted by the Centre for Translational Research in Public Health has found that young people in the UK consume more energy drinks than those in other European countries, with consumption in the UK increasing by 185% between 2006 and 2015. A report by the European Food Safety Authority found that 68% of those aged 10-18, and 18% of those aged 3-10, were consumers of energy drinks.

Accepting written submissions

Galileo

Inquiry announced 23 October 2017 into UK access to Galileo, the European global satellite-based navigation system, and the implications for UK defence and industry

Digital Government

Inquiry announced 25 July 2018 into the progress of introducing Government digital services and how well protected these are from cyber attack.

The Government published its 'Digital Transformation Strategy' in February 2017, focusing on how digital technology can improve and redesign services as well as the internal workings of departments.

A June 2017 Report from the Institute for Government, Improving the management of digital government, stated that "the spread of new digital services for the public has been slower than planned" and that a cyber-attack that hit the NHS showed "the fragility of some of the systems being used in the public sector".

In March 2018, the Prime Minister announced that the data policy and governance functions of the Government Digital Service (GDS) would transfer from the Cabinet Office to the Department for Digital, Culture, Media and Sport (DCMS), effective from 1 April.

Accepting written submissions until 28 September

Technologies for meeting Clean Growth emissions reduction targets

Inquiry announced 23 October 2017

The Government published its 'Clean Growth Strategy' in October 2017, setting out how it intended to meet the 'carbon budget' emissions reduction targets under the Climate Change Act. The Strategy lists four areas where progress is planned:

- 'Improving Our Homes';
- 'Accelerating the Shift to Low Carbon Transport';
- 'Delivering Clean, Smart, Flexible Power'; and
- 'Enhancing the Benefits and Value of Our Natural Resources'.

The Strategy emphasised the role that innovation can play in meeting the targets, with £2.5bn allocated for 'low carbon innovation' between 2015 and 2021. It also stressed that as well as cutting emissions, such innovation can "create jobs and help companies grow".

A wide range of technologies are being developed with the hope of contributing to emissions reductions including – but not limited to – small modular reactors, nuclear fusion, hydrogen and fuel cells, smart grids, negative emissions technologies and innovative construction materials or methods.

Accepting written submissions until 26 October 2018

Balance and effectiveness of research and innovation spending

Inquiry announced 20 July 2018 inquiry into the balance and effectiveness of research and innovation spending following publication in May of UKRI's Strategic Prospectus. This will consider

- The effectiveness of public spending on R&D, including through mechanisms such as the Industrial Strategy Challenge Fund;
- The rationale needed for deciding on the balance of public R&D funding between:
  - individual research disciplines, research councils and cross-disciplinary schemes;
  - the two research funding streams of the 'dual support' system;
  - research and innovation;
  - pure and applied research;
  - block funding, responsive mode funding and directed funding for the Industrial Strategy;
  - the 'golden triangle' of London, Oxford and Cambridge, and the rest of the UK; and
  - global challenges and other strategic/national priorities.
- The effectiveness of and balance between the different available UKRI/Government levers for encouraging innovation, including: R&D tax credits, the Small Business Research Initiative (SBRI), Innovate UK loans and grants, measures proposed in the 'patient capital' review, and other initiatives.
- The most appropriate phasing of the increase in R&D spending by UKRI over the next few years, in order to meet the Government's 2.4%/3.0% of GDP targets, and what if any changes will be needed in the forthcoming 2019 Spending Review to deliver these targets.
- Assumptions about the public/private mix in delivering the 2.4%/3.0% of GDP targets, the extent past patterns will be replicated in future and the levers that can be used to increase private sector spend on R&D.

Accepting written submissions until 28 September 2018

Evidence-based early-years intervention

Inquiry announced 26 October 2017 on the health impacts of adverse childhood experiences and examine the strength of the evidence linking adverse childhood experiences with long-term negative outcomes, the evidence base for related interventions, whether evidence is being used effectively in policy-making, and the support and oversight for research into this area.

Deadline for written submissions has passed. Contact Select Committee staff if you wish to make late submission.

Impact of social media and screen-use on young people's health

Inquiry announced 21 February 2018

The Royal Society for Public Health's 2017 report '#StatusofMind' called for action to promote the positive aspects of social media for young people, whilst mitigating the potential negatives.

The Youth Select Committee's 2017 report 'A Body Confident Future' examined negative and positive impacts of social media on body image. One recent US study reported that the presence of smartphones damages cognitive capacity. On the other hand, another study found no link between children's use of various screens and any harm to their health.

Accepting written submissions

Quantum technologies

Inquiry announced 08 February 2018

Quantum technologies have been selected by the Government as one of fourteen 'core industrial challenges' to be tackled through its Industrial Strategy Challenge Fund. The Industrial Strategy itself announced that the quantum technology sector will be allocated £20m of 'pioneer funding' and be the subject of a minister-led review. This follows the establishment of the National Quantum Technologies Programme in 2013, and a Government Office for Science report on quantum technologies in 2016.

Accepting written submissions

BUSINESS, ENERGY AND INDUSTRIAL STRATEGY

This Select Committee is appointed by the House of Commons to examine the administration, expenditure and policy of the Department for Business, Energy and Industrial Strategy (BEIS) and its associated public bodies. The BEIS Committee is chaired by Rachel Reeves MP.

Contact: Business, Energy and Industrial Strategy Committee, House of Commons, London SW1A 0AA Telephone: 020 7219 5777 Email: beiscom@parliament.uk

CURRENT WORK

Carbon Capture, Usage and Storage (CCS)

Inquiry announced on 29 May 2018 into CCS and efforts to kickstart this technology in UK

Deadline for written submissions has passed.

Geological Disposal Infrastructure

Inquiry announced on 25 May 2018 into draft guidelines on nuclear waste disposal planning applications

Deadline for written submissions has passed.

Clean Growth Strategy

Inquiry announced on 27 November 2017 following publication of the UK Government's Clean Growth Strategy

Oral evidence concluded

ENVIRONMENTAL AUDIT COMMITTEE

The remit of the Environmental Audit Select 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.

The Chair of the Environmental Audit Select Committee is Mary Creagh MP.

Contact: Environmental Audit Committee, House of Commons, London SW1A 0AA Telephone: 020 7219 5776 Email: eacom@parliament.uk

REPORTS ISSUED

25 Year Environment Plan

Inquiry announced on 1 February into the Government's long-awaited 25-year plan for the Environment

Report published on 24 July

Government response awaited.

UK progress on reducing F-gas emissions

Inquiry announced on 13 October 2017 about UK progress on reducing fluorinated gas emissions.

Report issued on 25 April 2018.

Government response awaited.

WORK IN PROGRESS

Sustainable seas

Inquiry announced into the future of the sea, protecting marine life from climate change, overfishing and pollution.

Oral evidence sessions taking place

The Changing Artic

Inquiry announced 7 March 2018 into the rapid changes in the Artic

Deadline for written submissions has passed.

Nitrates

Inquiry announced on 8 December 2017 on the scale of nitrate pollution in the UK and the solutions the Government should implement

Accepting written submission

HEALTH COMMITTEE

The Health Committee is appointed by the House of Commons to examine the policy, administration and expenditure of the Department of Health and its associated bodies The Committee chooses its own subjects of inquiry.

Dr Sarah Wollaston has been re-elected as Chair of the Health Committee for the 2017 Parliament.

Contact: Health Committee, House of Commons, London SW1A 0AA Telephone: 020 7219 6182 Email: healthcom@parliament.uk

CURRENT WORK

Antimicrobial resistance

Inquiry announced on 24 May into the significant and increasing threat to public health in the UK and globally from antimicrobial resistance

Deadline for written submissions has passed. Oral evidence sessions taking place

Brexit – medicines, medical devices and substances of human origin inquiry

Report published on Wednesday 21 March 2018.

Government Response published on Friday 6 July 2018.

HOUSE OF LORDS SELECT COMMITTEES

SCIENCE AND TECHNOLOGY COMMITTEE

REPORTS ISSUED

Life Sciences and the Industrial Strategy

Report published 26 April 2018. This raises serious concerns about the Government's commitment to delivering its Industrial strategy in relation to Life Sciences which has so far been "wholly inadequate" and recommends there should be sweeping simplification of its implementation arrangements.

Government Response published 27 June 2018.

Awaiting debate.

Off-site manufacture for construction

Report published 19 July 2018. This states that the construction sector as it currently operates cannot meet the UK's need for housing and may struggle to meet the need for infrastructure. Given that the UK already lags behind other countries in construction productivity, and is facing a labour shortage, the Government and the construction sector must urgently find solutions.

Awaiting Government Response and debate

WORK IN PROGRESS

Forensic science

Inquiry announced 23 July 2018 into what new research programmes are needed in forensic science; the level of understanding within the criminal justice system and what routes are available to improve understanding; the performance of the market for forensic services in the UK; and the detection, recovery, integrity, storage and interpretation of evidence from digital devices and networks.

The closing date for submissions is 14 September 2018.

ARTIFICIAL INTELLIGENCE COMMITTEE

AI in the UK: ready, willing and able?

Report published on 16 April 2018. This said 'The UK currently enjoys a position as one of the best countries in the world in which to develop artificial intelligence, but this should not be taken for granted. We recommend the creation of a growth fund for UK SMEs working with AI to help them scale their businesses; a PhD matching scheme with the costs shared between the private sector; and the standardisation of mechanisms for spinning out AI start-ups from the excellent research being done within UK universities. We also recognise the importance of overseas workers to the UK's AI success, and recommend an increase in visas for those with valuable skills in AI-related areas. We are also clear that the UK needs to look beyond the current data-intensive focus on deep learning, and ensure that investment is made in less researched areas of AI in order to maintain innovation.

Government Response published on 28 June 2018. Awaiting debate.

EU ENERGY AND ENVIRONMENT SUB-COMMITTEE

Brexit: food security

Inquiry announced 07 February 2018 to explore what impact Brexit could have on the price and availability of food in the UK

Report published 10 May 2018. This found that even in the 'best case scenario', with no tariffs and few customs barriers, international rules would oblige the UK to conduct more customs and borders checks than is currently the case. If an agreement cannot be negotiated by the time the UK leaves the EU the increase in tariffs could lead to significant price rises for consumers, whilst the additional customs workload could choke the UK's ports and airports and significantly disrupt food deliveries.

Government response published 19 July 2018. Awaiting debate.

OFFICE OF NUCLEAR REGULATION'S BREXIT PREPAREDNESS

Inquiry announced 05 July 2018 into the Brexit preparadness of the Office of Nuclear Regulation

Oral evidence concluded.

Food safety risk management post-Brexit

Inquiry announced 04 July 2018 into food safety risk management post-Brexit

Oral evidence concluded. Awaiting response from Minister.

REACH regulations

Inquiry announced 22 June 2018 into what Brexit means for REACH Regulations

Oral evidence ongoing.

Air quality

Inquiry announced 08 June 2018 into the implementation of the EU air quality directive

Oral evidence concluded.

Brexit: plant and animal biosecurity

Inquiry announced 16 March 2018 into the impact of Brexit on the UK's biosecurity.

Oral evidence concluded; report in preparation.

UK Research and Innovation

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Operating across the whole of the UK with a combined budget of more than £6 billion, UK Research and Innovation brings together the seven Research Councils, Innovate UK and Research England.

We are an independent organisation with a strong voice for research and innovation, both to government and internationally, we are supported and challenged by an independent chair and board. We are principally funded through the Science Budget by the Department for Business, Energy and Industrial Strategy (BEIS).

Our mission is to be a trusted partner and to ensure research and innovation continues to flourish in the UK. We will support and help connect the best researchers and innovators with customers, users and the public. We will invest every pound of taxpayers' money wisely in a way that maximises impact for citizens, in the UK and across the world.

Arts & Humanities Research Council

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AHRC funds world-class, independent researchers in a wide range of subjects. Their research provides social and cultural benefits and contributes to the economic success of the UK but also to the culture and welfare of societies around the globe.

Biotechnology and Biological Sciences Research Council

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

Economic & Social Research Council

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

EPSRC

Engineering and Physical Sciences Research Council

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EPSRC funds engineering and physical sciences research, covering fields from healthcare technologies to structural engineering, manufacturing to mathematics, advanced materials to chemistry.

Innovate UK

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Innovate UK works with people, companies and partner organisations to find and drive the science and technology innovations that will grow the UK economy. They drive growth by working with companies to de-risk, enable and support innovation.

Medical Research Council

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MRC is at the forefront of scientific discovery to improve human health. Their 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

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NERC is the driving force of investment in environmental science. Their 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

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Research England is a new council within UK Research and Innovation. Taking forward the England-only responsibilities of HEFCE in relation to research and knowledge exchange, Research England will create and sustain the conditions for a healthy and dynamic research and knowledge exchange system in English universities.

Science & Technology Facilities Council

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

Association of the British Pharmaceutical Industry

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

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

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

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

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

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

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

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

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

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

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

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

British In Vitro Diagnostics Association (BIVDA)

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

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www.e-opat.com | www.nas-pps.com
|www.appg-on-antibiotics.com
www.bsacsurv.org

The BSAC is an inter-professional organisation with over forty years of experience and achievement in antibiotic education, research and leadership. The Society has an active international membership and:

- Is dedicated to saving lives through the effective use and development of antibiotics, now and in the future.
- Communicates effectively about antibiotics and antibiotic usage via workshops, professional guidelines and its own high impact international journal, the Journal of Antimicrobial Chemotherapy.
- Is home to the UK-led global initiative Antibiotic Action
- Serves as secretariat to the All Party Parliamentary Group on Antibiotics

SCIENCE DIRECTORY

British Society for immunology

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The BSI is one of the oldest, largest and most active immunology societies in the world. We have over 5,000 members who work in all areas of immunology, including research and clinical practice.

The BSI runs major scientific meetings, education programmes and events for all ages. We disseminate top quality scientific research through our journals and meetings and we are committed to bringing the wonders and achievements of immunology to as many audiences as possible.

BRITISH SOCIETY OF SOIL SCIENCE

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United Kingdom

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

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

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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Ergonomics, also called Human Factors, sometimes abbreviated 'E/HF' is a science-based discipline about 'designing for people'. E/HF takes into account the physical and mental capabilities, aptitudes and abilities of people acting individually (a pilot, a surgeon or nurse, train driver) or collectively, with or without equipment (a theatre team, air traffic control) in the design of workplaces, equipment and ways of working to deliver the least harmful, safest, most efficient, most elegant possible outcomes'. E/HF uses science to improve the places in which we work, live and relax and the ways in which we interact with people, equipment and systems.

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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Science for Real- Science for Life-Science for Citizenship and Employability

We build grass-roots partnerships between school and the wider world of professional science and engineering

- encountering science as a creative, questioning, collaborative human activity
- bringing school science added meaning and motivation, from primary to post-16
- locally, nationally, internationally (our UK-Japan Young Scientist Workshop Programme in since 2001)

Clifton Scientific Trust Ltd is registered charity 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

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. Our Fellowship programme, working in partnership with universities, research councils, 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 scientific credentials, update skills and redevelop confidence, in a suitably supportive environment.

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The Energy Institute (EI) is the chartered professional membership body bringing global energy expertise together. 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 250 companies from 120 countries to the heart of the public debate. And we're an independent, not-for-profit, safe space for evidence-based collaboration, an honest broker between industry, academia and policy makers.

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

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

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

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.

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

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

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Advancing knowledge and setting standards in biomedical science

With over 20,000 members in over 30 countries, the Institute of Biomedical Science is the leading professional body for biomedical scientists, support staff and students.

For over 100 years we have been dedicated to the promotion, development and delivery of excellence in biomedical science within all aspects of healthcare, and providing the highest standards of service to patients and the public.By supporting our members in their practice of biomedical science we set quality standards for the profession through: training, education, assessments, examinations and continuous professional development.

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IFST is the independent qualifying body for food professionals in Europe. Membership is drawn from all over the world from backgrounds including industry, universities, government, research and development and food law enforcement.

IFST's activities focus on disseminating knowledge relating to food science and technology and promoting its application. Another important element of our work is to promote and uphold standards amongst food professionals.

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

Institute of Marine Engineering, Science and Technology (IMarEST)

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

The Institute of Materials Finishing

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The Institute of Materials Finishing is the premier technical organisation representing industry, academia and individual professionals in both the UK's and global surface engineering and materials finishing sector.
We actively promote continual education and knowledge dissemination by providing both distance learning and tutored training courses, as well as a technical support service. We also provide bespoke courses that are tailored to an employer's specific needs. The Institute also publishes *Transactions of the Institute of Materials Finishing* and a bimonthly newsletter (*IMFormation*), as well as holding regular regional and international technical meetings, symposia and conferences.

Institute of Measurement and Control

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

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

IOP Institute of Physics

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The Institute of Physics is the professional body for physics in the UK and Ireland, inspiring people to develop their understanding and enjoyment of physics. We are a world-leading science publisher and proud to be a trusted voice for the physics community.

Our work includes supporting the teaching of physics, encouraging innovation in business and providing evidence-based advice to Government. Our members are from across the physics community – in academia, the classroom, and industry – and our reach extends to all who have an interest in physics and its contribution our culture, society and economy.

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

With over 44,000 members in 120 countries, IChemE is the global membership organisation for chemical engineers. A not for profit organisation, we serve the public interest by building and sustaining an active professional community and promoting the development, understanding and application of chemical engineering worldwide.

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

Institution of Civil Engineers

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Established in 1818 and with over 86,000 members in 167 countries worldwide, ICE is a leading source of expertise in infrastructure and engineering policy and is widely seen as the independent voice of infrastructure. ICE provides advice to all political parties and works with industry to ensure that civil engineering and construction remain major contributors to the UK economy.

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 science for a safer world

LGC is an international leader in the extended life sciences sector. Our products and services are designed to improve human healthcare, agri-food technology & the environment.

We provide reference materials, genomics solutions and analytical testing products and services, based on our innovations and own intellectual property. We work with customers in the pharmaceuticals, agricultural biotechnology, food, environment, security and sports sectors as well as with governments and academia to achieve excellence in investigative, diagnostic and measurement science.

Our offering is underpinned by our heritage and expertise in regulation, accreditation and standard setting.

We help customers conform to international statutory and regulatory standards.

Science is at the heart of all we do - for a safer world.

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

London School of Hygiene & Tropical Medicine

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The London School of Hygiene & Tropical Medicine is a world-leading centre for research and postgraduate education in public and global health, with over 4,000 students and more than 1,000 staff working in over 100 countries across the world. Our depth and breadth of expertise encompasses many disciplines, and we are one of the highest-rated research institutions in the UK.

Marine Biological Association

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.

SCIENCE DIRECTORY

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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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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

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Physiology is the science of how molecules, cells and organs work in the body. Representing over 3500 life scientists, The Physiological Society supports scientific research through its grants schemes, conferences and its three open access journals.

The Society also supports the teaching of physiology in schools and universities, and works to promote an understanding of physiology amongst policy-makers and the general public.

prospect

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Prospect is an independent, thriving and forward-looking trade union with 117,000 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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Opening fully in mid-2018, the Quadram Institute will be an interdisciplinary research centre capitalising on the academic excellence and clinical expertise of the Norwich Research Park. Its mission is to understand how food and the gut microbiota link to the promotion of health and preventing diet and age related diseases. The Quadram Institute brings together fundamental and translational science with a clinical research facility for human trials and one of Europe's largest gastrointestinal endoscopy units. This will synergise interactions between basic and clinical research, delivering a step change in the understanding of the role of food in health.

ROYAL ACADEMY OF ENGINEERING

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

Kew

ROYAL BOTANIC GARDENS

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

Kew's strategic priorities for science are:

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

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

The Royal Institution
Science Lives Here

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

THE ROYAL SOCIETY

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

Royal Society of Biology

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

ROYAL SOCIETY OF CHEMISTRY

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

society for applied sfam microbiology

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SfAM is a UK organization, serving microbiologists internationally. It works to advance, for the benefit of the public, the science of microbiology in its application to the environment, human and animal health, agriculture, and industry. With Wiley-Blackwell, SfAM publishes five internationally acclaimed journals. Value for money and a modern, innovative and progressive outlook are its core principles. A friendly society, SfAM values integrity, honesty, and respect, and seeks to promote excellence and professionalism and to inspire young microbiologists.

Society for Underwater Technology

SUT Society for Underwater Technology

Society for Underwater Technology
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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

SCI: where science meets business

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

We deliver our charitable objective by:

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

Society of Cosmetic Scientists

SCS SOCIETY OF COSMETIC SCIENTISTS

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Website: www.scs.org.uk

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

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

Society of Maritime Industries

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The Society of Maritime Industries (SMI) is the voice of the UK's maritime engineering and business sector promoting and supporting companies which design, build, refit and modernise ships, and supply equipment and services for all types of commercial and naval ships, ports and terminals infrastructure, offshore oil and gas, maritime security and safety, marine science and technology, maritime autonomous systems and marine renewable energy.

UK INNOVATION & SCIENCE SEED FUND

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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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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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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.

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

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

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

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

Wednesday 17 October 2018
Discussion meeting. Portcullis House. 09.30 – 12.30

Monday 12 November 2018
Discussion meeting. Portcullis House. 17.30 -19.00

Tuesday 20 November 2018
Annual Lunch (House of Lords) 12.30

Tuesday 4 December 2018
Discussion meeting on Brexit. Portcullis House 17.30- 19.00

ROYAL SOCIETY

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

10 October Biology Week Reception Churchill Room, House of Commons, Houses of Parliament SW1A 0AA

5 December Christmas Parliamentary Reception Churchill Room, House of Commons, Houses of Parliament SW1A 0AA

Please contact Karen Patel and Stephen Benn at events@rsb.org.uk for more details.

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Rt Hon Norman Lamb MP and Stephen Metcalfe MP

Carol Monaghan MP and Chi Onwurah MP

invite you to attend a Parliamentary Reception to celebrate

Biology Week

Wednesday 10 October 2018 | 19:00 - 22:00

The Churchill Room, House of Commons, London SW1A 0AA

Please RSVP to Karen Patel at events@rsb.org.uk by 3 October

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