

Antimicrobial resistance research: learning lessons from the COVID-19 pandemic

**Summary of a FORUM workshop held on
15 December 2021**



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Executive summary

The COVID-19 pandemic triggered an unprecedented global public health response. Antimicrobial resistance (AMR) is another public health crisis that also requires urgent attention.

Much has been achieved by the scientific and policy response to the COVID-19 pandemic, including the rapid development of safe and effective vaccines and therapeutics, the large-scale implementation of testing in healthcare settings and people's homes, unbiased community-based COVID-19 surveillance, and extensive genomic sequencing to detect and track variants of concern. The UK has played a leading role in several key areas, although the pandemic has also exposed some shortcomings.

On 15 December 2021, the Academy of Medical Sciences' FORUM, the Department of Health and Social Care (DHSC), and the National Institute for Health and Care Research (NIHR) convened a multistakeholder workshop to consider the lessons that could be learned from the scientific and policy response to the COVID-19 pandemic. The workshop was chaired by **Professor Alison Holmes** OBE FMedSci and **Professor Sharon Peacock** CBE FMedSci, and focused on two key areas of relevance to AMR, which were identified by a panel of experts working on AMR or COVID-19 across a range of disciplines:

1. Diagnostics and surveillance
2. Therapeutics and vaccines

Several themes emerged through discussions at the workshop:

COVID-19 and AMR have much in common, but also some key differences: Both are major public health challenges, requiring coordinated global action. Both are also associated with the concept of 'One Health'. The response to AMR will need to span not just basic biology, clinical medicine and human behaviour, but also veterinary and environmental research and practice. Similarly, our ability to respond to emerging infectious diseases, including coronaviruses, will require an understanding of how animal, environmental and human systems interact. However, AMR is an even more complicated systems problem, as resistance has the potential to evolve in multiple species through multiple mechanisms and in a plethora of environments. Furthermore, while a vital aspect of our response to COVID-19 has been the development of new vaccines and therapeutics, it is important to recognise that the long-term solution to AMR will not lie with the continuous development of new antimicrobials. As such, advances in research and policy that will enable the conservation of existing antimicrobial assets are desperately needed. Finally, AMR is likely to have longer-term implications and, given the need for urgent action across multiple disciplines and sectors, could be considered a challenge that has more in common with climate change than COVID-19.

Multiple research communities came together to combat the COVID-19 pandemic: The research response to the pandemic has been based on unprecedented levels of coordination and

collaboration across disciplines. The research response to AMR needs to be similarly multidisciplinary and focused.

COVID-19 research responses were strongest where the UK was already strong: The UK had existing strengths in areas such as vaccine research, clinical research within the NHS, genomics across the academic and public health sectors, and in pharmaceutical development; each of these areas could swiftly pivot to work on COVID-19. Rapid success was based on 'deep roots', the result of substantial past investment in research. Responses were more mixed in areas that lacked such firm foundations, such as diagnostics. Although the UK has many research strengths relevant to AMR, some need nurturing to provide a more solid basis for future responses, including a strengthening of the AMR research workforce and career progression pathways.

COVID-19 research and policy responses were rapid, focused and well-funded, and drove innovation and new ways of working: There is a need to capture this focus and energy in the response to AMR. If the COVID-19 pandemic could be considered a tsunami, AMR is more akin to sea-level rise – unfolding over longer timescales but still a public health crisis that must be addressed.

Patients and the public have a critical role to play in the AMR response: Patient and public involvement is essential at multiple levels, from the development of strategies to the identification of effective ways to communicate with different audiences. Securing public support for action to address AMR will also be vital, as it has been for COVID-19 and will be for climate change.

Diagnostics and surveillance are crucial aspects of the AMR response and can draw on the COVID-19 experience:

- **The testing infrastructure developed for COVID-19 could be repurposed to support AMR surveillance:** This could extend to wastewater and other environmental monitoring as well as surveillance in veterinary medicine. Linkage of data across sectors needs to be a key priority.
- **Engagement with industry should be strengthened:** The diagnostics sector is more fragmented than the pharmaceutical industry and was not sufficiently prioritised early in the pandemic. Stronger and earlier engagement would ensure that industry is better able to support public health responses to AMR. Mechanisms are also needed to provide access to clinical samples and curated panels of susceptible and resistant microorganisms to accelerate diagnostic development.
- **Regulatory pathways for diagnostics should be reviewed:** Such pathways are complex and often slow, an issue that should be addressed through dialogue between regulators, developers and other stakeholders.
- **Technological innovation and public adoption of testing are creating new opportunities:** Multiple diagnostic platforms have been developed for COVID-19, covering a range of uses for testing and providing rapid turnaround times. This burst of innovation could be harnessed to deliver more tools for tracking AMR in different settings and to support interventions to prevent the spread of resistant infections. In addition, widespread public uptake of testing would offer opportunities to capture AMR-relevant data directly from communities and to integrate AMR screening in the community into patient admission pathways. Patient and public engagement is essential to secure support for new community-based approaches and data sharing, and to ensure that the implications of test results are fully understood.
- **An end-to-end focus is needed for diagnostic development, with multistakeholder engagement:** Diagnostic development takes place in a complex environment, requiring

input from multiple stakeholders, including researchers, product developers, funders, clinicians, public health professionals, patients and the public. Technical innovations will not succeed unless an integrated view is taken of the needs and interests of these different players, with cross-sectoral collaborations at the heart of product development.

Rapid development and approval of COVID-19 therapeutics and vaccines also offers lessons for AMR research:

- **Innovations in regulatory practice were crucial to the rapid but rigorous evaluation of COVID-19 vaccines and could be applied to AMR therapeutics:** Regulatory bodies such as the Medicines and Healthcare Products Regulatory Agency (MHRA) have been willing to consider innovative trial designs and closer dialogue with intervention developers. There is a need to embed this new model, with regulators acting as flexible facilitators rather than just enforcers of regulation.
- **Capture and analysis of real-world and pragmatic trial data was crucial to inform COVID-19 care:** Studies such as the RECOVERY trial drew on existing research infrastructure and NHS systems, and were able to rapidly initiate research. For AMR, major opportunities exist to collect real-world data to understand links between antimicrobial use and resistance and to inform dosing and prescribing, for example to optimise prescribing based on type of infection or patient demographic (e.g. children or people with co-morbidities).
- **Innovations in vaccine technology could offer a way to reduce antibiotic use:** Several COVID-19 vaccines have been based on novel platforms that could potentially be adapted to combat priority bacterial pathogens. Vaccines against viral pathogens could also reduce unnecessary antibiotic use, while additional vaccines for veterinary use could also be developed. Global structures such as the Coalition for Epidemic Preparedness Innovations (CEPI) have been critical for accelerating development of vaccines and a similar model could be developed for AMR-related vaccine priorities.

The COVID-19 response has been imaginative and characterised by a willingness to think outside the box: This may be a unique ‘teachable moment’ when radical new ideas could be considered to address another public health crisis in the making. Possibilities include:

- **Given the lack of progress in antibiotic development, an end-to-end public sector-based system driven by public health needs could be considered:** Despite some progress, the antibiotic pipeline is not well stocked, and a sustainable business model has yet to be identified. By building on existing global research and development (R&D) infrastructure, a clinical trial system entirely within the public sector could be envisaged, taking products from the discovery stage through to market authorisation. Agreements could be negotiated with industrial partners to support manufacturing and to ensure equitable and sustainable access following approval.
- **AMR could be ‘rebranded’ to capture political and public attention better:** Through extensive advocacy, AMR is now on the global political agenda, but may not yet be considered of sufficient priority by national governments and the general public. Thought could be given to how AMR is communicated to support stronger advocacy and to achieve greater political and public buy in.

And finally, ***the UK’s 5-year national action plan could be reviewed and redeveloped in light of lessons learned from COVID-19:*** A timely review of the remit of the research agenda of the 2019–2024 national action plan is needed to ensure lessons learned from COVID-19 are taken on board. The next national action plan should encompass all levels from basic biology through to implementation and policy research. It’s One Health focus should be enhanced, identifying

opportunities for interdisciplinary research and collaboration. The findings of this workshop were presented to the Research Coordination Group of the national action plan in February 2022, and will inform their work moving forwards.

During the scoping process for this workshop, several other areas where lessons could be learned from COVID-19 were identified, including those related to **infection prevention and control (IPC)** within both health care settings and communities. Although not a focus of this workshop due to time constraints, it was noted that it will be important to review the successes and challenges related to IPC in controlling the spread of COVID-19 and consider whether there are any implications for AMR research and policy.

Antimicrobial resistance is a 'slowburn' public health crisis that could ultimately have an impact far in excess of COVID-19.¹ Combating AMR will require, at the very least, the same degree of national and international focus and coordinated action, political commitment and public engagement, with a long-term, sustainable approach. The response to the COVID-19 pandemic proves that things can be done differently when circumstances demand – the challenge now is to achieve something similar for AMR.

¹ Murray CJL, et al. (2022). *Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis*. The Lancet **399**, 629-655. [https://doi.org/10.1016/S0140-6736\(21\)02724-0](https://doi.org/10.1016/S0140-6736(21)02724-0)

Introduction

Early in 2020, the global spread of COVID-19 triggered a wave of research activity to understand and help control this new threat to human health. Globally, research has rapidly provided insights into the biology of SARS-CoV-2 and mechanisms of COVID-19 disease, and provided tools to diagnose, treat and track, and prevent disease. The UK has played a pivotal role in many of these advances, with the UK research community swiftly pivoting to work on COVID-19 and the UK Government rapidly providing substantial funding for research.

Similar to COVID-19, antimicrobial resistance (AMR) is another global public health crisis. AMR is the ability of microorganisms (bacteria, fungi, viruses and parasites) to resist the effects of medicines that were once able to successfully kill them or inhibit their growth. Although AMR occurs naturally, the overuse and misuse of antimicrobials in healthcare, livestock and agriculture accelerates the development of AMR.

Antibiotic, antifungal, antiviral and antiparasitic medicines (collectively known as 'antimicrobials') have transformed modern medicine, but increasing drug resistance is threatening our ability to treat and control the spread of infections. AMR has particularly serious implications for people with health conditions that make them more susceptible to infectious diseases, such as cancer, diabetes and HIV. It also has the potential to make routine surgery and other medical practices, including some cancer treatments, much riskier or no longer possible because of the difficulty in controlling infections.

In recent years, AMR has been recognised as one of the most critical health challenges of our time. A recent study estimated that 1.3 million people globally died as a direct result of an antibiotic-resistant bacterial infection in 2019, and that bacterial AMR was a contributing factor in an additional 3.7 million deaths.² AMR is therefore a key priority for researchers and policymakers. In 2019, the UK Government published a 20-year vision³ and a five-year national action plan for tackling AMR.⁴

However, AMR has not yet captured political and public attention and investment to the same degree as COVID-19. Multiple challenges persist around our ability to develop new antimicrobials, protect our existing antimicrobial assets, and to detect and prevent infections with antimicrobial resistant pathogens.

² Murray CJL, et al. (2022). *Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis*. The Lancet **399**, 629-655. [https://doi.org/10.1016/S0140-6736\(21\)02724-0](https://doi.org/10.1016/S0140-6736(21)02724-0)

³ UK Government Department for Health and Social Care (2019). *UK 20-year vision for antimicrobial resistance*. <https://www.gov.uk/government/publications/uk-20-year-vision-for-antimicrobial-resistance>

⁴ UK Government Department for Health and Social Care (2019). *UK 5-year action plan for antimicrobial resistance 2019 to 2024*. <https://www.gov.uk/government/publications/uk-5-year-action-plan-for-antimicrobial-resistance-2019-to-2024>

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- Briefly consider the outstanding challenges facing AMR research and policy.
- Identify the key relevant lessons learned from the COVID-19 pandemic.
- Consider how lessons learned from the COVID-19 pandemic can be applied to advance AMR research and policy.

The workshop focused on two key areas of relevance to AMR: (1) **diagnostics and surveillance**, and (2) **therapeutics and vaccines**. These topics were identified by a panel of experts working on AMR or COVID-19 across a range of disciplines. This report summarises points raised by the speakers and attendees through a series of talks, question and answer sessions and group discussions. The findings of this workshop were presented to the Research Coordination Group of the UK's 2019-2024 national action plan for AMR in February 2022, and will inform their work moving forwards.

Providing introductory comments, **Professor Dame Sally Davies** DBE GCB FRS FMedSci, UK Special Envoy on AMR, highlighted some of the key features of the UK's response to the COVID-19 pandemic and the challenges presented by AMR.

Dame Sally began by noting the remarkable speed of vaccine development, thanks to the proactive investment of the UK Vaccine Network. Protection of the population through vaccination has been a major success, and a **scientifically informed risk-based approach to vaccine procurement** was central to this success. Importantly, COVID-19 vaccine development was rapid thanks to **early and long-term investments** in vaccine research. Development of new antimicrobials and diagnostics for AMR will be similarly dependent on a well-resourced research foundation.

Vaccines are likely to play a similarly critical role in the battle against AMR, directly and indirectly. Studies of the impact of pneumococcal conjugate vaccine, for example, have identified substantial reductions in both antibiotic-resistant infections and antibiotic use.⁵ In Scandinavia, vaccines have led to a major reduction in antibiotic use in fish farming.⁶

Dame Sally noted that the global profile of AMR has been expanding, with G7 finance ministers, for example, committing to create the right economic conditions to tackle market failure for antimicrobials. However, Dame Sally argued that in order to achieve significant progress in our response to AMR, it needs to **capture the attention of politicians and funders** to the same extent as COVID-19. Innovative financial models, including the UK's subscription model,⁷ are being piloted to incentivise new antibiotic development. The next step will be to **consider access and**

⁵ Klugman KP & Black S (2018). *Impact of existing vaccines in reducing antibiotic resistance: Primary and secondary effects*. PNAS **115** (15), 12896-12901. <https://dx.doi.org/10.1073/pnas.1721095115>

⁶ World Health Organisation Regional Office for Europe (2015). *Vaccinating salmon: how Norway avoids antibiotics in fish farming*. <https://www.euro.who.int/en/health-topics/disease-prevention/food-safety/news/news/2015/10/vaccinating-salmon-how-norway-avoids-antibiotics-in-fish-farming>

⁷ UK Government Department of Health and Social Care (2020). *World-first scheme underway to tackle AMR and protect UK patients*. <https://www.gov.uk/government/news/world-first-scheme-underway-to-tackle-amr-and-protect-uk-patients>

stewardship issues during the development of new antimicrobials to ensure global equitable and sustainable access, along with appropriate stewardship, after licensing.

Dame Sally also highlighted the critical importance of **surveillance** for fully understanding the nature of the threat and for guiding interventions. For AMR, surveillance needs to be based on a **One Health approach** that encompasses the veterinary field as well as the medical sector.⁸ There is also an important role for **environmental monitoring**, for example of discharge from factories and livestock waste. Globally, the Fleming Fund has made an important contribution to the development of surveillance capacity in low- and middle-income countries,⁹ which was repurposed to support COVID-19 surveillance.

Above all, Dame Sally emphasised, there was a need to **communicate the value of new antimicrobials** to policymakers so that they can reward and incentivise these treatments, ensuring patients can benefit. Furthermore, tackling AMR will require a **cross-sectoral approach**; she praised the Medical Research Foundation's multidisciplinary PhD programme in AMR¹⁰ but also argued that a comprehensive programme was required to establish a **clear career pathway** for researchers, in both the public and private sectors.

⁸ One Health is a collaborative, multisectoral, and transdisciplinary approach — working at the local, regional, national, and global levels — with the goal of achieving optimal health outcomes recognising the interconnection between people, animals, plants, and their shared environment. Definition from CDC (<https://www.cdc.gov/onehealth/basics/index.html>).

⁹ <https://www.flemingfund.org/>

¹⁰ <https://www.medicalresearchfoundation.org.uk/projects/national-phd-training-programme-in-antimicrobial-resistance-research>

Diagnostics and surveillance

The diagnostics sector is ready to engage

Doris-Ann Williams MBE, Chief Executive of the British In Vitro Diagnostics Association, discussed some of the experiences of the commercial diagnostics sector during the COVID-19 pandemic. Early in the pandemic, the UK's testing capacity was highly constrained, taking several months to build adequate testing capacity. Ms Williams suggested that a key learning was that engagement between the diagnostics sector and the UK Government was initially not strong enough to ensure a rapid and effective response.

However, the diagnostics industry was still able to play a key role in the COVID-19 response, for example by helping to establish the **Lighthouse laboratories**, a network of laboratories and testing sites organised by a variety of public and private suppliers.¹¹ This network could play a key role in future responses, including to AMR, and could be critical to future research and surveillance activities.

The COVID-19 pandemic spawned considerable innovation in diagnostics, leading to the development of many different types of diagnostic tests based on different technologies. To facilitate the rapid introduction of high-quality tests, Ms Williams suggested that further discussions with regulators are required to develop a more **fit-for-purpose regulatory process** for diagnostics, ideally incorporating mechanisms for emergency use authorisation. This point was reiterated by other attendees, who noted that regulatory processes for diagnostics are often slow and difficult to navigate.

Looking back on the early days of the pandemic, Ms Williams suggested that **earlier and better communication between Government and industry** would have been beneficial. The diagnostics sector is small and more diverse compared to the pharmaceutical industry, but provides tools that generate critical evidence to guide decision-making. She suggested that there is a need for greater networking and building of trust, based on an awareness that both industry and policymakers share the same goal of improving health. She noted that innovative potential was widely spread across the sector and suggested that public funding opportunities should therefore be open to all.

She also highlighted the importance of ensuring that **samples are made available to the diagnostics sector** – in the COVID-19 pandemic, prioritisation of samples for research and vaccine development meant limited supplies were available to support diagnostic development. In a later discussion, it was suggested that the UK Health Security Agency, which has an extensive and representative collection of cultures, could consider developing a **biobank providing access to fresh or stored clinical samples**.

¹¹ <https://www.gov.uk/government/publications/nhs-test-and-trace-how-we-test-your-samples/nhs-test-and-trace-how-we-test-your-samples>

Previous Academy of Medical Sciences meetings have considered the lessons that can be learned from diagnostic development during the COVID-19 pandemic¹² and how they can contribute to a sustainable diagnostics sector in the UK.¹³

Enhanced understanding of the diagnostics pathway

Dr Jesus Rodriguez Manzano, Lecturer in Antimicrobial Resistance and Infectious Diseases, Imperial College London, discussed some of the challenges faced by diagnostic developers working in academic settings.

Dr Rodriguez Manzano stressed that translation of laboratory findings into successful diagnostic products can be extremely challenging for academic researchers. The WHO's **ASSURED principles** (**A**ffordable, **S**ensitive, **S**pecific, **U**ser-friendly, **R**apid, **E**quipment-free, **D**elivered) were created to guide the development of point-of-care tests and emphasise the importance of accuracy, accessibility, and affordability.¹⁴ Dr Rodriguez Manzano suggested that, in reality, trade-offs between these three criteria are inevitable. More recently, the importance of ensuring **Real-time** connectivity for point-of-care diagnostics to facilitate sharing of data and the **Ease** of sample collection has led to an extended set of **REASSURED** principles.¹⁵

For diagnostics, the translational pathway is complex, with many different stakeholders involved, including clinicians, policymakers, regulatory bodies, patients, industry, and manufacturers. This can be difficult territory for academic researchers to navigate, highlighting the importance of working in partnership to ensure that user needs and preferences, evidence needs, and other constraints are considered early in development. Dr Rodriguez Manzano suggested that more could be done to **educate developers in academia about the complex diagnostic development ecosystem**.

While data typically flows from diagnostic facilities to policymakers to inform decision-making, the conversation should ideally be two-way so that diagnostic developers can respond to decision-makers' needs and optimise their products. Results of surveillance could be used to identify emerging and key needs and inform the development of diagnostics.

Many of these challenges and ideas were re-emphasised during the group discussion session. It was noted that **academia-industry partnerships** are a good way to give researchers a better understanding of the pathway to market. Furthermore, in addition to ensuring two-way dialogue between developers and policymakers, there is also a need for **feedback loops from users to developers** to ensure diagnostics meet user needs and are implementable at scale.

¹² Academy of Medical Sciences (2020). *Lessons learnt: the role of academia and industry in the UK's diagnostic testing response to COVID-19*. <https://acmedsci.ac.uk/file-download/23230740>

¹³ Academy of Medical Sciences FORUM (2021). *Building a sustainable UK diagnostics sector*. <https://acmedsci.ac.uk/file-download/89102189>

¹⁴ Mabey D, et al. (2004). *Diagnostics for the developing world*. *Nature Reviews Microbiology* **2(3)**, 231-40. <https://doi.org/10.1038/nrmicro841>

¹⁵ Land KJ, et al. (2019). *REASSURED diagnostics to inform disease control strategies, strengthen health systems and improve patient outcomes*. *Nature Microbiology* **4(1)**, 46-54. <https://doi.org/10.1038/s41564-018-0295-3>

Dr Rodriguez Manzano also noted how unexpected supply chain issues, such as a shortage of computer chips, could disrupt diagnostic development. It was later suggested that **local production of test components** could help address international supply chain challenges.

In summary, Dr Rodriguez Manzano suggested that the pathway from fundamental and innovative diagnostic research to implementation in community and/or healthcare settings is complex, should be more transparent, and is an iterative process which should engage all stakeholders from the beginning.

Wastewater monitoring could provide a low-cost solution to AMR surveillance

Professor Mark Woolhouse OBE FRSE FMedSci, Professor of Infectious Disease Epidemiology, University of Edinburgh, highlighted some of the ways in which **wastewater surveillance**, which has been used for community-level COVID-19 surveillance,¹⁶ can be used to gain insights into AMR in human populations.

Wastewater surveillance has expanded globally through the application of **metagenomics**, involving whole genome sequencing of micro-organisms directly from water samples. This is now based on standardised technologies and is relatively cheap to implement. One application has been to track the presence of AMR genes in different regions,¹⁷ which has identified unanticipated high levels of AMR genes in Africa and South America. Further studies have examined patterns in the distribution of genes associated with resistance to particular families of antibiotics, allowing comparisons between regions.¹⁸ An approach for **global AMR monitoring based on metagenomics** has been proposed.¹⁹

For SARS-CoV-2 environmental monitoring, PCR-based rather than metagenomics approaches have typically been used. In Scotland, viral load in wastewater has been found to correlate well with clinical case numbers.²⁰ Wastewater monitoring can achieve good population coverage, for example 77% of the population in Scotland.²¹ Retrospective screening of wastewater samples for specific genetic signatures revealed that the Omicron variant was first circulating in the UK in late November 2021.²²

¹⁶ Fitzgerald SF, et al. (2021). *COVID-19 mass testing: harnessing the power of wastewater epidemiology*. medRxiv. This work has not been peer reviewed.

¹⁷ Hendriksen RS, et al. (2019). *Global monitoring of antimicrobial resistance based on metagenomics analyses of urban sewage*. Nature Communications **10(1)**, 1124. <https://doi.org/10.1038/s41467-019-08853-3>

¹⁸ Munk P, et al. Under review.

¹⁹ Aarestrup FM & Woolhouse MEJ (2020). *Using sewage for surveillance of antimicrobial resistance*. Science **367(6478)**, 630-632. <https://doi.org/10.1126/science.aba3432>

²⁰ Fitzgerald SF, et al. (2021). *Site Specific Relationships between COVID-19 Cases and SARS-CoV-2 Viral Load in Wastewater Treatment Plant Influent*. Environmental Science & Technology **55(22)**, 15276-15286. <https://doi.org/10.1016/j.scitotenv.2022.153906>

²¹ Fitzgerald SF, et al. (2021). *COVID-19 mass testing: harnessing the power of wastewater epidemiology*. medRxiv. This work has not been peer reviewed.

²² UK Health Security Agency (2021). *SARS-CoV-2 variants of concern and variants under investigation in England. Variant of concern: Omicron, VOC21NOV-01 (B.1.1.529). Technical briefing 30*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1038404/Technical_Briefing_30.pdf

Surveillance could in practice be highly granular, as illustrated by work on wastewater monitoring within a single hospital complex.²³ This revealed marked differences in the AMR gene profiles of waste from different clinical areas.

Professor Woolhouse argued that metagenomics is now a proven technology, is relatively easy and cheap to implement, and can be designed to support a range of public health agendas, including monitoring of AMR. However, he emphasised that it was not a substitute for clinical surveillance and was not suitable as an early warning system in isolation. A more appropriate use would be for epidemiological monitoring and as a 'safety net' to confirm the absence of AMR genes after the use of interventions.

Next steps for implementation would need to include **validation and calibration, addressing the risk of contamination from animal and environmental sources, and developing international standards**. In the longer term, **submission of data to global databases** such as WHO's Global Antimicrobial Resistance and Use Surveillance System (GLASS)²⁴ could be considered.

Discussions highlighted other aspects of environmental surveillance that could prove important, such as the monitoring of wastewater from farms and the detection of antimicrobials in the environment, in addition to specific drug-resistant organisms or AMR genes.

Some participants indicated that for wastewater surveillance to be successful in practice, the **responsibility of organisations outside of the health sector**, the **purpose and outcomes** of the programme, and how wastewater surveillance data could be **integrated with clinical data**, would need to be carefully considered. It was suggested that wastewater surveillance, as with pathogen surveillance more widely, would need to be prioritised in the long-term, even if its benefit did not immediately become apparent.

Diagnostics have a range of roles to play in AMR

As well as guiding therapeutic decision-making, diagnostics can also be used in surveillance, to inform infection prevention and control strategies to deliver safe care, and to support targeted interventions. As such, diagnostics need to be developed with their application, including the stage of the clinical pathway in which they will be used, in mind.

It will be important to **consider the better use of diagnostics for screening purposes within clinical pathways**, beyond current screening for methicillin-resistant *Staphylococcus aureus* (MRSA) and carbapenemase-producing Enterobacterales (CPE). A range of strategies could be considered - the triaging of patients with respiratory infection symptoms before contact with the health system was highlighted as one approach that has already been implemented for COVID-19.

To better integrate diagnostics within clinical decision making and infection management, it was suggested that **connections between the diagnostic and therapeutic industries need to be strengthened**, with the aim of matchmaking diagnostics with different therapeutic strategies.

²³ Perry MR, et al. (2021). *Secrets of the Hospital Underbelly: Patterns of Abundance of Antimicrobial Resistance Genes in Hospital Wastewater Vary by Specific Antimicrobial and Bacterial Family*. *Frontiers in Microbiology* **12**, 703560. <https://doi.org/10.3389/fmicb.2021.703560>

²⁴ <https://www.who.int/initiatives/glass>

It was also emphasised that, clinically, the results of a diagnostic test may need to be interpreted in the context of the **individual patient** before decisions on antibiotic use are made. What is pathogenic in one site or in one group of patients may be harmless in another. This may ultimately require tests designed for better **personalised prescribing**. It was also noted that the need for antibiotics might depend on which combinations of micro-organisms are present, highlighting further potential complexity in the use of diagnostics to guide antibiotic use.

Diagnostics could be a critical tool for antimicrobial developers, for example to identify suitable patients for clinical trials of targeted treatments. There is a need to consider how they should guide the use of newly developed narrow-spectrum antimicrobials, which would require careful stewardship to preserve their potency. **Dialogue across researchers in the diagnostic industry, the pharmaceutical and biotech sectors, and clinicians, patient groups and members of the public** is required to explore these issues.

Despite the importance of diagnostics in the effective treatment of infection and the optimisation of antimicrobial use, they are often given less attention than interventions such as medicines or vaccines. One critical challenge is **evaluating the impact of diagnostics and determining their value**, which may be less obvious than for other types of intervention. In particular, one key contribution may be in delaying resistance and protecting the potency of antimicrobials, but this value is hard to quantify in terms of commonly used metrics for health interventions, which typically focus on the benefits to individuals receiving those interventions.

Engaging patients and members of the public is vital

Sharing and linkage of data and improving researchers' **access** to data was seen as critical, but often limited by data privacy regulations. It was suggested that patients were typically more open to data sharing than regulators assume, if informed in advance and when the benefits are clearly explained. One attendee gave the example of COVID-19 research in care homes as an example of where data was able to be accessed and linked across different settings at scale. Progress made during the pandemic needs to continue beyond COVID-19. It was noted that one advantage of wastewater surveillance studies is that they raise few if any ethical issues, as samples cannot be linked back to individuals.

A number of attendees highlighted that the widespread access to and uptake of **home testing** for COVID-19 could be replicated for AMR, transforming our ability to trace carriage of resistant organisms and to identify, manage and prevent resistant infections. Crucial to the success of COVID-19 surveillance has been the substantial scale of **diagnostic test procurement**, and the rapid **integration of test results into medical records**. With greater public understanding of testing and surveillance, there are opportunities for the public to be more directly involved in generating data, described as '**citizen science**'.

As public and patient representatives at the meeting emphasised, it is important that **patients and the public are involved and engaged** in dialogue about how and why diagnostics are used, and how data is collected and shared, to ensure that proposed approaches are acceptable and widely supported. At an individual level, there may be a need to discuss with patients the meaning of test results and the implications for treatment. As well as development of new diagnostics, research is therefore also needed into how best to communicate with patients, carers and the public about diagnostics. Patient and public representatives could play a key role in communication with patient

groups, helping to translate complex material into more digestible resources and making it more relevant to target audiences.

A previous Academy of Medical Sciences FORUM meeting considered how public and patient involvement has been addressed during the pandemic, and how it could be more strongly embedded in research.²⁵

²⁵ Academy of Medical Sciences FORUM (2020). *Public involvement and engagement in research during the COVID-19 pandemic*. <https://acmedsci.ac.uk/file-download/77957062>

Therapeutics and vaccines

Long-term investment was crucial to the success of COVID-19 vaccines

Dr Stephen Lockhart, Vice-President, Vaccine Clinical Research and Development (R&D) Europe and Asia-Pacific Head, Pfizer, noted that rapid successes were achieved in the R&D response to COVID-19 because of 'deep roots' following years of investment, echoing comments made by Professor Dame Sally Davies. Pfizer was already working with BioNTech on mRNA vaccines and the Oxford Vaccine Group was testing viral vectored vaccines, platforms that were rapidly adapted to tackle SARS-CoV-2, prior to the pandemic.

Dr Lockhart also highlighted the important role played by the **Coalition for Epidemic Preparedness Innovations (CEPI)**, which works with many vaccine developers globally. CEPI was supporting research on vaccines for Middle East respiratory syndrome (MERS), also caused by a coronavirus, which was then applied to SARS-CoV-2 vaccine development. CEPI is a model for integrating and focusing funding on priority challenges and represents a model that could be applied to AMR.

As well as these strategic and translational initiatives, Dr Lockhart also stressed that studies of the **basic biology** of pathogens in academic settings was equally important, to provide insights to guide diagnostic, vaccine, and therapeutic development.

Although new platform technologies such as mRNA vaccines have generated much excitement, Dr Lockhart stressed that they were not a guarantee of success and might not be suitable for every pathogen, particularly bacteria. However, alternative technologies, such as conjugate vaccines, may hold promise for bacterial pathogens.

Plenary and group discussions highlighted the need for greater awareness of the role that **vaccines** could play in combating AMR, both by preventing bacterial infections but also by reducing the number of viral infections that are treated inappropriately with antibiotics. However, it was also noted that regulatory systems do not currently incentivise the development of vaccines (or medicines) to address AMR, with the focus instead being on therapeutic use for individuals.

It was noted that antibiotic use has been reduced in the UK livestock sector, and that further gains may be dependent on prevention of infection, for example through use of **veterinary vaccines**. For new platforms such as mRNA vaccines, cost may be an obstacle but increasing use of these new platforms might lead to a fall in production costs.

Strengthening clinical research into AMR

Professor William Hope, Dame Sally Davies Chair of AMR Research, University of Liverpool, discussed recent work carried out by the NIHR Clinical Research Network (CRN), which facilitates clinical research within the NHS. The CRN organised an Urgent Public Health Group to support the selection, prioritisation, set-up, and delivery of COVID-19-related public health projects, ultimately

supporting more than 100 studies that enrolled over 2 million patients.²⁶ Several of these projects were relevant to AMR, including studies examining antimicrobial use in hospital settings.

The CRN was also asked to consider how lessons learned from the COVID-19 response could be applied to clinical AMR research. Although there are many AMR-related policy and strategy documents, there are none that specifically focus on clinical AMR research. The CRN's expert working group noted that there were two key elements to clinical AMR research – **development of new antibiotics**, which typically receives most attention, but also research to **preserve and enhance antimicrobial assets**.

Professor Hope stated that there are a number of issues hindering the progress of new antimicrobials through the development pathway, most notably between the latter stages of clinical trials and market authorisation, creating a gap in the pathway (**Figure 1**). These include a lack of understanding of the value of antimicrobials, a lack of real-world evidence, and a lack of understanding of drug behaviour in specific populations.

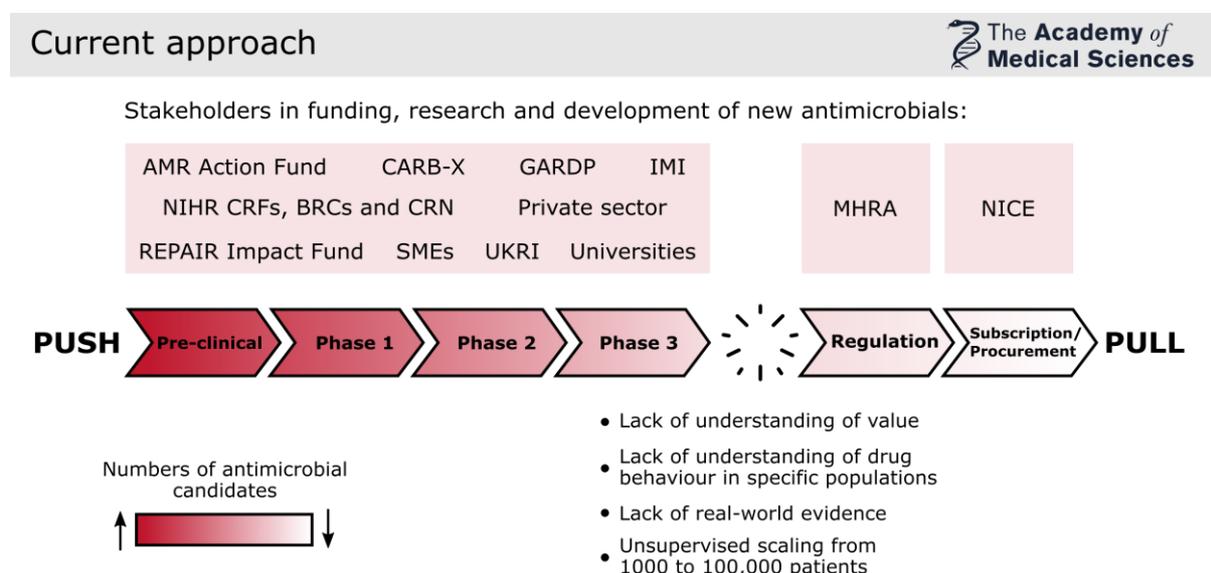


Figure 1: The current funding, research and development pathway for antimicrobials. CARB-X: Combating Antibiotic-Resistant Bacteria. GARDP: Global Antibiotic Research and Development Partnership. IMI: Innovative Medicines Initiative. NIHR: National Institute for Health and Care Research. CRFs: Clinical Research Facilities. BRCs: Biomedical Research Centres. CRN: Clinical Research Network. REPAIR: Replenishing and Enabling the Pipeline for Anti-Infective Resistance. SMEs: Small and medium-sized enterprises. UKRI: UK Research and Innovation. MHRA: Medicines and Healthcare products Regulatory Agency. NICE: National Institute for Health and Care Excellence.

Professor Hope suggested that the UK may not be particularly well placed to focus primarily on the development of new antimicrobials. As a result of several international funding programmes, drug discovery and early clinical studies are leading to a slightly improved antimicrobial pipeline, and multiple mechanisms are being developed to incentivise investment in antimicrobial R&D. The UK's efforts should aim to **collaborate and complement** these activities.

²⁶ National Institute for Health and Care Research (2020). *NIHR Urgent Public Health Group Terms of Reference*. <https://www.nihr.ac.uk/documents/nihr-urgent-public-health-group-terms-of-reference/25053>

Analysis of the CRN project portfolio identified just 24 AMR-specific studies out of more than 6000 in total, highlighting the relative lack of clinical AMR research in the UK. Professor Hope suggested that insufficient attention was being placed on the **translational pathway between initial licensing and scale up of use**. At this stage, there is an important need for research to **optimise the use of antibiotics**, for example in different groups of patients, and to gather the critical **real-world evidence** that would inform prescribing guidelines, pharmacoeconomic analyses and discussions of the value of antibiotics.

The CRN's Expert Working Group recommended three research programmes for the UK:

- **Cohort studies using antimicrobial registries**, for example to explore relationships between dose exposures, pharmacokinetics, and responses in the real world.
- **Studies of special populations** (e.g. pregnant women, babies, children, groups at high risk such as those with obesity, critically ill and burns patients and those with co-morbidities, including complex respiratory tract infections). Current use of antibiotics relies on data from population-based averages, but all of these groups are likely to handle antibiotics differently to the average person. A better understanding of these differences would facilitate more personalised prescribing and antibiotic use tailored to their specific needs.
- **Platform trials to examine antimicrobial performance in real-life settings**; platform trials are a type of randomised clinical trial that allow the simultaneous comparison of multiple interventions against a single control group, with the possibility of adding new interventions during the trial. For example, the RECOVERY trial was embedded in routine clinical care and used to evaluate different COVID-19 treatments with rigorous study designs. A similar model could be developed for antimicrobial use, for example to test the effectiveness of new combination treatments or alternative (e.g. shorter) dosing regimens.

Given the potential rapid loss of potency due to resistance once antimicrobials begin to be used, attendees suggested that additional research, conducted during antimicrobial development, should focus on **how and to what extent resistance emerges**. One major challenge is that increasing dosing levels in clinical studies to prevent the emergence of resistance typically leads to an increased risk of adverse events, so there is always a trade-off between suppressing resistance and safety.

Strategies to **conserve our existing antimicrobial assets** will include improving the practice and regulation of appropriate prescribing. Although not covered in detail due a lack of translatable lessons learned from COVID-19, there was some discussion on the wisdom of the current practice of 'one-size-fits-all' dosing and prescribing. It was acknowledged that, while extensive data on individual responses to antibiotics are collected during testing to explore dose exposures and responses, little or no effort is made in clinical practice to adjust dosing according to the individual characteristics of patients. It was recognised that although feasible, a substantial culture change is required to go from a **one-size-fits-all to a fully individualised approach**.

It was argued that major opportunities exist to use **real-world data** to inform dosing and prescribing. As mentioned by Professor Hope and others, platform-based studies could be carried out to develop more optimised and personalised dosing regimens, to explore links between antimicrobial use and the emergence of resistance, and to test new formulations and combinations of antibiotics.

An alternative approach to the antibiotic development pipeline

Dr Rebecca Glover, Head of Economic, Social and Political Sciences, Antimicrobial Resistance Centre, London School of Hygiene and Tropical Medicine, proposed that radically different models might be needed to address the shortage of new antibiotics.

Dr Glover noted that few new antibiotics have been licensed in recent decades and several pharmaceutical companies have pulled out of antibiotic R&D. Multiple innovative financing schemes have been introduced to incentivise new antibiotic development, supported by government agencies, the philanthropic sector and even industry itself. There are now more promising compounds in early phase clinical evaluation, but later parts of the pipeline remain poorly stocked. Furthermore, even when products gain approval, the long-term sustainability of companies remains insecure – by one estimate, of the 18 antibiotics approved in the past decade, the makers of seven have gone bankrupt or their investors lost most of their stake.²⁷

Another approach could be to establish a network of international, publicly funded clinical trials institutes, **the network institute model (NIM)**.²⁸ This model would provide an infrastructure capable of conducting all stages of clinical trials, including manufacture of trial batches of antibiotics, taking products all the way through to market authorisation (**Figure 2**). Within this pathway, discussions could be held on supply and use, with long-term pre-agreed contracts to supply countries, healthcare facilities or aid organisations. Such a model would enable profitable production by generic manufacturers, de-risk clinical trials and provide public control over intellectual property, likely improving costs and access.

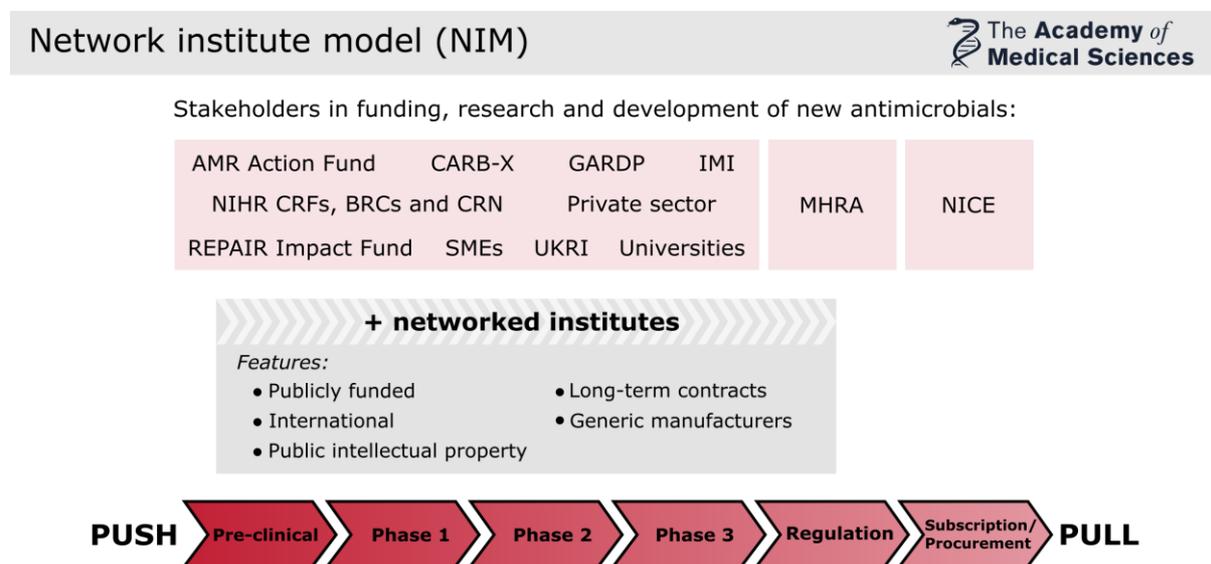


Figure 2: The network institute model for the funding, research and development of antibiotics. Such a model could be implemented alongside existing infrastructure and strategies.

²⁷ Mancini DP (2021). *Push and pull: funding drugs to be used only sparingly*. Financial Times, February 10. <https://www.ft.com/content/69edbd0d-da11-4b27-8b73-7aeab34da780>

²⁸ Glover RE et al. (2021). *NIMble innovation: A networked model for public antibiotic trials*. *Lancet Microbe* **2(11)**, E637–E644. [https://doi.org/10.1016/S2666-5247\(21\)00182-8](https://doi.org/10.1016/S2666-5247(21)00182-8)

The NIM would help to ensure that the antibiotic development ecosystem is driven primarily by public health needs. It would focus public investment on bridging critical clinical trial bottlenecks for public and private developers, and is compatible with subscription models and equitable pricing initiatives. Although a shift in the antibiotic development paradigm, elements of it have already been introduced, and the change in perspective driven by COVID-19 may mean there is a greater appetite to consider alternative approaches.

Attendees generally considered the NIM approach as a potentially interesting new model. One possible risk is that it might squeeze out private investment in new antimicrobial development. It was argued that this has been happening anyway, and that the model would not necessarily exclude industry participation or entirely replace commercially driven approaches.

It was noted that **strong leadership** would be required to drive forward radical change in this area, which could potentially come from within the scientific community if political leaders are reluctant to step forward. However, it was noted that antimicrobial development involves a complex set of stakeholders, and driving forward change would be challenging. Active **support for careers** in AMR research and policy, as mentioned by Dame Sally, was emphasised as being vitally important to create leadership in this area.

Reflections

Capturing public and political attention

Summing up the meeting, **Professor Lucy Chappell** FMedSci, Chief Scientific Adviser to the DHSC and CEO of the NIHR, noted that the COVID-19 pandemic may be a 'teachable moment', offering an opportunity to reconsider how clinical care and research are done. In particular, the public has been highly engaged with the COVID-19 pandemic and made important contributions to public health responses. A key challenge now is to see how this level of engagement can be mirrored for AMR. For example, public familiarity with dashboards could be leveraged to support enhanced **public communication** around AMR. The complexities and uncertainties associated with AMR also need to be communicated, potentially requiring closer collaboration with the education sector.

In the group discussions, participants highlighted the need to capture the energy, urgency and 'can-do' mentality that has characterised the COVID-19 response and apply it to AMR. Professor Chappell voiced support for the idea of '**rebranding AMR**' to consider the wider concept of antimicrobial stewardship, saying that reassessment of key messages to be communicated could also be explored. Questions surrounding the **positioning and communication** of AMR were brought up throughout the event. AMR is often considered separate from the more general field of infectious diseases, yet any treatment of an infection has implications for AMR. There may be merit in considering how to integrate AMR into wider discussions of infectious diseases and their control, so that AMR research is not siloed, or to consider more carefully those aspects that make it distinct.

It was also noted that **targeted communication** with particular groups of patients and the public will be necessary to gain public support for any new policies. As scientists are a trusted voice among public audiences, they have a key role to play in this dialogue.

Coordination and collaboration across sectors and disciplines

The response to the COVID-19 pandemic has been **coordinated and collaborative**, spanning multiple sectors. Professor Chappell suggested that this needs to be replicated for AMR, recognising the power of '**team science**' to address complex public health threats. Patients and the public bring an important perspective and need to be integral to these team efforts.

Translation of academic research has traditionally been portrayed as a linear process. In reality, argued Professor Chappell, it is circular – **evidence from implementation needs to further inform early phase research and discovery science**, and there is also a need to learn from failures. Given the cross-sector nature of the AMR threat, this circular model needs to extend into the third dimension, to span veterinary and environmental domains as well as medical interventions.

In addition to strengthening academia-industry partnerships, attendees mentioned the need to **reinforce relationships between researchers and policymakers** as a means to achieve coordination between different sectors (such as discovery research, clinical research and public health). It was noted that policymakers could also help to unite the currently fragmented system of

AMR research by ensuring that **future research agendas, including the next 5-year national action plan for AMR, have a cross-disciplinary and cross-sectoral outlook.**

Improving data access and linkage is a key aspect of coordination. Participants identified improvements in **open access research** during to COVID-19 pandemic as a key enabler of information sharing.

Prioritisation within AMR research

The need for **prioritisation** was raised by participants. Although priority pathogens have been identified, there are more detailed issues such as which specific clinical scenarios should be prioritised, which interventions will be most effective in the areas of highest burden and highest transmission, and how public health value can be assessed and inform prioritisation. There are opportunities for greater public and patient input into such discussions. Professor Chappell emphasised that **prioritisation** is critical and is being taken forward through the Research Coordination Group of the national action plan for AMR.

Final reflections from participants stressed that, while there is undoubtedly much that can be learned from the response to COVID-19, AMR and COVID-19 are quite distinct challenges. In some respects, COVID-19 has been less complex to address, as a single pathogen representing an acute public health emergency. AMR is intrinsically more complex and playing out over longer timescales, so direct translation from one area to the other may not always be relevant or appropriate. The urgency to tackle both remains clear.

Conclusion and next steps

Many aspects of the UK's scientific response to the COVID-19 pandemic have gone well, although some could have been improved. There are opportunities to learn both from successes and shortcomings and apply them to AMR, another public health crisis.

Although there are significant differences between the UK's COVID-19 and AMR challenges, discussions at the meeting highlighted several areas where responses to the COVID-19 pandemic could have important implications for AMR. One important lesson from COVID-19 is that effective responses are based on 'deep roots'. We need to invest in young trees now to ensure that these roots are strongly embedded as we encounter further AMR challenges in the longer term. This will require a combination of **targeted funding, training of the next generation of scientists, and pathways and partnerships to translate scientific discoveries into clinical and public health practice.**

Some advances may be **incremental and readily achievable**, particularly where significant capabilities and capacity have been built during the pandemic. **Testing, epidemiological and wastewater surveillance** fall into this category, but their adoption for AMR detection and control will depend on preventing the decline of capabilities that are deemed to be non-essential as the pandemic shifts to become endemic. A further example is the use of **platform trials to generate real-world evidence** to improve understanding of the links between antimicrobial use and resistance. AMR research could build on trial designs and innovative thinking developed during the COVID-19 pandemic. Leadership already exists through the NIHR Clinical Research Network, but progress in this area would require targeted funding.

There are also examples where a more **radical step change** is needed. These would likely require strong **planning and leadership**, and **involvement of stakeholders** including the scientific community, industry and the public. More radical ideas include the **network institute model**, which describes a network of international, publicly funded clinical trials institutes to take antimicrobial candidates from early-stage clinical trials through to market authorisation. Creating a tangible and sustainable change in the **relationships between stakeholders involved in diagnostics development** to speed up development, ensure that surveillance needs inform development and improve understanding of the value of diagnostics will also require new approaches. Finally, the response to the COVID-19 pandemic may hold important lessons to energise and inform the national response to AMR, which has yet to receive the same level of political or public attention as COVID-19. Thought could be given to how AMR could be **'rebranded' and communicated better** to support stronger advocacy and to achieve greater political and public buy in.

What is certain is that the status quo is not a long-term option if the threat of AMR is to be effectively addressed in the UK and globally. A review of the **remit of the research agenda of the national action plan for AMR** will provide a first step towards shifting the status quo. The

findings of this workshop were presented to the Research Coordination Group of the national action plan in February 2022, and will inform their work moving forwards.

Annex I: Agenda

8:50-9:00	Participants join meeting
9:00-9:10	<p>Welcome and introduction</p> <p>Professor Sharon Peacock CBE FMedSci, Executive Director and Chair of the COVID-19 Genomics UK consortium and Professor of Public Health and Microbiology, University of Cambridge</p> <p>Professor Alison Holmes OBE FMedSci, Professor of Infectious Diseases and Director of the NIHR Health Protection Research Unit in Healthcare Associated Infections and AMR, and the Centre for Antimicrobial Optimisation (CAMO), Imperial College London</p>
9:10-9:25	<p>What have we learned from COVID-19?</p> <p>Professor Dame Sally Davies DBE GCB FRS FMedSci, Special Envoy for AMR, will focus on the learnings from the COVID-19 pandemic and how they can be applied to AMR challenges. This will be followed by a short Q&A session.</p> <p><i>Chair: Professor Alison Holmes OBE FMedSci</i></p>
9:25-10:15	<p>Theme 1: Diagnostics and surveillance</p> <p>A series of talks on diagnostics and surveillance, outlining key learnings that emerged during the pandemic and how they can be applied to the field of AMR. This will be followed by a Q&A session with all speakers.</p> <p>Speakers:</p> <ul style="list-style-type: none"> • Doris-Ann Williams MBE, Chief Executive, British In Vitro Diagnostics Association • Professor Mark Woolhouse OBE FRSE FMedSci, Professor of Infectious Disease Epidemiology, University of Edinburgh • Dr Jesus Rodriguez Manzano, Lecturer in Antimicrobial Resistance and Infectious Diseases, Imperial College London <p><i>Chair: Professor Alison Holmes OBE FMedSci</i></p>
10:15-10:20	Break
10:20-11:10	<p>Theme 2: Therapeutics and vaccines</p> <p>A series of talks on therapeutics and vaccines, outlining the key learnings that emerged during the pandemic and how they can be applied to the field of AMR. This will be followed by a Q&A session with all speakers.</p> <p>Speakers:</p> <ul style="list-style-type: none"> • Professor William Hope, Dame Sally Davies Chair of AMR Research, University of Liverpool • Dr Stephen Lockhart, Vice President, Vaccine Clinical R&D Europe and Asia-Pacific Head, Pfizer • Dr Rebecca Glover, Head of Economic, Social and Political Sciences, Antimicrobial Resistance Centre, London School of Hygiene and Tropical Medicine <p><i>Chair: Professor Sharon Peacock CBE FMedSci</i></p>
11:10-11:20	Break

11:20-11:50	<p>Break-out sessions</p> <p>Participants will be allocated to breakout rooms to discuss following questions in relation to either Theme 1 (diagnostics and surveillance) or Theme 2 (therapeutics and vaccines):</p> <ol style="list-style-type: none"> 1. What lessons have been learned during the COVID-19 pandemic? 2. What are the next steps required to apply these lessons learned and new innovations to AMR? <p><i>Chair: Professor Sharon Peacock CBE FMedSci</i> <i>Breakout room discussions to be facilitated by experts in the respective fields.</i></p>
11:50-12:10	<p>Feedback session</p> <p>Breakout group facilitators will be invited to share key points from their group's discussions, followed by an open discussion.</p> <p><i>Chair: Professor Sharon Peacock CBE FMedSci</i></p>
12:10-12:20	<p>Reflections</p> <p>Professor Lucy Chappell FMedSci, Chief Scientific Adviser for DHSC will provide reflections on the meeting's discussions.</p> <p><i>Chair: Professor Alison Holmes OBE FMedSci</i></p>
12:20-12:30	<p>Closing remarks</p> <p>Professor Sharon Peacock CBE FMedSci and Professor Alison Holmes OBE FMedSci</p>
12.30	Close of meeting

Annex II: Participants

Co-Chairs

Professor Alison Holmes OBE FMedSci, Professor of Infectious Diseases, Imperial College London; Director, NIHR Health Protection Research Unit in Healthcare Associated Infections and AMR; Director, Centre for Antimicrobial Optimisation (CAMO)

Professor Sharon Peacock CBE FMedSci, Executive Director and Chair, COVID-19 Genomics UK (COG-UK) consortium; Professor of Public Health and Microbiology, University of Cambridge; Member, UK AMR Research Coordination Group

Steering group

Dr Flic Gabbay FMedSci, Founding and Senior Partner, tranScrip; President, Faculty of Pharmaceutical Medicine

Professor Sir Andrew Pollard FMedSci, Professor of Paediatric Infection and Immunity, University of Oxford; Director, Oxford Vaccine Group

Doris-Ann Williams MBE, Chief Executive, British In Vitro Diagnostics Association; Vice President, Parliamentary and Scientific Committee

Attendees

Dr Chioma Achi, Cambridge-Africa PhD scholar, University of Cambridge; Student of the Year, 2020 Antibiotic Guardian Awards

Dr Nicholas Adomakoh, Global Medical Affairs Lead for Anti-infectives, Sandoz

Professor Claire Anderson, President, Royal Pharmaceutical Society; Professor of Social Pharmacy, University of Nottingham

Dr Kate Anderson, Senior Policy Officer, AMR Policy and Strategy Team, Chief Nursing Officer's Directorate, Scottish Government; Member, UK AMR Research Coordination Group

Dr Diane Ashiru-Oredope, Lead Pharmacist, AMR Programme, UK Health Security Agency

Dr Mark Bale, Deputy Director, Genomic Science Policy, Department of Health and Social Care

Arlene Brailey, Patient Support Lead, Antibiotic Research UK; Trustee, Lyme Resource Centre

Dr Colin Brown, Director (Interim), Clinical and Emerging Infections; Deputy Director (Interim), Healthcare-associated Infections, Fungal, AMR, AMU and Sepsis Division, Clinical & Public Health Group, UK Health Security Agency

Professor Chris Butler FMedSci, Professor of Primary Care, University of Oxford; Clinical Director, University of Oxford Primary Care Clinical Trials Unit

Professor Lucy Chappell FMedSci, Chief Scientific Adviser, Department of Health and Social Care; Professor of Obstetrics, Kings College London

Professor Myron Christodoulides, Professor of Bacteriology, University of Southampton; AMS-Hamied Foundation UK-India AMR Visiting Professor

Professor Dame Sally Davies DBE GCB FRS FMedSci, Master, Trinity College, University of Cambridge; UK Special Envoy on Antimicrobial Resistance

Dr Jennifer Dow, Programme Manager, Veterinary Medicines Directorate

Professor Paul Elliott CBE FMedSci, Professor of Epidemiology and Public Health Medicine, Imperial College London; Director, MRC Centre for Environment and Health; Director, REACT study

Dr Jayne Ellis, Head of Medical and Clinical Affairs, LumiraDx

Sophie Evans, patient and public representative

Jeff Featherstone, Head of Antimicrobial Resistance, NHS England

Dr Sarah Gerver, Lead Epidemiologist/Head of Antimicrobial Resistance and Prescribing Section, Healthcare-associated Infections, Fungal, AMR, AMU and Sepsis Division, Clinical & Public Health Group, UK Health Security Agency

Dr Rebecca Glover, Head of Economic, Social and Political Sciences, Antimicrobial Resistance Centre, London School of Hygiene and Tropical Medicine

Professor Herman Goossens, Professor of Medical Microbiology, University of Antwerp; Director, Department of Clinical Pathology, University Hospital, Antwerp

Dr Alwyn Hart, Lead Scientist, Air Land and Water Research, Environment Agency

Steve Hoare, Quality, Regulatory Science and Safety Policy Director, The Association of the British Pharmaceutical Industry

Professor William Hope, Dame Sally Davies Chair of AMR Research, University of Liverpool; Director, Centre of Excellence in Infectious Diseases Research

Dr Susan Hopkins, Chief Medical Advisor Transition Lead, UK Health Security Agency, Honorary Clinical Senior Lecturer, Imperial College London

Simon Horvat-Marcovic, patient and public representative, Positively UK, Terrence Higgins Trust and UK Community Advisory Board (UK-CAB)

Dr Robin Howe MBE, National Clinical Lead, Public Health Wales Microbiology

Dr Timothy Jinks, Head of Drug Resistant Infections Priority Programme, Wellcome Trust

Dr Carolyn Johnson, Programme Manager for Bacteriology, Mycology and Antimicrobial Resistance, MRC

Dr Stephen Lockhart, Vice President, Vaccine Clinical R&D Europe and Asia-Pacific Head, Pfizer

Dr Liying Low, Clinical Research Fellow and honorary Specialty Registrar, University of Birmingham and Birmingham and Midland Eye Centre

Dr Seamus O'Brien, R&D Director, Global Antibiotic Research and Development Partnership

Karen O'Dwyer, Project Leader, Innovative Medicines Initiative AMR Accelerator, GSK

Professor Isabel Oliver, Interim Chief Scientific Officer, UK Health Security Agency; Visiting Professor, University of Bristol

Dr Jesus Rodriguez Manzano, Lecturer in Antimicrobial Resistance and Infectious Diseases, Imperial College London

Dr Daniela Rodriguez Rincon, Research Policy Manager, The Association of the British Pharmaceutical Industry

Mandy Rudczenko, patient and public representative

Professor Laura Shallcross MBE, Professor of Public Health and Translational Data Science, University College London; Honorary Consultant in Public Health, University College London NHS Trust

Dr Robert Skov, Scientific Director, International Centre for Antimicrobial Resistance Solutions; Senior Consultant, National AMR Coordinator, Statens Serum Institut

John Turner MBE, patient and public representative; Member, Diabetes UK Grants Advisory Panel

Professor Sarah Walker OBE FMedSci, Professor of Medical Statistics and Epidemiology, MRC Clinical Trials Unit, University College London; Director, NIHR Health Protection Research Unit in Healthcare Associated Infections and Antimicrobial Resistance, University of Oxford

Professor Mark Wilcox, Professor of Medical Microbiology, University of Leeds; Consultant, Head of Microbiology R&D, Infection Lead, Leeds NIHR Diagnostic Technologies Medical Technology and In Vitro Diagnostic Cooperative; Member, UK AMR Research Coordination Group

Professor Mark Woolhouse OBE FRSE FMedSci, Professor of Infectious Disease Epidemiology, University of Edinburgh

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