# Horizon Scanning – research and innovation to transform the health of society by 2048

Findings from a survey and series of workshops held in 2017/18

The Academy of Medical Sciences

**The Academy of Medical Sciences**
The Academy of Medical Sciences is the independent body in the UK representing the diversity of medical science. Our mission is to promote medical science and its translation into benefits for society. The Academy's elected Fellows are the United Kingdom's leading medical scientists from hospitals, academia, industry and the public service. We work with them to promote excellence, influence policy to improve health and wealth, nurture the next generation of medical researchers, link academia, industry and the NHS, seize international opportunities and encourage dialogue about the medical sciences.

Opinions expressed in this report do not necessarily represent the views of all participants at the event, the Academy of Medical Sciences, or its Fellows.

All web references were accessed in January 2019

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# Overview

It is difficult to think what the world will be like in 30 years' time when the Academy will celebrate its 50th anniversary. Our environment – political, economic, natural and social – is constantly changing. The pace of technological advances seems to accelerate continuously, and new and exciting innovation always seems to be around the corner. To help the Academy and its partners navigate the complex and shifting landscape in which we operate, and be ready to make the most of available opportunities and to tackle forthcoming challenges, we called on our Fellows, grant awardees and others to consider areas of research and innovation with the biggest potential to transform society's health by 2048, and consider their impact.

This report is a summary of this exercise, which consisted of a survey of our Fellows and grant awardees that was launched in 2017, followed by a series of workshops in early 2018 to further explore some of the core themes that emerged from the survey. It is not a comprehensive scan of the current R&D and innovation landscape nor a trend analysis. It is also not an attempt to predict the future. Rather, it is intended to stimulate thinking about our possible future trajectories and what we could and should be doing to prepare for different eventualities.

Genomics and artificial intelligence (AI) were the most frequently cited areas with transformative potentials in our survey. This may be a reflection, in part, on the substantial media, public and UK government interest and investment provided to the field at the time of the survey. As genome-editing techniques continue to advance[1] and target for the number of whole genomes to be sequenced in the NHS grows[2], genomics and its related fields are increasingly becoming part of everyday life. There is also considerable excitement about the prospect of AI[3] and its application in healthcare[4]. The challenge now, for both areas, is how to fully realise their potential in transforming disease prediction and diagnosis, prevention strategies, treatment options and service delivery for maximal health impact.

Advances in genomics and AI and their application is expected to accelerate the shift towards population stratification and personalised treatments, and should be combined with ongoing emphasis on prevention – also personalised – over treatment. The aspiration of many, was that in 30 years' time the concept of patient-led care and ownership over their health would come to the fore, with technology enabling each of us to monitor our health and decide when, where (and by whom) care is delivered.

Our survey and workshops also highlighted two areas where greater understanding through research could be transformative for society's health: the impact of environmental factors on health, and neuroscience. Closely linked to the need to have a better understanding of the impact of our wider environment on health was the requirement for a better evidence base in behavioural science. Public engagement with these issues, with the need for ongoing public communication and dialogue, and enhanced efforts to track knowledge and attitudes over time, being highlighted as important by many. Data was widely acknowledged to be a fundamental enabler to accelerate our knowledge in these fields; whilst improving access and data quality were seen as the biggest challenges. Better cross-disciplinary/cross-sector working and effective reform of the health and care system were also regarded as essential to realise the potential benefits of advances in medical science.

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1 https://acmedsci.ac.uk/more/news/human-genome-editing-research-should-proceed-say-leading-uk-science-bodies

2 https://www.genomicsengland.co.uk/matt-hancock-announces-5-million-genomes-within-five-years/

3 https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/100.pdf

4 http://www.ahsnnetwork.com/ai-in-health-and-care/

This project offered a unique opportunity for the Academy to bring together its Fellows, grant awardees and other experts, in venues across the UK using novel meeting formats designed to spark creative thinking. Aside from the positive feedback from participants, insights gained from the project have helped inform our current portfolio of work – from the working group project on data-driven technologies (the report of which has since been launched[5]) to forthcoming meetings on AI and health, genome editing, the developing brain in health and disease[6], and behaviour change[7]. They will also inform our FLIER programme[8] to develop future leaders who can collaborate across sectors and our future projects and activities. We thank all those who generously gave up their time to participate in our survey and workshops to offer their expertise in imagining our futures 30 years from now.

[5] https://acmedsci.ac.uk/policy/policy-projects/use-of-patient-data-in-healthcare-and-research
[6] https://acmedsci.ac.uk/policy/policy-projects/the-developing-brain-in-health-and-disease
[7] https://acmedsci.ac.uk/more/events/behaviour-change-to-improve-health-for-all
[8] https://acmedsci.ac.uk/grants-and-schemes/mentoring-and-other-schemes/FLIER

# 1. Introduction and methodology

Between November 2017 and January 2018 the Academy of Medical Sciences surveyed its Fellowship and grant awardees to identify areas of research and innovation with the most potential to transform society by 2048 (see Annex 1). The survey was followed by seven workshops held around the UK attended by Fellows, grant awardees, and contacts from areas outside health and science (including journalism, digital technologies, engineering and law; Annex 2). The reports of these workshops are published separately. The project aimed to help the Academy consider topics and priorities for its future policy work and meetings, as well as potentially inform the future plans of our partners and stakeholders.

This report provides a high-level summary of the key themes that emerged from our survey and workshops. The first section summarises areas of opportunity for innovation and research thought most likely to transform our health in 30 years: genomics, AI, neuroscience and environmental factors. The second section outlines cross-cutting challenges that need to be addressed if we are to realise the opportunities identified.

Undertaking futures studies, including horizon scanning, commonly presents a wide range of challenges as well as opportunities and the Academy's project was no exception.[9,10] It was often difficult for contributors to forecast transformations over a 30-year timeframe, and many of the predictions and implications could be viewed as more near-term. That said, the results have been very helpful to us in identifying the broad domains and directions that have the potential to transform health over the coming decades. We hope that they will be valuable to others.

# 2. Potentially transformative opportunities

Participants in the survey and workshops identified genomics and AI, as well as a better understanding of neuroscience, mental health, and environmental factors, as areas that offered potentially transformative opportunities for healthcare. These are expanded on below.

Participants also identified additional cross-cutting challenges that might impact the likelihood or desirability of their predictions coming to fruition highlighted in section 3 of this document.

## Genomics

Survey and workshop participants' thoughts on the impact of genomics in the near to mid-term can be grouped under three domains: genetic / genomic sequencing; genome editing; and research methods. Their predictions for the next 30 years are below.

### *Genetic and genomic sequencing*

- Participants believed that genetic sequencing would be in widespread use by 2048, forming a first-line technology for healthcare. They predicted that better understanding of the functional meaning of genomic sequences (both coding and non-coding) will expand clinical use to allow **stratified diagnostics and treatments**, with genetic biomarkers for disease becoming the norm. They also considered that the identification of genetic diagnostic markers for neurological and psychiatric conditions would have the most transformational impact, given the increasing prevalence of these conditions and current challenges in diagnosis.
- Sequencing will be used to **detect new molecular cancer subtypes**, along with liquid biopsies that inform the type and location of cancer based on genomic information from immune cells indicating the cell's inflammatory state, according to participants.

[9] https://foresightprojects.blog.gov.uk/2018/03/08/the-ten-commandments-of-horizon-scanning/
[10] https://academic.oup.com/jpubhealth/article/39/2/248/3002966

- heap, simple and rapid genome sequencing in a 'lab-on-a-chip' format are expected to be used to **diagnose infections rapidly** in a universal test requiring only limited laboratory space and operational training.
- By 2048, the aspiration was that the clinical value of genetic testing would shift from diagnosis and treatment to **disease prediction**. This has the potential to allow pharmaceutical and non-pharmaceutical interventions to prevent ill health before disease has even occurred.
- As knowledge of the genome's function continues to evolve, **genomic reanalysis** was predicted to be in use to ensure up-to-date interpretation of a person's genome. This could be done at regular time intervals or be triggered by certain events, such as a cancer diagnosis in a close family member.
- Participants raised significant **ethical and privacy issues** relating to storing and sharing genetic data, and identifying genetic risk that cannot be acted upon.

### *Genome editing*

- It was considered that genome editing techniques, with their potential to focus on specific genes in human and animal models of disease, could be used to **assess genetically determined physiology** on a large scale, and to be used in [somatic] gene therapies.
- Pending public opinion of the desirability of doing so, genome editing and embryo selection was predicted to be used widely to avoid disease-associated gene polymorphism and to potentially **eradicate certain (mainly single gene) disorders.**
- By 2048, genome editing was expected to have been used to decipher the role of the **metabolome** – a potentially valuable but significantly more complex information resource than the genome.
- In **communicable disease**, genome editing was predicted to find utility in excising viral DNA from the host genome or to alter insect vector genomes to prevent spread of infection.
- While genome editing is typically used to remove genes associated with ill-health, its impact may be widened in 40 years' time to find use in **upregulating genetic sequences associated with healthy states**.
- The need for ongoing analysis, discussion and debate around the significant **ethical and societal issues** related to wider use of gene editing was raised by participants, particularly with regard to impacts on social diversity and equality of opportunity.

### *Research methods*

- More dynamic methodologies will be developed to characterise diseases that drive, or are driven by, genome changes across the life course, according to participants. Technology such as **CRISPR** demonstrates the potential to focus on specific genes in both human and animal models to translate genetic associations into phenotypes over time.
- Contributors also believed that better laboratory models would be developed to investigate the influence of environmental factors on genetic predispositions, and the interplay between environment and genetics.

## Artificial Intelligence

Survey and workshop participants' thoughts on the impact of AI can broadly be grouped under: smart devices, robots and avatars, public health and drug development. These are expanded on below.

### *Smart devices*

- Devices such as apps will routinely collect patient-generated information, for example, exercise, blood pressure, nutrition, mood, cognition and motor control and collate personal data packages for clinical analysis. Combined with machine learning algorithms, they will **monitor health and diagnose disease** outside of traditional healthcare settings, according to participants.
- Apps may also **provide advice or reminders**, such as personalised nutritional guidance or prompts for getting a flu jab.
- Other smart devices, based on AI technology, whose transformative potential was predicted to include:
    - Retinal scans to diagnose diabetes/hypertension more accurately
    - Screen-writing challenges to detect signs of Parkinson's disease
    - Nano-devices that detect enzymes, for example to diagnose fatty liver disease
    - Skin patches that analyse vitamin deficiencies
    - Drugs with in-built sensors that collect data on drug action, efficacy, compliance and outcomes
    - Implanted sensors that collect data on blood glucose level and prompt automated insulin release.
    - Smart speakers in hospitals guiding patients and healthcare workers, for example to prompt washing

### *Robots and avatars*

- Avatars were expected to be in widespread use to **expand access to health and social care**. Emotionally intelligent 'companion robots' were predicted to be employed in supporting the health and social care of vulnerable groups, such as the elderly or children with special needs.
- Online or app-based avatars will be used not just to improve access but also to **increase adherence**, for example to Cognitive Behavioural Therapy (CBT) to treat anxiety and post-traumatic stress disorder.
- Robots were predicted to be used to assist with routine tasks, **freeing capacity for healthcare professionals** to address tasks that are more complex.

### *Public health*

- By 2048, public health research was predicted to use data for intelligent monitoring of population health, to assess the scale of a health issue, to support health economic modelling and to deliver interventions.
- Repurposing data from online searches or social media was expected to identify and **track infectious disease outbreaks** and create targeted adverts with NHS-certified advice to treat and prevent further infection.

### *Drug development*

- Automated AI-based interfaces and processing using algorithms trained on large datasets will assist researchers to manage and interpret data for drug development, according to contributors. They believe that **virtual models** will predict drug mechanisms and simulate drug trials in a fast, cost-effective way.
  Participants also predicted that population-level health data will be used to identify drug side-effects as part of Phase 4 development/modelling. Machine learning algorithms applied to data from online search engines was predicted to support **pharmacovigilance** into drug effects or toxicity using codified word associations that occur in searches over a certain frequency.

## Neuroscience and mental health

The potentially transformative impact of advances in neuroscience and mental health research was highlighted consistently by participants, with developments in diagnosis, treatment and research methods being raised as described below.

### *Diagnosis and treatments*

- More **sensitive and objective diagnostics** will be developed for neurological and mental health disorders. In addition to biomarkers, novel diagnostic tools were envisioned to allow non-invasive and accurate diagnosis of mental health disorders even at very early stages, such as:
    - Monitoring devices that identify voice pattern changes or alterations in online behaviours.
    - Portable imaging techniques, aided by machine learning analysis, that measure brain tissue properties and diagnose disorders such as Alzheimer's disease before the appearance of symptoms.
- Better tests will be developed to **measure improvement in neurological and life quality**, not just in patients with advanced cognitive impairments, but those at an earlier stage of disease.
- Contributors predicted that **tailored treatments** will be developed that encompass drug responses, dosage and resistance to increase effectiveness and reduce neurodevelopmental and neurocognitive side effects.
- A key aspiration was that a greater understanding of the normal function of brain proteins and inflammatory responses could ultimately lead to a **'dementia vaccine'**.

### *Research models*

- **Novel research models** will be developed that are more predictive of human neuro-biochemistry and drug efficacy. In the near-term, it was considered that this will be achieved by a better understanding of the strengths and limitations of animal models for human neurobiology. In the longer term it was thought that this would involve replica human organs produced in the laboratory. Efficacy studies in healthy volunteers using biomarkers and surrogate endpoints were predicted to form 'Phase 0' trials for both neurological and mental health disorders.
- **Central resources of brain samples** of all ages were envisioned to improve our understanding of the brain over the life course.
- Better social science measurements and population data for mental health were predicted to improve modelling for interventions at population level.

## Environmental factors

Survey and workshop participants highlighted a range of environmental factors, including climate change and pollution, nutrition, and demography, where deeper insight would potentially transform our health. Models of multifactorial environmental and genetic risk factors need to be developed across both communicable and non-communicable diseases. These need to be combined with evidence generated from behavioural science, to enable effective disease prevention and health promotion strategies to be incorporated at all levels – from work, school, online, built and natural, through to gestational environments.

- It was predicted that transformative gains in understanding how health-related behaviours are influenced by social, biological, economic and cultural factors will be made. This includes linking social science approaches with an enhanced understanding of the basic neural mechanisms of reward to expand our understanding of choice at fundamental levels.
- Social science and related areas (such as psychiatric epidemiology) will better target public health initiatives, such as targeted advertising, food pricing and availability. Repurposing

information and strategies used by supermarkets to influence purchasing behaviour could be used to promote healthy eating habits.
- Measuring personal exposure to pollution in real time, for example using a wristband or other wearable device, were envisioned to directly link pollution to patient health and focus urban planning measures across housing and transport.
- Developing minimally invasive techniques to study the microbiome over time, will support the use of microbiome information to monitor disease and direct diagnosis and treatment, according to participants.

# 3. Cross-cutting challenges and areas for improvement

Both in the survey and the workshops, the need for **public engagement** was highlighted by many. Public communication and dialogue, and enhanced efforts to track knowledge, beliefs and attitudes over time were needed to understand the acceptability of developments. Should society support their identified areas of research and innovation, contributors identified a range of barriers which, if overcome, might deliver transformational improvements in health and care – some of which have been highlighted in recent Academy reports. In addition to the areas for improvement outlined below, **sufficient funding** was frequently cited as a key consideration.

### *Improved data access and interoperability*

- Linking and standardising data on an unprecedented scale is seen as a key requirement to advance knowledge and support cross-disciplinary research, according to our contributors. New, centralised resources will need to combine different sources of evidence, including self-reported data and information from commercial sources (e.g. tech and food), and ensure that datasets are diverse across age, gender, geography and ethnicity.
- Data security and privacy will continue to be a major source of public concern, and many participants emphasised that data access should only be enhanced in a manner that protects patients and citizens from harm – as highlighted in our data-driven technologies report[11]. A wide variety of models could be explored, ranging from making all data public to individual data 'ownership'. A blockchain-style approach was highlighted as a means by which individuals could see who has accessed or shared their data. Transparent contracts, codes of conduct and significant sanctions for misuse could build public trust.
- Ensuring secure, cost-effective and environmentally sustainable data storage will continue to be a major consideration.

### *Integrated health and care and training for HCPs*

- As highlighted in our 2018 report on multimorbidities.[12] It was clear from the discussions that more integration is needed across the health and social care systems that can provide continuity across diagnosis, treatment, recovery, and monitoring, as well as cope with the demands of multimorbidity and ageing populations.
- Linked to this is the need to consider how to train the next generation of healthcare professionals who will work in new integrated models of care supplemented by advanced technology.
- Contributors believed that healthcare should focus on improving life quality rather than that extending life expectancy.
- Changes to training of healthcare professionals should be accelerated in the areas of risk, genomics, AI and digital technologies, with new 'data practitioner' roles as the Academy highlighted in its submission to NHS England's long-term plan[13]. Healthcare workers will have a major role in helping patients to understand and use health-relevant information.

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11 "Our data-driven future in healthcare" https://acmedsci.ac.uk/file-download/74634438

12 "Multimorbidity: a priority for global health research" https://acmedsci.ac.uk/file-download/99630838

13 https://acmedsci.ac.uk/file-download/67473779

- Participants believed that more rigorous and standardised evaluation of new/repurposed technologies will be needed to ensure clinical utility and cost-effectiveness for adoption into health and care systems. Incorporating elements of horizon scanning into evaluations may help to futureproof new technologies and interventions, and support more responsive strategies for regulators to consider.

### *Improved cross-sector and cross-disciplinary working*

- The most transformational research and innovation will come from cross-disciplinary and cross-sectoral collaborations that extend beyond biomedicine. For example, as highlighted in our report, Improving the health of the public[14], the Research Excellence Framework (REF) 2014 sub-panel report acknowledged that 'the UK is a world leader in the inter-linked and complementary disciplines of public health, health services and primary care research', noting that a large proportion of research in these areas is conducted by collaborative, multidisciplinary teams.
- Such collaboration will support the more cohesive, holistic approach to healthcare that is needed to address issues such as multimorbidity and increase preventative approaches to disease.
- In some fields, transformational advances were only considered to be possible with industry collaboration in ways that maintain public trust and prevent health equalities.

## Acknowledgements

Thanks to Katharine Fox, former Policy Officer at The Academy of Medical Sciences for her support on the report and the development of the Horizon scanning project; and to Melanie Etherton, Communications Officer at The Academy, for her work with Katherine on organising the workshops.

[14] "Improving the health of the public by 2040: Optimising the research environment for a healthier, fairer future" https://acmedsci.ac.uk/file-download/41399-5807581429f81.pdf

# Annex 1: Survey

The first stage of the Academy's horizon scanning project was a survey that was circulated to all Academy Fellows and active awardees from certain Academy grant schemes.

## *Methods*

Horizon scanning can be described as a systematic examination of information to identify potential threats, risks, and emerging issues and opportunities [in the future].[15] There are many tools to help gather insights from expert and lay person speculation, which forms the basis of this information. We used an adapted Delphi method to gather insights from Fellows and grant awardees for this project, with the survey questions developed using the Seven Questions framework.[16]

## *Survey questions*

The following questions were emailed to the Academy's Fellows and grant awardees in the form of an online survey:

1. What areas of research or innovation do you think will be most transformative in understanding disease and achieving a healthier society within 30 years?
2. What are the possible scientific, health and societal benefits from this area of research or innovation?
3. What ethical concerns do you have about this research or innovation?
4. What is the most significant barrier to progressing this research or innovation and achieving its benefits?
5. Looking back, what challenges have led to the need for this research or innovation?
6. How do you predict these challenges will change in the next 30 years?

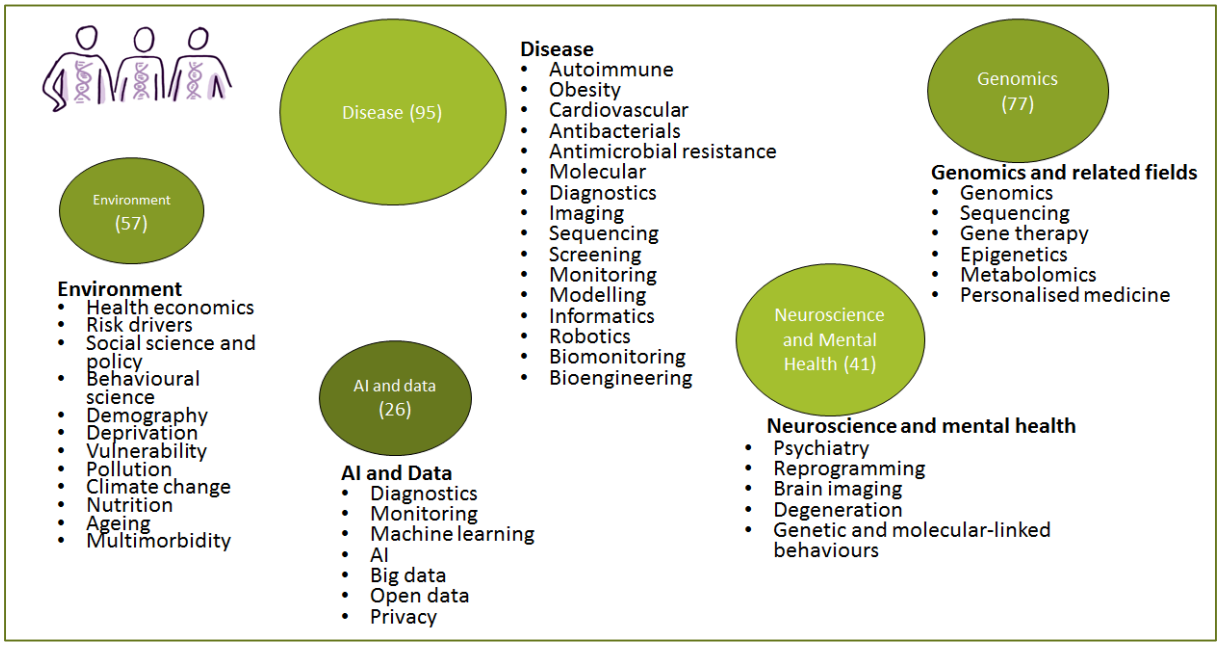
Survey data was collected between November 2017 and January 2018. Data was anonymised[17] and analysed immediately after.

## *Structuring the data*

The survey data gave us insight into topics of interest to Fellows and grant awardees, and the associated challenges for health and wellbeing in 2048. We initially used a simple framework to group specific individual survey responses into topics of interest. These topics were then ranked by the number of responses grouped into the topic to select a small number of core topics and additional topics with less responses referring to the same area of research or innovation (see Box 1). Benefits, ethical concerns, barriers and trends from survey questions two – six were associated with topics and summarised in Strength, Weakness, Opportunity and Threat (SWOT) tables.

[15] Horizon Scanning Programme: a new approach for policy making (Cabinet Office, 2013)
[16] More can be read about both tools in the UK Government's Futures Toolkit: https://www.gov.uk/government/publications/futures-toolkit-for-policy-makers-and-analysts
[17] Contact information was removed but no further cleaning of individual responses was carried out

# Box 1: Themes of Interest




We used a simple framework to describe topics of interest after grouping similar survey responses. The most common research and innovation groupings highlighted in the survey are summarised here.

# Annex 2: Workshops

The second stage of the Academy's horizon scanning project was a series of workshops, held in cities including Birmingham, Brighton, Cambridge (2 workshops), Edinburgh, Leeds and Manchester. The workshops engaged Academy Fellows, active awardees from specific Academy grant schemes, and individuals with other perspectives, including journalism, digital technologies, engineering and law. The Academy's Regional Champions and its staff led workshops at which the themes of interest identified in the survey were discussed and expanded on in more detail, alongside a discussion of the barriers and enablers. The aim was to bring an interdisciplinary approach to the discussion rather than simply to bring together subject matter experts.

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