

2030

life sciences and health in the digital age

One of the key ways in which The Pistoia Alliance works with its members is to help them not just deal with the problems of today, but also to look ahead, to anticipate how the industry is going to change, and understand how they might prepare for these changes. As part of this effort, The Pistoia Alliance has developed a research paper which sets out to consider what the life science, biopharma R&D and healthcare ecosystem might look like in 2030. This paper was developed with the input of global healthcare, biopharma and digital experts, during a series of face-to-face meetings in the US and UK.

In particular, the 2030 paper looks at how the increasing adoption and sophistication of technology will affect companies and patients alike. Technology is responsible for the development of healthcare devices that are transforming the quality and quantity of life. These devices, in combination with medical science, are enabling society to progress from a ‘one-size fits all’ management of disease, to a personalised, preventive and predictive approach, even to the cure of previously incurable disease.

The research also looked at the costs which come with such developments, including the need for society to think of new ways of valuing, calculating and funding the costs of healthcare delivery. This is critical because, unless developments in healthcare delivery are encouraged, progress in healthcare delivery will stall, falling short of the WHO Constitution (1946) which states that “...the highest attainable standard of

health is a fundamental right of every human being”.

This article is the first in a two-part series based on The Pistoia Alliance report. Written in retrospect from the world as it is in 2030, it looks at how healthcare has changed in the intervening decade, covering the socio-economic and political evolutions that have happened, the subsequent effects on population health and the innovative technologies which have had the greatest impact.

The intention of this 2030 report is to stimulate debate as to what the future may hold, and to identify the key areas where stakeholders must work together to advance. There are many scenarios one could legitimately put forward and challenge. We have chosen one such set of scenarios. It is not to say it will be correct. However, in presenting these scenarios it is hoped one can identify signals that identify the likely drivers of change over the next 10 years or so.

**By Dr Steve
Arlington and
John Wise**

Table 1: Global innovation index 2018

Rank in 2018	Country	Rank in 2017	Rank in 2018	Country	Rank in 2017
1	Switzerland	1	11	Israel	17
2	Netherlands	3	12	Korea, Republic of	11
3	Sweden	2	13	Japan	14
4	United Kingdom	5	14	Hong Kong (China)	16
5	Singapore	7	15	Luxembourg	12
6	United States of America	4	16	France	15
7	Finland	8	17	China	22
8	Denmark	6	18	Canada	18
9	Germany	9	19	Norway	19
10	Ireland	10	20	Australia	23

https://www.wipo.int/pressroom/en/articles/2018/article_0005.html

Socio-economic and political trends from 2020 to 2030

Looking back on the last decade, it is safe to say the world experienced a difficult time between 2019 and 2023. Recessionary economic forces and austerity dominated, yet government deficits skyrocketed. However, after 2023 some growth thankfully resumed, trade normalised and market stability returned.

By the late 2020s, the disruptions caused by Brexit and the US/China trade wars had receded and the predictions of global economic growth meltdowns had been avoided. China had cemented itself as the world’s leading economy and became a stabilising force in global business and politics. India was not far behind, having become the third largest consumer economy¹. Indeed, its population had risen to more than 1.5 billion and had overtaken China’s population – somewhat stabilised at 1.4 billion. India’s economy is on target to surpass the USA in terms of purchasing power parity (PPP) by 2040, according to a report by PwC². Overall, growth markets in Asia have continued to outperform the West.

The East now leads in many sectors and former wealthy, Western-based nations are increasingly reliant on innovation from these countries³. The future of this trend was already visible in 2018 where the global innovation index showed Singapore, the lead economy in the Association of Southeast Asian Nations (ASEAN), and China improving their position in the global innovation index. Now, in 2030 the flow of new technologies from the East rivals those from the West (Table 1).

Africa, meanwhile, had moved towards a period of improved political and economic stability⁴.

Physical terror-related events had largely disappeared but had been replaced with chronic, low-level cyber-crime which had been costly, and many expensive remedies had to be developed to try to stem the disruptions to global businesses. Today, displaced populations from unrest in the Middle East and Africa are starting to return home. The poor condition of those war-torn countries has improved considerably, and the diseases and malnutrition suffered in the early 2020s are no longer an issue.

Today in 2030, the world is enjoying a prolonged period of sustained growth. Economic prosperity had allowed for an increase in investment in many social projects. Healthcare as a fundamental human right⁵ has become one of the new generation’s principles. This translated to a societal movement, led by millennials and Generation X, that strived toward fairness across societies and regions. As a result, while environmental issues such as global warming remain a challenge⁶ the severe predictions made between 2000 and 2020 have not materialised following the worldwide implementation of new legislation agreed at successful global climate summits held between 2021 and 2025. The US finally re-signed up to the climate change initiatives.

However, significant challenges remain. Some nations have failed to meet basic societal demands⁷, such as ensuring adequate clean water supplies and unpolluted air⁸, commodities which are now being supplied by private companies to those who can afford them. At the same time, access to medicines remains a political juggling act with governments and healthcare providers facing increasing demand for new vaccines, diagnostics and therapies.

The pharma industry

From a healthcare perspective, underfunding has been a chronic problem for the last decade in many of the more established economies; diseases that had been assumed to be under control had started to re-emerge – not least caused by the spread of misinformation about vaccines on social media⁹.

The previously inexorable rise of healthcare costs in relatively rich economies is now under control. In the US, Medicare and Medicaid¹⁰ reimbursements have been trimmed to align with average OECD levels¹¹. In Europe, the Beneluxa¹² initiative on pharmaceutical pricing, along with the ‘Valletta Declaration’¹³, has reduced expenditure on medicines. Alongside other pharmaceutical price control activities¹⁴ these measures have lowered revenues for the Western-based biopharmaceutical and life science industry, resulting in a decrease in R&D expenditure and a subsequent challenge to innovation. Consolidation in the industry continues thanks to technology giants swallowing some of the traditional research-based biopharma companies¹⁵.

Outside of the West, Chinese pharmaceutical companies have been significantly more successful and are now among the top tier global players¹⁶, having disrupted the status quo with high-quality, low-priced innovative healthcare solutions, including many traditional Chinese medicines (TCMs). This has driven an overall improvement in access to healthcare in China for the many and an expansion of healthcare markets.

Today, patient empowerment is fully embedded into the healthcare industry and the ability to compare treatments with outcomes is actively promoted. The prevention of disease has become an inter-governmental initiative with trillions of dollars being invested in fundamental research promising breakthroughs in many chronic, debilitating diseases¹⁷. The use of vast data resources is having a positive impact on discovery and the Real World Data feedback loop is an established part of research and development in health-related industry. This had led to a real increase in true cross-industry and within-industry pre-competitive collaboration¹⁸⁻²⁰.

Technology and healthcare

By the early 2020s, technology such as AI-powered search allowed patients to arrive for appointments at their clinician’s office knowing more about their own morbidity than their doctor²¹. Soon, diagnosis, treatment and prognosis were largely being determined by AI. Healthcare providers started experiencing a serious shortage of physicians due

to talented students no longer viewing medicine as a quality career²².

However, despite AI and Machine Learning (ML) having success in some areas²³ – not least where image analysis formed an important part of the diagnosis²⁴ – progress in, and the widespread deployment of, automated diagnosis had failed to live up to its early expectations after lives had been lost due to algorithms making ‘stupid’ errors.

By 2030, the ‘Quantum Advantage’, ie the threshold where quantum computing applications could perform significant, useful tasks that classical computing applications could not, had been achieved and some exciting progress has been made. Today, drug discovery has been transformed thanks to pharma companies using hybrid machines – high-performance classical computers tightly coupled with quantum computers – and advanced AI/ML algorithms. These hybrid machines have enabled *ab initio* drug design, coupled with advanced modelling to design innovative drugs of high specificity and low toxicity. The fundamental requirement of AI/ML – ie access to sufficient data of sufficient quality – remains a significant hurdle but has been overcome in part by the use of AI federated learning (FL) techniques²⁵.

Population health trends

From the early 2000s onwards, many predictions had been made about the increase in HONDAs (Hypertension, Obesity, Non-Compliance, Diabetes and Asthma). By 2030 these concerns had not materialised as extensively as had been expected, but nonetheless HONDAs were imposing a significant burden on world healthcare resources.

HONDAs

- **Hypertension:** As predicted by the World Health Organisation (WHO)²⁶, a significant percentage (35-45%) of the world population over the age of 25 continues to suffer from hypertension, particularly in less mature economies.

- **Obesity:** Back in 2016, the WHO reported that approximately 39% of people over 18 years old were overweight with 13% of them being obese²⁷. More than one in 20 cancer cases were caused by excess weight²⁸. Obesity in 2030 remains a global health challenge with many more diet-associated disease states becoming symptomatic at younger ages.

- **Non-compliance:** Depending on definitions, reported non-adherence rates in cancer patients ranges from 16% to 100%, illustrating a serious problem²⁹. Although technology has enabled progress on this front with innovations such as

continuous monitoring and patient reminders, the compliance challenge remains unchecked, especially in poorer economies.

● **Diabetes:** In 2014, it was estimated that 422 million people worldwide were living with diabetes (a major cause of blindness, kidney failure, heart attacks, stroke and lower limb amputation)³⁰. This was approximately one in 11 of the world's adult population and the figure is expected to rise to around 642 million people by 2040³¹.

● **Asthma:** The incidence of asthma (in 2017 approximately 8% of the UK population was asthmatic³² with a similar percentage estimated in the USA³³) remains significant. Environmental pollution and continued use of fossil fuels in emerging economies had not reduced sufficiently and the occurrence of asthma, particularly in the young, continued to rise throughout the 2020s.

Outside of the HONDA conditions, several other issues are worthy of note:

● **Cancer:** In 2018, cancer was the second leading cause of mortality globally, responsible for an estimated 9.6 million deaths³⁴. The economic impact of cancer was significant, it remains so and is increasing. The total annual economic cost of cancer in 2010 was estimated at approximately \$1.16 trillion. By 2030, the number of global cancer deaths has increased by 45% with about 70% of those deaths occurring in low and middle income economies.

● **Mental health:** Mental health issues have continued to dominate, in particular depression, anxiety, schizophrenia, bipolar disorder³⁵ and the dementias. These conditions have driven huge increases in cost pressures on social care across the world. The current cost of Alzheimer's alone is estimated to be around \$2 trillion annually³⁶. However, the use of digital technologies (eg in-dwelling biosensors, monitoring, diagnostics, therapeutics, robotics, the implementation of social care initiatives, such as the intelligent home) has helped to deliver significant, cost-effective support for patients³⁷. No affordable and widely-effective new therapies for dementia had been approved and released by 2029. (Note: Since 1998, ~100 drugs had been tested but by 2019 only four had been authorised for use.)

● **Anti-microbial resistance:** The predictions of AMR causing a meltdown in routine medical procedures was narrowly averted by using breakthroughs in phage therapy³⁸ and anti-bacterial monoclonal antibodies³⁹. The challenging economic issues that had prevented the pharmaceutical industry from diverting resources into AMR

were overcome during a global summit in the mid-2020s when a new reward structure was implemented giving substantial tax advantages to companies that brought anti-microbial molecules to the market. New challenges continue to emerge, however, as people live longer. Managing and curing pathologies related to ageing has become the next unconquered field^{40,41}.

Innovative technology

The last decade has also seen numerous technological advances which have profoundly transformed the pharmaceutical and healthcare industries:

● **AI and ML:** AI has long been seen as integral to the healthcare industry. By 2018, more than a third of healthcare providers had made investments into healthcare AI and medical-predictive analytics, preparing for the next generation of automated healthcare. In its *2019 AI Predictions*⁴², PwC asserted that AI "...could contribute up to \$15.7 trillion to the global economy by 2030", a prediction which has proven relatively astute in hindsight.

For example, in pathology the extensive use of whole-slide imaging aligned with pattern recognition methods based on deep learning and incorporating clinical, radiologic and genomic data allowed highly-sophisticated, rapid and accurate diagnosis and prognosis⁴³.

Elsewhere, the genomes of patients were available to AI/ML-based prescribing systems allowing physicians to deliver low-risk, highly-effective stratified medicine prescriptions.

Furthermore, big data analytics and Machine Learning algorithms were widely deployed to analyse large scale data of Electronic Medical Records (EMR), automatically learning how physicians treated patients in real-world settings. When newly-written prescriptions deviated from the spectrum of typical treatment patterns, they were flagged as a potential error prompting the physicians to double check. Such technologies reduced the burden of adverse events and medically-induced deaths which was estimated by a Johns Hopkins study to be the third-largest cause of death in the US⁴⁴.

● **The role of the physician:** By the mid-2020s, it was clear that the role of the physician was changing, becoming more like a technician, patient/carer educator and counsellor, while high-powered, RWD-driven AI/ML-based systems performed the differential diagnoses and provided treatment suggestions. Robotics were supporting many areas of care, especially for the aged⁴⁵. The Japanese

Ministry of Economy, Trade and Industry has estimated the Japanese robot industry alone will grow to 400 billion yen (\$3.8 billion) by 2035, by which point a third of Japan's population will be 65 or older⁴⁶.

Today, pharma, healthcare and digital have become deeply intertwined⁴⁷. Working with other industry verticals has become critical and those with the business skills to do so are highly valued. Care delivery has significantly improved under the influence of AI/ML, robotics, automation, breakthrough services and adjunct therapies. Regulatory-approved digital therapeutics⁴⁸ now contribute substantially, especially in addictive and cognitive diseases, with organisations such as the Digital Therapeutics Alliance established to support such work⁴⁹. The social costs of an ageing population related to care delivery are no longer rising unchecked and governmental intervention has been required to ensure affordability is no longer an issue.

● **Blockchain:** In recent years, blockchain technology has transformed healthcare, placing the patient at the centre of the healthcare ecosystem and increasing the security, privacy and interoperability of health data. This technology provided a new model for Health Information Exchanges (HIE) by making EMRs more efficient, disintermediated and secure. While not a panacea, this rapidly-evolving field provided fertile ground for experimentation, investment and proof-of-concept testing⁵⁰.

● **Cloud computing:** The adoption of cloud computing by biopharma R&D has been steady but slow. The PRISME Forum – the *de facto* R&D IT leadership group of the biopharmaceutical industry – explored this topic as long ago as 2010⁵¹, yet by 2019 some biopharma companies were still nervous of the unstoppable encroachments of this widespread technology, not least in the implementation of GxP solutions⁵².

The implementation of Life Science Clouds to support R&D continued to make slow progress during the 2020s. Vested interests within pharma were an obstacle to progress but senior management eventually grasped the nettle and forced through cloud implementation on a global scale. By 2030 the cloud has been accepted as the platform of choice for the life science ecosystem, significantly improving the efficiency and effectiveness of biopharma R&D.

Furthermore, cloud computing increased the security of computer-based transactions in significant part due to cloud companies, whose core business was to supply high-performance and secure computing, employing the best talent and tech-

nologies. This expertise went a considerable way to bringing the wave of low-level cyber-crime under control.

● **Devices:** Advances in medical devices, wearables and multi-dimensional imaging⁵³ led to diagnostic insights in numerous, previously-untreatable conditions. The increase in reliability and accuracy of implantable monitoring devices for serious disease⁵⁴ in the general population, and for most of the common health-related issues, meant that real-time monitoring of patients undergoing therapy was possible. Further, outcomes data was used routinely to demonstrate the health-economic value of drugs, procedures and devices.

One of the challenges of such implantable monitoring devices was the risk of causing infection in patients – not least due to difficult-to-eradicate biofilms. Thankfully, this has largely been overcome⁵⁵ by new nanomaterials with superhydrophobic properties that could repel blood on common materials leading to self-cleaning biosensors⁵⁶.

As a result, clinical trials were transformed by researchers employing digital solutions; with companies such as Science 37 working effectively with big pharma⁵⁷ to exploit wearables and simplify the clinical trial patient experience. CROs such as PAREXEL also developed platforms that securely capture, transmit and visualise medical device data; such platforms have been specifically built to support the volumes of data collected by modern sensors⁵⁸.

In 2017, more than 320,000 mobile digital health apps were in use and had proven particularly useful in the treatment of diabetes, asthma, cardiac and pulmonary rehabilitation, with estimated savings to the US health system of \$7 billion per year. However, the lack of a clear regulatory framework for such innovation was a risk to both doctors and their patients, and was yet another example of how the regulatory agencies were struggling to keep up with the pace of innovation⁵⁹. The evolution of adaptive clinical trial design, and the regulators' acceptance to adaptive studies, accelerated due to the widespread availability of sensors, wearables and software as a medical device.

These hardware and software devices also enabled secure, physician-approved, direct-to-patient clinical trial recruitment, and thus changed drug and device clinical studies dramatically. Clinical trial protocols moved to favour continuous streaming of data from these devices to cloud-based data collection systems. This change had the positive impact of speeding up clinical trials and reducing clinical trial costs as the number of protocol

amendments diminished, saving the industry trillions of dollars.

In 2030, global standards⁶⁰ are in place that allow outcomes measurement to be useful and the many disparate Health Technology Assessment (HTA) agencies, such as NICE⁶¹, are now aligned into a global consortium (similar in concept to the current EUnetHTA⁶² but with global reach) providing support and advice to the global life science and medical device industries.

● **Internet of Things (IoT):** Today the IoT has matured to the point where it can handle trillions of devices generating zettabytes (10²¹) of data⁶³; the predictive capabilities of AI/ML have improved based on such vast amounts of data, enabling new avenues of research to be identified. Many forms of dementia can now be identified before symptomatic onset through the use of digital diagnostic approaches⁶⁴, and prevention through drug and cognitive therapy has become a real possibility. The effectiveness of psychiatric intervention has also been significantly enhanced by the introduction of digital therapeutics. Psychiatric rehabilitation, which had been heavily dependent on the physical presence of the psychiatrist with the patient, is now being substantially reinforced by the availability of digital applications.

Nanotech and associated non-invasive implantable surgery⁶⁵ has delivered huge advantages to the medical device industry and sensors have become self-powered (from the human body)⁶⁶. Lab automation revolutionised the life science industry in clinical testing laboratories experiencing unprecedented demand from the age-related morbidities of the ageing baby boomers⁶⁷, and also in the processes of drug discovery. Many tasks that used to require human skills are now no longer needed, allowing the industry to reduce costs significantly. 3D-printing, organ regeneration⁶⁸ and targeted therapeutics working at the nucleic acid level⁶⁹ emerged, with the potential to change the face of medicine. Now in 2030, we have entered an era where tissue and whole organ regeneration is no longer experimental but is widely available to those who can afford it, for the costs remain high.

● **Digital biomarkers** are now in use. They are defined as objective, quantifiable physiological and behavioural data that are collected and measured by digital devices such as portables, wearables, implantables or ingestibles. The data is typically used to explain, influence and/or predict health-related outcomes. Digital biomarkers also represent an opportunity to capture clinically meaningful, objective data⁷⁰.

● **Liquid Next Generation Sequencing:** The ability accurately to analyse circulating DNA and circulating tumour DNA (ctDNA) provided the opportunity to screen patients cost-effectively and with considerably less stress. Analysis of ctDNA provides better information than that acquired from a single biopsy of a tumour, which was limited and failed to reflect its heterogeneity. Such screening allowed early detection of cancers before overt symptoms were expressed, transforming the treatment and management of cancers. Today we have entered an era where cancer is no longer feared as a death sentence. For some it is curable and for many others it is a long-term disease which can be managed and successfully treated.

● **Quantum Computing** has the potential to revolutionise a number of computational use-cases within life sciences R&D and medicine, such as quantum energy calculations for molecules and some aspects of Machine Learning. During the late 2010s, annealing devices became commercially available and a number of companies were developing universal quantum computers, using a variety of substrates (eg solid state junctions, ion-traps, NVCs, photons).

These devices were limited in scale and were error-prone due to the difficulties in maintaining qubit coherence. They formed a class of machines known as Noisy Intermediate-Scale Quantum (NISQ) systems. NISQs offered little advantage in real-world use-cases, compared to classical HPCs. However, quantum computing outgrew its NISQ status during the early 2020s, opening the door for unique benefits of working on the quantum platforms. Some Pistoia Alliance members were already exploring quantum computing applications and the Alliance created a cross-industry community of interest – especially for its many members from smaller organisations who were not equipped to navigate this complex journey alone.

One challenge that quantum computing addressed was to solve the logistics and supply chain optimisation challenges that even the most advanced classical supercomputers were unable to solve. This was no small issue – for the cost savings from optimised supply chains represented trillions of dollars globally and such financial returns funded the increased investments in quantum computing.

● **Therapeutic molecule synthesis:** The smaller, specialised markets that resulted from the explosion in genomics-based precision medicine have become very significant in the new healthcare delivery system. Biotechnology, micro-fluidics, nanotechnology and other advancements in chemical technologies were continuing to open up new frontiers.

As the University of Edinburgh noted in its report *Health Biotechnology to 2030*⁷¹, “...One innovation-related factor that made it possible to develop such niche markets on a profitable basis was the development of new approaches to the synthesis of complex biological and chemical molecules. Many potential products had been rejected from drug development pipelines in the past because they could not be synthesised at an affordable cost, even if they could be proven to be safe and effective. Synthetic genomics had an important impact in this area, as did the use of GM plants, animals and micro-organisms”.

Broad application of DNA-encoded libraries⁷², containing hundreds of billions of compounds⁷³, effected a streamlined search for chemical matter and drug candidates, rapidly reducing the time and costs associated with discovery and preclinical development, while increasing transition probabilities to preclinical and clinical development.

Furthermore, significant developments in biopharmaceutical manufacturing occurred. The European Medical Agency (EMA) in its publication *EMA Regulatory Science to 2025 Strategic reflection*, revealed it needed to encourage inter alia point-of-care-manufacturing⁷⁴, and therefore might be required to facilitate a flexible approach to the application of GMP. The implementation of synthetic biology⁷⁵ and AI-informed continuous flow drug manufacturing^{76,77} decreased the formidable capital investments that used to be necessary to build chemical laboratories and pharmaceutical manufacturing plants. These were huge, multi-story facilities with more floor space than a dozen football fields and with a footprint that often included separate buildings for quality testing, utilities and a warehouse, all of which took many years and more than \$1 billion dollars to build⁷⁸.

The next generation of biopharmaceutical facilities developed beyond multiproduct to true multipurpose capabilities. The multi-purpose facility could enable rapid scale-up of a process and be used for clinical testing, product launch, inventory building and long-term commercial supply. By 2020, drug manufacturing facilities could be created as small as a ship’s container; now in 2030 they can sit on a hospital laboratory bench.

Looking to the future

It is clear there are a great many sociological, demographic and technological changes that life science, biopharma R&D and healthcare organisations need to be preparing for. However, this is only part of the whole picture. In the second article

in this series, we will cover the other challenges set to affect the industry in the next decade, including patient-centric innovations, a growing skills shortage and evolving regulations around the world. The full report is available on the Pistoia Alliance website. **DDW**

Dr Steve Arlington has worked in the pharmaceutical and diagnostics industry for more than 40 years. He began as a research scientist in the field of immunology and developed and launched many products in this arena – he was part of the team that developed and launched Clearblue pregnancy tests. Steve is a retired partner from PwC and led the Pharmaceutical Team in Advisory Services and also previously led the IBM Life Sciences and Pharmaceutical Global Teams. In his career, Steve has grown two global consultancies into billion dollar businesses and launched a biotech company; he has also served on the advisory boards of major pharma and diagnostic companies, start-ups, venture capitalists and health providers. Steve became president of The Pistoia Alliance in 2015.

John Wise specialises in precompetitive collaboration in the life science R&D information ecosystem. He is a consultant to the Pistoia Alliance, a not-for-profit organisation committed to lowering the barriers to innovation in life science R&D, and also serves as the programme co-ordinator for the PRISME Forum, a not-for-profit biopharma R&D IT/Informatics leadership group focused on the sharing of best practices. John has worked in life science R&D informatics in a variety of organisations, including academia, the pharmaceutical industry and a cancer research charity, as well as in the technology supply side of the industry. John graduated in physiology before obtaining a post-graduate certificate in education.

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