editorial

# Materials at the heart of the COVID-19 pandemic

Materials scientists have played a key role in the global response to the COVID-19 pandemic from the development of vaccines and diagnostic tools to the rapid prototyping of ventilators.

Collaborations between materials scientists, virologists, immunologists and clinicians were established at unprecedented pace to tackle the coronavirus disease 2019 (COVID-19) pandemic challenges, ranging from the development of early sensing systems through to vaccine and antiviral drug development. In order to discuss the scientific, technological and political developments during the pandemic, in March 2022, the Royal Society organized a conference on 'The Science of COVID', bringing together experts from academia, industry and government[1]. The meeting explored the basic science, vaccine efforts, diagnostic logistics, treatment, and recovery from long and acute COVID-19. Emphasis was placed on how lessons learned during the global COVID-19 response across sectors can be taken forward for future pandemic preparedness. Echoed throughout the conference was the need for more open scientific cooperation and international collaboration, and the importance of open data and code sharing. For instance, the rapid COVID-19 vaccine development was only possible due to worldwide sharing of the genomic sequence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) early in the pandemic, providing the raw data needed to start making a vaccine. Similarly, we should develop mechanisms to ensure rapid access to innovation in low- and middle-income countries and to systematically address failures in pandemic preparedness.

At the onset of the pandemic, there was a clear and urgent need to manufacture thousands of life-saving mechanical ventilators to match an unprecedented demand. Collaboration across sectors, including medical device, automotive and aerospace industries, was essential to repurpose existing technologies and overcome manufacturing challenges. Materials scientists were uniquely positioned to leverage experiences in virtual modelling and 3D printing for rapid prototyping and validation of devices. Similarly, while the COVID-19 vaccines were developed at extraordinary scale and speed, the core technologies underlying the effective delivery of mRNA vaccines have been investigated for decades by the RNA and nanomedicine communities[2]. Extensive optimization of lipid nanoparticle formulations to improve biocompatibility, stability, circulation time and targeting has enabled safe and efficient nucleic-acid delivery. Companies, for example BioNTech, were able to reorient years of work on an 'mRNA toolbox' and optimized lipid formulations for targeted personalized vaccines for cancer immunotherapy[3] towards an mRNA-based COVID-19 vaccine in less than one year. The ability to deliver multiple antigens in a single or 'multiplexed' vaccine (for example, antigens specific to different variants, viruses, or cancers) that could potentially elicit broader immune responses and improve durability and efficacy was highlighted in the meeting as a potential future development.

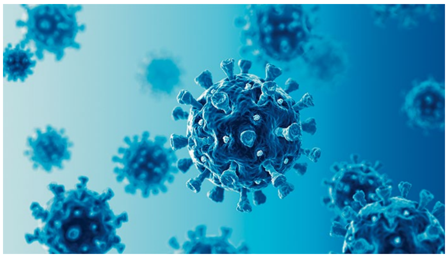

Illustration of coronavirus particles. Credit: Getty Images / BlackJack3D.

Many countries are currently at an inflection point in the pandemic — moving from broad social interventions (in the face of limited diagnostic and therapeutic tools) in the early phases of the pandemic to the current phase of medical interventions to de-risk COVID-19. Moving through these phases in this pandemic has required the cooperation of epidemiologists, engineers, behavioural and social scientists, and anthropologists. However, to prepare for the next pandemic we need agile and adaptable tools, including vaccines, diagnostic tests and antivirals, to efficiently tackle emerging infectious disease outbreaks. At the same time, we need to improve the resilience of our health systems. Materials scientists are well positioned to develop technologies for virus detection and treatment to reduce the impact of future pandemics[4]. Access to lateral flow testing has been a game-changer for self-testing as the public is more informed about diagnostics. This may enable a renaissance of rapid home and remote testing for other diseases, which could shape future care-pathways. Materials-based amplification technologies and high-affinity binding reagents are critical to improve the sensitivity and specificity of these rapid diagnostic tests. Large-scale biosurveillance projects, for example detecting SARS-CoV-2 passively on public transit[5], transforms the way we may think about public infrastructure as a network of passive sensors. To enable truly rapid global deployment of therapeutics in the future, materials-enabled strategies that circumvent the need for temperature-controlled environments (for example, refrigeration) and needle-based delivery (for example, oral, inhalable, or transdermal formulations) will be required to democratize access to these life-saving therapeutics[6]. Future vaccine technologies will inevitably require a pan-coronavirus vaccine that can protect against emerging variants of SARS-CoV-2 and perhaps against other coronaviruses, which may be possible with multiplexed vaccine technologies. Additionally, broad-spectrum antiviral drugs and materials will become part of our pandemic preparedness toolkit[7].

As we move into a new phase of the pandemic, it is important to reflect on how we can build on the enormous diagnostic and therapeutic capacity and experience gained during the earlier phases of the pandemic for the future — not only for emerging infectious diseases, but also for antimicrobial resistance and non-communicable diseases such as cancer. We must continue to invest in treating and monitoring other infectious threats, maintain preparedness and embrace new technologies. It is also important to recognize the importance of international scientific collaboration, open data sharing, effective communication of scientific uncertainty to policymakers and the public, and equitable global health. ☐

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