Review of the research, development and innovation organisational landscape: Royal Society of Chemistry input

The Royal Society of Chemistry welcomes the independent review of the research, development and innovation organisational landscape and is grateful for the opportunity to provide input. Ensuring that there is a joined up and strategic approach to RDI infrastructure and capability across the UK will be vital for achieving the Government's science ambitions.

About the Royal Society of Chemistry

With about 50,000 members in 120 countries and a knowledge business that spans the globe, the Royal Society of Chemistry is the UK's professional body for chemical scientists, supporting and representing our members and bringing together chemical scientists from all over the world. Our members include those working in large multinational companies and small to medium enterprises, researchers and students in universities, teachers and regulators.

Relevant material

Below we have brought together material and excerpts that we believe would be useful for the Review of the RDI organisational landscape. This short paper includes the following:

i. Future opportunities: Securing UK position and capability in 21st century chemistry, materials and life sciences
ii. Brief summaries of RSC's Science Horizons and Digital Futures reports
iii. What works for innovation
iv. Financial health and capability of UK university chemistry departments

If you have any questions or wish to know more about any particular area we have covered, please do not hesitate to get in touch with us (policy@rsc.org).

i. Future opportunities: Securing UK position and capability in 21st century chemistry, materials and life sciences

To develop solutions to national and global challenges from net zero and circular economy to a healthy population, we need to discover and make new types of materials and molecules. We also need to understand and control how they interact and behave, whether that is how medicines or pollutants interact with the human body and ecosystems or how battery materials perform over repeated use cycles.

We have identified a rapidly emerging opportunity which the UK will benefit from and indeed risks being left behind if it does not seize. Our research (see next section)[1] shows that the way in which scientists discover, understand, measure and make materials and molecules is changing and this change is accelerating.

Currently academic chemistry research challenges across the 'design-make-test-understand' spectrum are often tackled independently by distinct groups of scientists working in different locations and relying on different types of equipment like computing capability, 'wet' labs and measurement or testing facilities. Most research is carried out by relatively small groups and the results are shared afterwards via published journal articles and conference presentations. Data sharing is limited, and there are even fewer mechanisms for sharing of data about what has not worked.

As the world transitions to the digital age, we are seeing the digital transformation of chemistry and its multi-disciplinary interfaces with biology, engineering, materials and physics. Chemistry is being

[1] The Royal Society of Chemistry, Science Horizons, 2019. See https://www.rsc.org/new-perspectives/discovery/science-horizons/
The Royal Society of Chemistry, Digital Futures, 2020. See https://www.rsc.org/new-perspectives/discovery/digital-futures/

revolutionised by frontier techniques like computational modelling, data analytics, AI, robotics/automation and advanced measurement and sensing.

These frontier techniques do not replace human scientists or wet labs, however they:

- Expand the toolkit scientists use to understand, design and make molecules and materials.
- Accelerate research, development and innovation.
- Enable scientists to tackle bigger, higher level, multi-disciplinary challenges from better battery materials and plastics to more effective medicines and diagnostics.
- Connect scientists within and between labs in ways that increase efficiency, reproducibility and accelerate R&D.

Chemistry-using industries[2] are increasingly embedding digital technologies across their operations including research, manufacturing and product development. Examples in R&D include BASF Digitization of R&D strategy[3], Johnson Matthey partnership with chemistry AI start-up as part of its digital strategy[4], and the new AstraZeneca Discovery Centre[5] in Cambridge which integrates state of the art digital discovery labs with wet labs and computation.

The UK now needs to integrate these frontier techniques into its chemistry RDI capability so that the UK science base keeps pace with global competition and delivers the transformational discovery research and translation that is vital for SMEs and large companies.

Our national capability, accessible to individuals, universities and companies (including SMEs) around the country, needs to include:

1. AI-enabled and automated chemistry synthesis, analysis & scale-up labs
2. Advanced measurement capability enabling automated and multi-modal measurement
3. Advanced computational modelling and data analytics for prediction and interpretation, with associated computing infrastructure
4. Accessible and reusable data on molecular and materials structures, properties and reactions
5. Hybrid modalities that blend automation and AI with wet lab and human exploration, developing and incubating new ideas and next generation techniques
6. Connectivity and inter-operability between 1-5 enabling universities and companies round the UK to harness the potential of these tools to discover and innovate faster
7. Connectivity to international nodes as part of increasingly globalized and distributed advanced chemistry and materials RDI missions

Currently no other country has built this capability, but some have started the journey. Some examples of elements of this future ecosystem from the US are:

- **Carnegie Mellon University Cloud Lab**[6]**:** The world's first university cloud lab, due to open in 2022 is a $40M remote-controlled lab which provides a universal platform for AI-driven experimentation. The facility will house more than 100 unique types of scientific instruments for life sciences and chemistry experiments. The CMU Cloud Lab will be capable of running more than 100 complex experiments simultaneously, processing them 24 hours a day, 365 days a year. This will allow users to individually manage many experiments in parallel and will increase the speed of discovery. Its mission includes the democratisation of research by giving access to individuals including high school students as well as to resource-limited institutions.

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[2] Chemistry-using sectors range from chemicals and materials to biopharmaceuticals, automotive and consumer products.
[3] BASF, Digitalization in research and development, accessed 8 December 2021. See https://www.basf.com/global/en/who-we-are/innovation/how-we-innovate/our-RnD/Digitalization_in_R-D.html
[4] Johnson Matthey, Johnson Matthey taps Kebotix's AI capabilities to enhance digital strategy, 3 August 2021. See https://matthey.com/en/news/2021/kebotix
[5] AstraZeneca, AstraZeneca unveils The Discovery Centre (DISC) in Cambridge, 23 November 2021. See https://www.astrazeneca.com/media-centre/press-releases/2021/astrazeneca-unveils-the-discovery-centre-disc-in-cambridge.html
[6] Carnegie Mellon University, Carnegie Mellon University and Emerald Cloud Lab to Build World's First University Cloud Lab, 30 August 2021. See https://www.cmu.edu/news/stories/archives/2021/august/first-academic-cloud-lab.html

- **Lilly Life Science Studio Automated Laboratory[7]:** Based in San Diego (US), the Lilly Life Science Studio Automated Laboratory is an example of a physically and virtually connected ecosystem designed to accelerate the drug discovery process through automation.
- **DARPA Accelerated Molecular Discovery (AMD) programme[8]:** The AMD programme is developing comprehensive computational and experimental methods to design, discover, validate and optimise new molecules, iteratively and actively learning to more efficiently and effectively discover molecules that enhance performance in applications relevant to national security.

The UK can continue to be a frontrunner in chemistry, advanced materials and life sciences if we build on our strengths to invest and connect strategically. The UK has a strong base of academic excellence and investments to build from, as well as many expert large companies and SMEs which will be key players in building this national and globally connected ecosystem.

ii. Brief summaries of RSC's Science Horizons and Digital Futures reports

In 2019 and 2020, the RSC published two reports, Science Horizons and Digital Futures, which looked into the direction, potential and needs of scientific research and development in the next 10-15 years. We engaged with over 700 academic researchers globally to seek views on key trends and emerging research areas in the chemical sciences and its interfaces from biology to materials to engineering. Frontier techniques – from advanced measurement and sensing to computational modelling and data analytics to applications of robotics and AI - emerged as a key driver that is transforming chemistry.

Science Horizons found that to meet global challenges, advances in three interdependent dimensions of scientific research will be important:

i. **Solutions to global & industrial challenges:** Researchers expect significant advances in the chemical sciences to underpin new technological solutions to major societal challenges from environment and energy to human health and agriculture. Researchers are also deeply embedded in enhancing the efficiency, safety and profitability of industry, in sectors from electronics to pharmaceuticals to energy.
ii. **Leading-edge questions**: Researchers are tackling an incredibly broad range of questions relating to the structure, properties and interactions of matter across multiple length scales and levels of complexity – from atoms, molecules and materials to organisms and ecosystems. Starting with atomic and molecular insights, chemical scientists are designing, making and modifying new molecules and materials with applications from new medicines to batteries and solar cells.
iii. **Frontier techniques**: Advances across a staggering range of techniques are enabling researchers to reveal the structure and properties of matter at unprecedented resolution in space and time. Scientists and engineers are pushing the frontiers of: measurement & imaging; sensors & screening and modelling & simulations. Data and digital technologies are central to these areas as researchers gather and analyse data from increasingly complex studies, going on to use data and digital technologies in new ways to make predictions and discoveries, and to deliver new insights and products.

Our Digital Futures report is a follow up to Science Horizons, which set out to gain a more in-depth understanding of the long-term promise of and concerns about the use of frontier techniques for scientific discovery by inviting experts from different scientific fields and sectors to our first Strategic Advisory Forum. It details how the new wave of technologies can turbocharge research speeds to respond to future global challenges.

The forum found the following key areas of technical opportunity:

[7] IEN Europe, Lilly Life Science Studio Automated Laboratory Goes Further in the Search For New Drugs, 6 August 2021. See https://www.ien.eu/article/lilly-life-science-studio-automated-laboratory-goes-further-in-the-search-for-new-drugs/
[8] DARPA, Accelerated Molecular Discovery (AMD), accessed 8 December 2021. See https://www.darpa.mil/program/accelerated-molecular-discovery

- **Data** – bringing together and sharing data from different sources to enable better, faster, bigger science
- **Modelling, simulations, AI** – crucial in everything from medicines to batteries
- **Sensing/diagnostics** –understanding how medicine interacts with human body and pollutants interact with the environment
- **Robotics/automation** – perform experiments remotely and orders of magnitude faster

iii. What works for innovation

The RSC works with and supports innovative chemistry SMEs. Whether it is tackling climate change, helping to create sustainable processes, or improving and saving lives, chemistry SMEs have a crucial role to play in developing new technologies which can transform our world.

We have also commissioned as yet unpublished research from the Enterprise Research Centre. The emerging findings are as follows. Findings on access to facilities and regional clusters (points 3 and 4) may be particularly pertinent to the review:

1. SMEs in chemistry-intensive sectors are around twice as likely to be investing in R&D as other SMEs and are also more likely to be investing in other innovation activities. They are more likely to be engaged in new to market innovation and more likely to collaborate in their innovation activities.

2. Access to capital for deep tech chemistry SMEs is a big challenge – proof of concept funding is essential and should be maintained but for businesses to grow and deliver products to markets, the equity gap needs to be addressed, as set out in the Innovation Strategy. Challenges to investment include:
    - Lack of investor and grant panel knowledge/understanding/expertise of chemistry deep tech
    - Length of time needed to develop and test a product before revenue and difficulty providing clear milestones for uncertain technologies, which can impact access to grant funding or mean it is for too-short time periods.
    - Scale of investment – particularly for equipment

3. Lack of availability of suitable premises and specialist equipment presents an acute challenge for many deep tech chemistry SMEs, particularly those seeking to scale and those outside the Golden Triangle. Given the particular challenges our interviewees identified which are faced by chemistry deep-tech SMEs in accessing suitable premises for scaling, an audit to establish what premises are available (for example in established Catapults) would be sensible. Improving the information available to firms about the facilities which are available would also be potentially beneficial.

4. The development of supported regional clusters of deep tech chemistry SMEs outside of the Golden Triangle would greatly enhance their chances of success and potentially reduce spatial/ geographical inequalities of provision for these companies. Regional clusters would:
    - Enable mobility between firms
    - Provide support and collaboration opportunities
    - Provide opportunities to share specialist equipment/facilities
    - Have lower rents/costs than within the Golden Triangle.

5. Peer-to-peer networking is essential to expand the ambition, skills and confidence of deep tech chemistry SME owners and managers.

6. Underdeveloped management and leadership skills, particularly entrepreneurial and innovation skills, are a significant issue in deep tech chemistry SMEs and a major constraint on business performance and the commercialisation their technologies.

iv. Financial health and capability of UK university chemistry departments

In September 2021, the RSC surveyed UK-based members of Heads of Chemistry UK (HCUK), a group comprising the heads of university chemistry departments in UK and Ireland[9]. The survey sought to identify potential risks in the chemical sciences university research system by exploring indicators of financial health and capability in the four-year period from 2018/19 to 2021/22. The results of this survey and accompanying report are not published yet, but some of the findings and analysis could be relevant to the review and are shared below.

Chemistry research and teaching have specific 'high cost' delivery requirements. This includes meeting health, safety and other regulatory requirements, the need for well-designed and provisioned laboratory space, specialist practical equipment and consumables, and technical support staff. These ongoing costs mean departments often return a deficit and as a result are vulnerable during times of financial pressure and fluctuating student demand.

The survey found:

- 86% of responding departments reported having insufficient resource to cover costs of equipment replacement and its depreciation
- 62% reported having insufficient resource to maintain technical expertise
- 55% reported having insufficient resource for equipment maintenance, running costs and consumables
- 54% reported having insufficient resource to maintain, upgrade and retrofit buildings.

In addition, 41% of respondents said they have some buildings, facilities or equipment that they are currently unable to use due to insufficient funds for maintenance or upgrading.

Investment in infrastructure must go beyond the immediate capital outlay and cover the longer-term costs of employing talented technical professionals and the depreciation, maintenance and replacement of equipment. Insufficient resource to maintain or upgrade will have an impact on what research can be carried out and could impact the sector's ability to develop and apply frontier techniques and meet future global challenges.

[9] 29 out of a possible 67 chemistry departments in the UK participated in our survey. While this is a good response rate, we must bear in mind that this means that the results and findings are indicative of UK chemistry departments and not conclusive.