

# Future of healthcare

The healthcare industry is on the cusp of a transformative journey. This paper delves into the anticipated evolution of the sector over the next two decades, revealing a shift towards patient-centric services that prioritise prevention, precision medicines, and personalised care. This transformation will be facilitated by the dynamic exchange of expertise, cutting-edge technologies, and best practices between the wellness and healthcare sectors, ultimately empowering individuals to take more control of their health and wellbeing.

## **CPI** **Part of the High-Value Manufacturing Catapult**

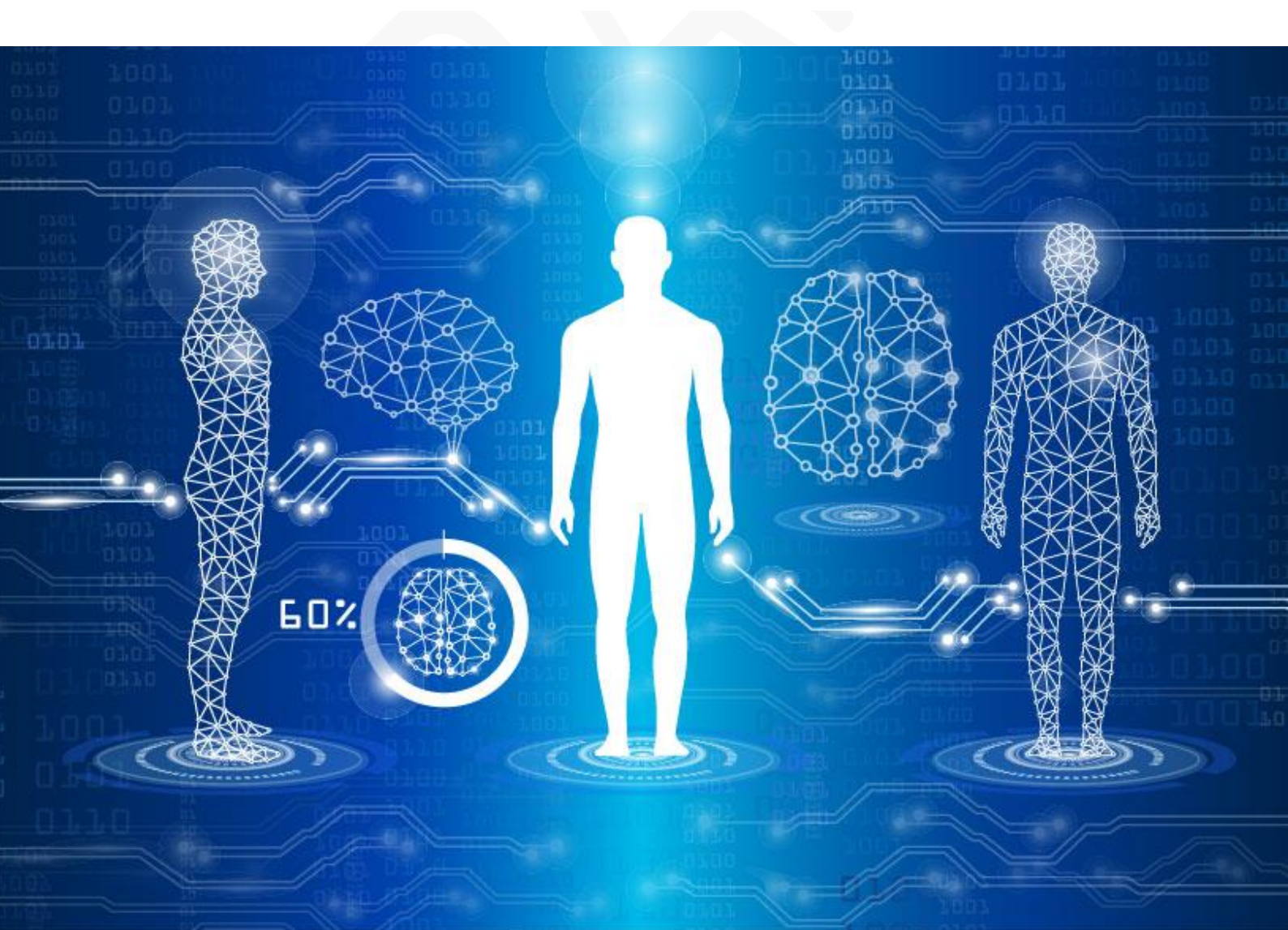
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## From innovation to commercialisation

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With a deep understanding of innovation processes and funding, outstanding technical expertise and industry relevant assets, we enable products and processes to be quickly and cost-effectively brought to market. This supports the development of next generation manufacturing, highly-skilled jobs and economic growth for the UK.



**The human body is made of trillions of cells.  
Each cell experiences about 10,000 to 100,000  
DNA lesions per day!**

**At the core of human physiology lies an  
amazing complex interplay of epigenetic  
switches, cellular machinery, and  
biochemical processes, intricately evolved to  
facilitate prevention, maintenance, and self-  
repair, working symbiotically with trillions of  
microbes that form our microbiome.**

**This delicate interplay is easily influenced by  
lifestyle and environmental exposures, which  
can either strengthen or erode its impact.**

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## Introduction

The future of healthcare is undergoing a transformative period that will have a profound impact on all stakeholders involved.

This report offers an analysis of the interplay between the forces shaping the future of healthcare, and reveals implications for policy makers, entrepreneurs, product manufacturers, and health care practitioners, helping them to prepare for the shifts that are already underway.

The fundamental driver of this transformation is the rising number of people with complex chronic diseases amongst both young and older people, underpinned by an ageing population, prone to multimorbidity. This is increasing healthcare costs, which are rising at an unsustainable rate in the UK as well as in other advanced nations. COVID has exacerbated the situation. Climate change will place yet further pressure on healthcare services, resulting from effects of extreme heatwaves on people with underlying health conditions and the elderly as well as tripling the risk of a future pandemic.

All this is adversely affecting the UK's economic performance and productivity. A healthy population tends to have a higher workforce participation rate and greater labour productivity. It is estimated<sup>1</sup> that 40% of the burden on health services in England may be preventable through action on the lifestyle determinants of avoidable chronic conditions. Determinates such as the food

choices, sleep quality, stress management and activity levels.

Whilst a significant majority of the translational research investment for healthcare needs to be directed towards the treatment and management of post-development stages of diseases, there is a rising need and urgency to increase investment in harnessing research outcomes and technologies to enable healthy living and preventive care models.

This shift is essential to address the root cause of the problem, enable healthy living and reduce demand for avoidable complex treatments. As these new services take hold, the demand for associated medicines and surgical interventions will diminish, helping to reduce the national spending on health and social care. In the UK, this expenditure is £176.2Billion 2023/24, making it the largest budgetary item by far covered by the government.<sup>2</sup>

The UK's National Health Service's (NHS) long-term plan recognises the need to go upstream to prevention. Indeed, when the NHS was initially created under the 1946 National Health Service Act<sup>3</sup> by the UK government, the act explicitly mandates the Minister of Health with the responsibility to promote the establishment of a comprehensive health service that prioritises the enhancement of both physical and mental wellbeing, whilst also focusing on the prevention, diagnosis, and treatment of illnesses.

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<sup>1</sup> The Long-term Sustainability of the NHS and Adult Social Care Report, House of Commons

<sup>2</sup> A Brief Guide to Public Finances, UK Office for Budgetary Responsibility

Healthcare is ripe for a huge transformation. Rather than focusing just on just symptom management, it is far more effective, beneficial to society, and economically viable to prevent and cure.

Over the next two decades, exponential technologies will enable this transformation, with advances in digitalisation, artificial intelligence (AI), life sciences, formulation science, new materials, and microelectronics playing a pivotal role.

AI for example can analyse vast amounts of data, rapidly learn, uncover patterns, and support decision-making that will revolutionise the relationship between healthcare providers, caregivers, and patients. Generative AI systems will not only automate tasks like reordering prescription medicines and automatically capturing notes and images during medical consultations, but also serve as medical co-pilots for patients and for healthcare providers. Equipped with access to patients' medical histories, real-time data from wearable devices, and extensive medical knowledge, these AI systems will improve the quality and efficacy of future healthcare services.

Today's basic medical check-ups offered by primary healthcare providers will appear inferior and even obsolete. In the future primary care providers will be able to monitor their patients using digital solutions before they develop a medical condition, and even help them to avoid chronic disease onset.

Chronic non-communicable diseases such as metabolic conditions, do not happen overnight. They develop over many years and even decades, as result of the accumulation of incremental damage to the body's cellular and biomolecular system,

caused everyday lifestyle habits, social norms, and environmental exposure.

This fact, when combined with the rise of enabling digital technologies, will drive the growth of the high-value wellness sector and eventually cross-fertilise capabilities into the healthcare sector, empowering consumers, and patients. This high-value wellness sector has already started to emerge, offering novel science-based services aimed at helping individuals maintain their health and avoid chronic diseases, prolonging their healthspan, and increasing their lifespan.

As such services democratise and become accessible by all, they have the potential to alleviate pressure on the healthcare system and change patients' expectations. Indeed, these solutions will cross fertilise into the medical community.

## Summary

The analysis in this report delves into 17 of the most significant factors and trends shaping the future of healthcare, grouped into three categories:

- Environmental and societal factors challenging healthcare services.
- Advancements in the life sciences and exponential technologies
- New and emerging care models.

Rather than focusing solely on episodic illness events and symptom management, the emphasis will shift increasingly towards patient-centred approaches, prevention, integration of lifestyle medicine, and personalised care models to address long-standing unmet needs of both healthcare providers and patients. It will empower individuals and patients to take better care of their own health and recovery.

These types of emerging services and innovations will disrupt traditional business models in the pharmaceutical and medical device industries. Increasingly in the future, it will be possible for individuals to avoid the onset of certain chronic diseases using emerging services offered by new entrants in the wellness sector. As this takes hold, it will start to reduce the demand for associated medicines and medical interventions. For the UK government it will help reduce the burden on health and social care expenditure, which is around 20% of the government's annual budget for all its departments.

Existing incumbents will need to lead the transformation or risk being replaced by more innovative new entrants who prioritise addressing long-standing unmet needs and creating new opportunities for healthcare professionals and patients. Innovative new entrants will not be impeded by existing

business models and mindsets. They will have deep digital expertise and access to the latest science underpinning healthy living, lifestyles choices, and medical conditions at a cellular and molecular level.

To stay competitive in the new landscape, pharmaceutical companies will need to focus increasingly on therapeutics that are more tailored and curative, such as personalised pills, poly-pills, precision medicines, gene therapy, stem cell therapy and therapeutics targeting the extension of healthspan. They will also need to look for solutions that enable the adoption of new digital and preventative care models.

Additionally, the strong association between lifestyle choices and chronic diseases will have an impact on the future of the food production and consumption system, as innovative businesses in the wellness sector harness this association as an opportunity to empower individuals.

Innovative early-stage firms are already offering individuals a personalised nutrition service, based on data from continuous blood glucose devices, regular blood tests and periodic microbiome analysis.

Such services empower individuals to make informed choices, helping them to improve their health and reduce their risk of chronic diseases. With tailored nutrition plans and precise visualised information, individuals will better understand how their bodies responds to different food choices and adjust their own behaviour.

The know-how of such digitally enabled services can be adopted by healthcare providers to incorporate lifestyle interventions into disease prevention and care plans for recovery from illnesses.

The future of healthcare in a time horizon of just beyond 2035 will be characterised by

several attributes as depicted in [Exhibit A](#), all fundamentally underpinned by advanced digitalisation.

Key features of the future landscape include:

1. National and regional government bodies will implement policies to help facilitate the adoption of healthy living and the creation of urban spaces and settings that facilitate healthy habits, access to healthy foods and active lifestyles.
2. Longevity science will unlock at a cellular, biochemical, and epigenetic level knowledge, lifestyle habits, products, and services to empower individuals to live well and healthier longer, through prevention.
3. The assessment of a patient's health status and recovery will incorporate the use of a blood biomarker test to establish biological age. This will give rise to emergence of the longevity sector for extending healthspan. This is a sector that is already today taking root.
4. An ageing population and growth of the longevity market will spark convergence of the high-value wellness and healthcare sectors driven by cross-fertilisation of knowledge, tools, practices, and mindsets.
5. Insights from a patient's microbiome will be harnessed to improve health and to address complex chronic conditions.
6. The healthcare system will shift towards prevention and curative approaches, that prioritises patient-centred care, meaning individuals will have access to tailored treatments and care plans, and services that offer targeted lifestyle medicine, personalised medicines, and targeted therapeutics. Aided by functional medicine and digitalisation.
7. Clinics will be highly digitalised, incorporating surgical and care bots, artificial intelligence, augmented reality, connected devices, internet of medical things (IoMTs) and 6G networks, enabling outcome-based care models.
8. The recent emergence of Generative AI models and the likely emergence of General Artificial Intelligence (AGI) in the coming decade will unlock very powerful opportunities that today may be difficult to foresee.
9. Deepening digitalisation will give rise to Digital Twins of patients and evolve further into AI-powered Wellness and Medical Co-Pilots, supporting healthcare professionals, patients, and caregivers.
10. The advent of carebots, smart exoskeletons, and advanced prosthetics promises to enhance social inclusion by fostering greater independence among patients. They will also contribute to the overall improvement in the quality of social care services.
11. Integration of patient data, along with the advent of Digital Twins, will enable population-level data analysis for a range of stakeholders.
12. Hospitals will adopt near-to-care production facilities, such as additive manufacturing for customised casts, implants, medicines and much more located onsite or near to clinics.
13. Healthcare services will also prioritise environmental sustainability and decarbonisation, prompting manufacturers of medicines and devices to rethink their supply chains.
14. Healthcare providers need to be prepared for public health threats, including pandemics, and effectively respond to peak demands during climate-related disasters.

In the final section of this report, the future healthcare developments are illustrated in the patient outcomes for two fictional characters, Lyra and Will, who have type 1 and type 2 diabetes, respectively. In the future, Lyra's disease progression follows a medical preventive model that includes gene therapy and lifestyle intervention. Will uses an AI-powered wellness service and li. Both live a long and healthy life.





**A powerful interplay of seventeen intrinsic market and technological forces are shaping the future of healthcare.**



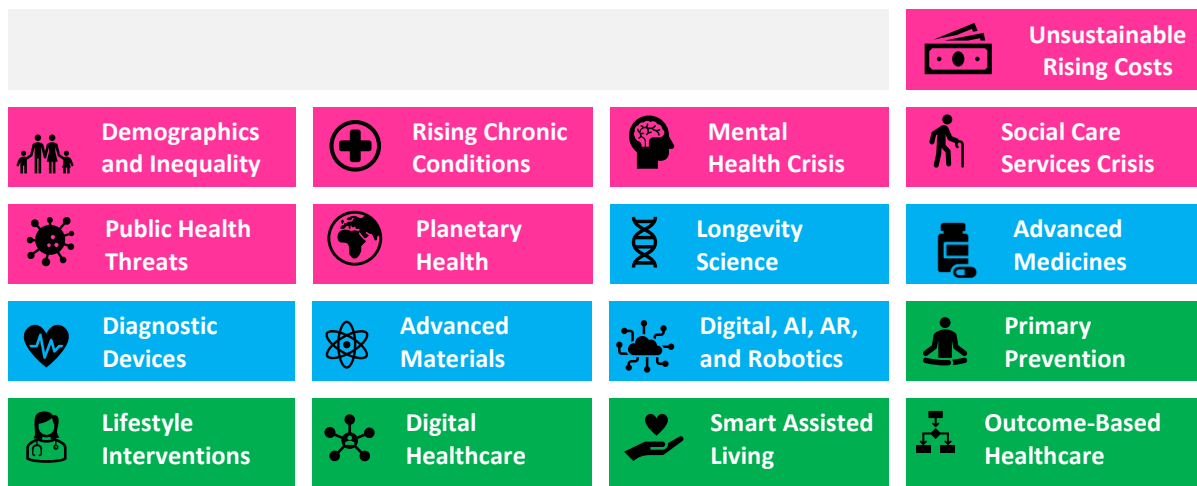
## Market Factors, Drivers, and Trends Shaping the Future of Healthcare

The healthcare sector is undergoing disruptive transformation underpinned by rising costs of health and social care, increasing levels of complex chronic diseases in both young and elderly people, the aftermath of COVID-19 and the growing effects of climate change. Individuals, patients, scientist, healthcare professionals and policy makers are also starting to better understand the scientific connection between chronic disease formation and lifestyle. Indeed, they are starting to realise the benefits of integrating lifestyle medicine into healthcare practices.

At the same time advances in medicines, materials, technologies and disruptive innovations from researchers, industry, new entrants, and healthcare service providers is set to revolutionise care models, enhance patient outcomes, drastically reduce healthcare costs, and give patients far greater control of their health and recovery.

Whilst existing large industrial players have the advantage of firmly anchored positions, deep regulatory expertise and access to investment capital, new entrants bring a fresh perspective, and if they are connected to a large corporation or investor, they also bring investment. Indeed, with the advent of artificial intelligence (AI) the pace of innovation is accelerating. This positions many new entrants well to bring to market compelling solutions.

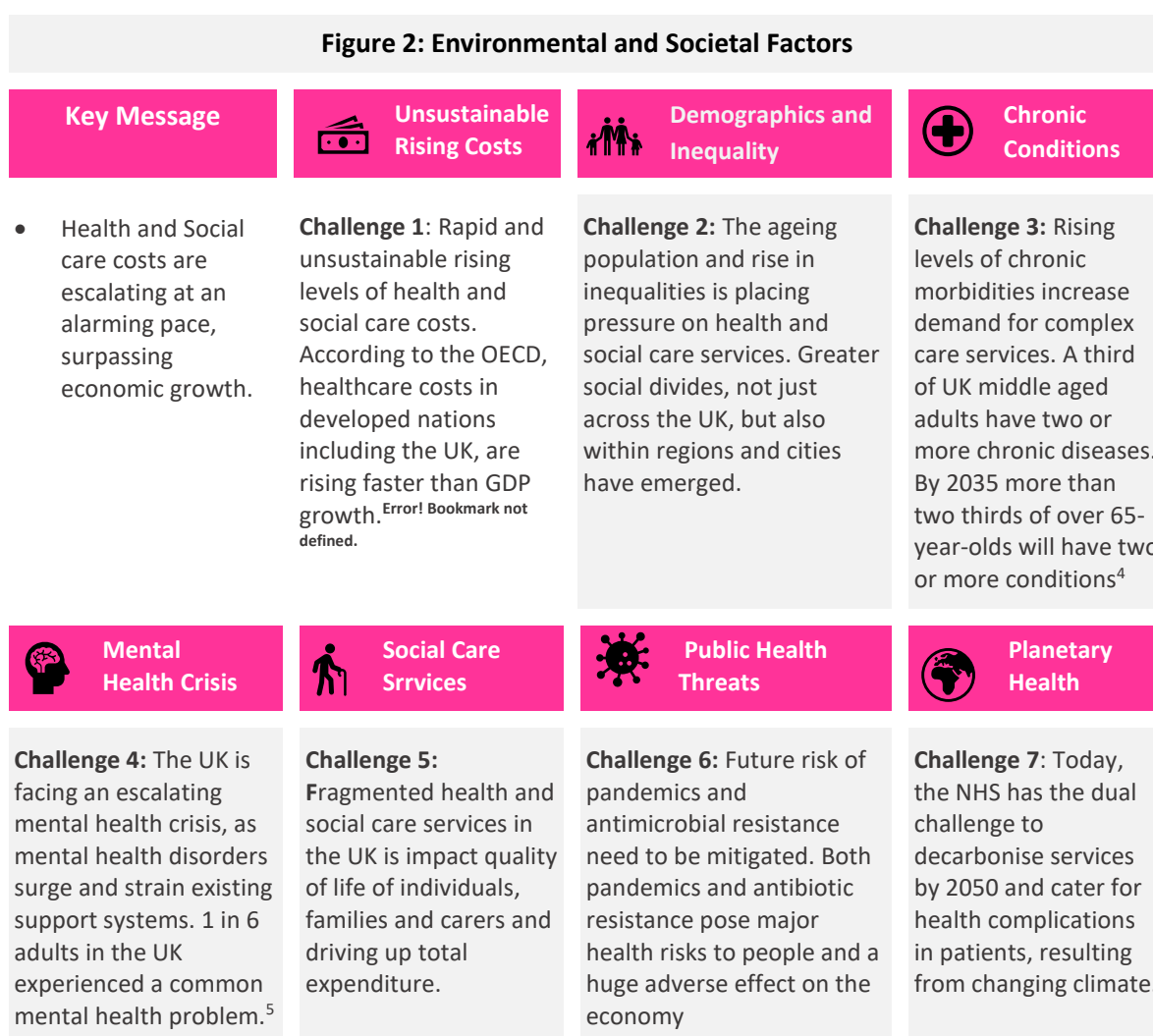
New entrants today are already bringing novel solutions enabled by artificial intelligence and the Internet of Medical Things (IoMTs) into every aspect of healthcare from disease diagnosis to a shift towards lifestyle and preventive care models. This in turn is driving cross-fertilisation and convergence between the medical and wellness sectors, through the exchange of scientific knowledge, expertise, tools, practices, and mindsets.



**Figure 1: Market Factors, Drivers and Trends Shaping the Future of Healthcare**

- Environmental and Societal Factors Challenging Healthcare Services
- Advancements in the Life Sciences, Material Science and Digital Technologies
- New and Emerging Care Models

## 1. Environmental and Societal Factors Challenging Health & Social Care Services



### Challenge 1: Unsustainable Rising Costs

In 2019, an OCED report<sup>6</sup> indicated that health expenditure will outpace GDP growth over the next 15 years in most OECD countries including the UK. The combined health and social expenditure in the UK as indicated by the Office of National Statistics (ONS) has reached £283 billion, including government and non-government expenditure. In 2013 the UK's Office for

Budget Responsibility's health and long-term care projections indicated healthcare spending<sup>7</sup> could range from 7.8% to 16.6% of GDP by 2061. Indeed, according to the Office of National Statistics (ONS)<sup>8</sup>, the UK's combined health and social costs reached 11.3% of GDP during 2022.

In the United States, the projections are even more eye watering with healthcare costs estimating to reach 33.3% of GDP by 2035 and 98.9% by 2082, as indicated by the

<sup>4</sup> The Health Foundation, Article "We get sicker while government policy on health drift", 2023.

<sup>5</sup> Mind. Mental Health Facts and Statistics, 2027.

<sup>6</sup> Health spending set to outpace GDP growth to 2030, published 2019 by the OCED.

<sup>7</sup> Spending on health and social care over the next 50 years: Why think long term? Kings Fund, January

<sup>8</sup> Healthcare expenditure, UK Health Accounts provisional estimates: 2022, ONS, May 2023

US Congressional Budget Office in their Long-term Outlook for Health Care Spending Report.

These levels of financial pressure are unsustainable and will necessitate huge transformation. Healthcare costs will have now been further compounded by the pressure placed by the COVID-19 pandemic and its aftermath.

A recent paper<sup>9</sup>, published by Oxford University and Harvard Medical School, shows if healthspan in the United States is increased by just one year, it is worth \$37 trillion in net present value. This is \$700 billion annually, or 3% of the United States' GDP.

Rising healthcare costs are due to a multitude of reasons, some of which are outlined below.

### **Challenge 2: Demographics and Inequality**

One factor driving up costs is the demand for services from an ageing population. This demographic group has a rising prevalence of complex multimorbidity conditions, which often require complex long-term expensive medications and treatments.

There is also clear link between an individual's socio-economic disposition and their health status and outcomes. In the UK for example, people living in more deprived areas are more likely to experience poor health, including higher rates of chronic diseases such as diabetes and heart disease, compared to those living in more affluent areas. Additionally, individuals from ethnic minority backgrounds may also experience health inequalities due to systemic racism and discrimination in society.

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<sup>9</sup> The Average American Would Pay \$242,000 For One Extra Year of Good Health, Future, Andrew Scott<sup>10</sup> Metabolical, The Truth about Processed Foods and how it poisons people and the planet, Dr Robert Lustig, 2023

### **Challenge 3: Chronic Conditions**

The rising levels and complexity of disease conditions and their treatments also contribute to rising healthcare costs and underpins the rising social care costs the UK faces.

Chronic conditions occur not just because of ageing but are often caused by and complicated by lifestyle and environmental factors such as smoking, poor diet, eating patterns, lack of quality sleep, inactivity, alcohol, and exposure to toxins. Such lifestyle factors accelerate disease formation by harming critical cellular structures and mechanisms.

This results in biological issues such as stem cell exhaustion, insulin resistance, epigenetic alternations, mitochondrial dysfunction, cellular senescence, genomic instability, telomere attrition, gut microbiome dysbiosis, and nutrient sensing distortion. In turn, this accelerates biological aging, reducing an individual's healthspan.

There is now sound scientific consensus that draws a clear link between the consumption of ultra processed foods and chronic disease formation and progression. This well documented in literature including a recent book by Dr Tim Spector "Food for Life. The New Science of Eating Well".

Despite recent technological advances in medicine, increasing numbers of people in the UK will be spending more years in poor health due to rising levels of lifestyle chronic diseases. Indeed, chronic diseases rates such as metabolic and autoimmune conditions are increasing in both young and older demographics.<sup>10</sup>

<sup>10</sup> Metabolical, The Truth about Processed Foods and how it poisons people and the planet, Dr Robert Lustig, 2023

Type 2 Diabetes is largely a lifestyle disease. It was once referred to as “adult-onset diabetes” and was renamed as an increasing number of children today are being diagnosed with the condition. As they age their condition is likely to worsen unless the root cause of the condition is addressed.

There is a clear growing need to shift towards preventing disease onset to improve lives and reduce demand for complex expensive interventions, by integrating lifestyle medicine into medical practices.

#### **Challenge 4: Mental Health Crisis**

We are witnessing a rising incidence of mental health issues, attributed to the demanding nature of modern lifestyles, heightened exposure to social media, evolving work patterns, traumatic experiences, and socio-economic circumstances. These factors contribute to elevated levels of anxiety, depression, and various other mental health disorders.

Compelling evidence is emerging that underscores the connection between mental health and the state of the gut microbiome. This relationship is further influenced by dietary choices, particularly the consumption of ultra-processed foods, which has discernible effects on the overall quality of the gut microbiome. Thus, the intricate interplay between lifestyle factors, mental health, and dietary habits is becoming increasingly apparent.

#### **Challenge 5: Fragmented Health and Social Care Services**

The fragmentation of the NHS and social care services in the UK has long been a source of concern, giving rise to a multitude of issues that impact the quality and efficiency of healthcare delivery. One key challenge lies in the disjointed nature of service provision, where healthcare and social care often operate as separate

entities with distinct funding streams and organisational structures distributed between central and local government. This fragmentation can result in a lack of coordination and communication between healthcare and social care providers, leading to gaps in patient care and a failure to address the holistic needs of individuals with complex health and social care requirements. This siloed approach not only hampers the overall effectiveness of the healthcare system but also poses obstacles to achieving a seamless and integrated experience for individuals, particularly those who may require both medical treatment and ongoing social support.

Moreover, the fragmentation of the NHS and social care contributes to inefficiencies in resource allocation and utilisation. With separate systems come duplicated administrative processes, redundancies in service delivery, and challenges in sharing critical patient information across different sectors. This not only results in increased costs but also impedes the optimal use of available resources, which could be better deployed to enhance patient care outcomes. The fragmented landscape further complicates the implementation of comprehensive preventive measures and early interventions, hindering the ability to address health and social care needs proactively.

Efforts to bridge these gaps and promote a more integrated approach to healthcare and social care services are crucial to overcoming these issues and ensuring a more streamlined, patient-centred, and sustainable system.

#### **Challenge 6: Planetary Health**

Health and social care costs will be exacerbated further by the effects of climate change on the elderly and people with complex medical conditions such as

autoimmune diseases, leading to costly NHS service demand peaks during summer heat waves and colder winter periods.

In addition, **recent studies** have indicated that climate change may triple the likelihood of public health threats from pandemics in the coming decades.

The convergence of climate change, awareness of pollution, and human health has given rise to a dynamic and interdisciplinary field known as **Planetary Health**. This groundbreaking concept was first introduced in 2015 through a collaborative endeavour involving The Rockefeller Foundation and The Lancet. Planetary Health explores the intricate connections between the well-being of natural ecological systems and their profound implications for society, encompassing human health as a central aspect. It draws the connection between the **Nine Planetary Boundaries Framework** and human health.

The nine planetary boundaries are critical environmental thresholds identified by scientists to safeguard Earth System's stability and the wellbeing of humans. They represent the maximum safe limits for essential global processes such as climate change, biodiversity loss, freshwater use, ocean acidification, ozone depletion, atmospheric aerosols, chemical pollution, nitrogen and phosphorus cycles, and land system change, beyond which there is a higher risk of triggering abrupt and irreversible environmental changes that could disrupt ecosystems, the economy and human health.

By delving into these intricate relationships, this field opens new avenues for investigation, transforming our understanding of health and the environment. One area of research for example, is the impact on human health of

micro-plastics, particulates, antibiotics, and other novel entities released into the environment.

This field will clearly influence future government policies on healthcare, wellbeing, climate change, the built environment and industrial pollution.

### **Challenge 7: Public Health Threats**

Mitigating future pandemics and antimicrobial resistance will be vital, given the dual impact on public health and the economy. Rapid spread of novel infectious agents in pandemics can overwhelm healthcare systems, disrupt societies, and trigger economic downturns. Beyond immediate health consequences, there are mental health effects and strains on healthcare infrastructure, leading to economic disruptions like recessions and unemployment.

Simultaneously, rising antimicrobial resistance complicates disease control, increasing illness severity, duration, and healthcare costs. The economic toll extends to productivity losses due to prolonged illnesses and complications from untreatable infections.

Addressing these challenges requires global surveillance, fortified resilient healthcare infrastructure, and responsible antimicrobial use. International collaboration is essential for a collective defence against both these transnational threats.

**Case Study: Strengthening UK's Resilience Against Healthcare Emergencies**

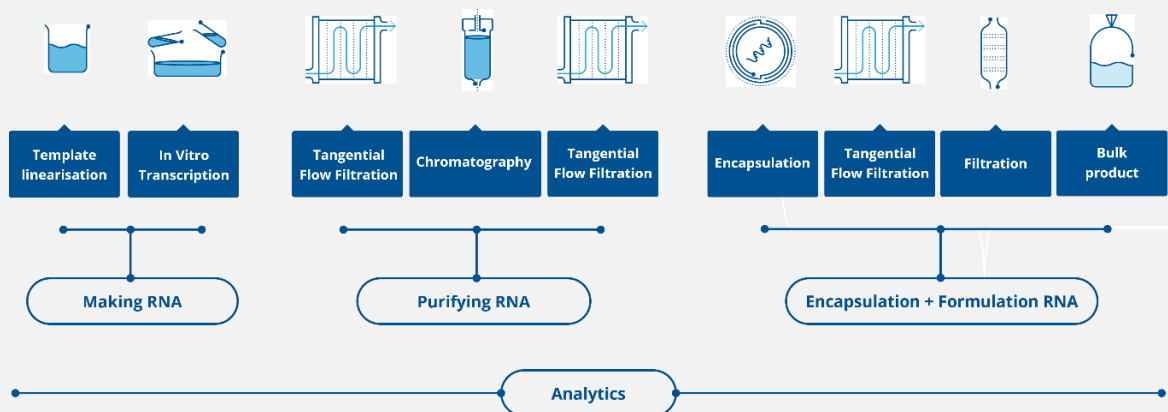
During the pandemic, CPI collaborated with Imperial College London, the UK Vaccine Taskforce and UK government departments to develop a self-amplifying ribonucleic acid (saRNA) vaccine for Covid-19. This work led to CPI establishing an **RNA Centre of Excellence** for developing messenger RNA (mRNA) and saRNA vaccines and the next generation of targeted therapies. It is designed to strengthen the UK's resilience and response to similar future public healthcare emergencies. It has the installed capabilities, expertise, training facilities, and capacity to manufacture millions of vaccine doses per year in the event of a future emergency.



RNA vaccines have already started to and will transform the future of medicines. Their potential was first unlocked on a global scale through use in the COVID-19 vaccines. The vaccine contains single stranded molecules of mRNA as the active ingredient, each holding the genetic instructions for making COVID-19 "spike" proteins. The mRNA is encapsulated within Lipid Nanoparticles (LNPs) to protect it from degradation and allow cellular uptake. Once inside the cells, the cellular machinery translates the mRNA into the coded spike protein and this triggers an immune response that teaches the immune cells to recognise it, providing protection against future encounters with the virus.

The success of RNA-LNP based COVID-19 vaccines was due to the groundbreaking nature of the technology underpinning them, which had already been established through decades of prior research. The mRNA construct can readily be designed with specific genetic instructions, encapsulated, and manufactured into a therapeutic – giving rise to an agile "Platform Technology" for RNA-LNP therapeutics. The use of a genetic code lends itself to a "plug-and-play" vaccines approach with rapid development times.

The illustration below depicts the Platform process at CPI used to help stakeholders formulate, develop and scale-up new RNA-based vaccines and the next generation of precision therapies:

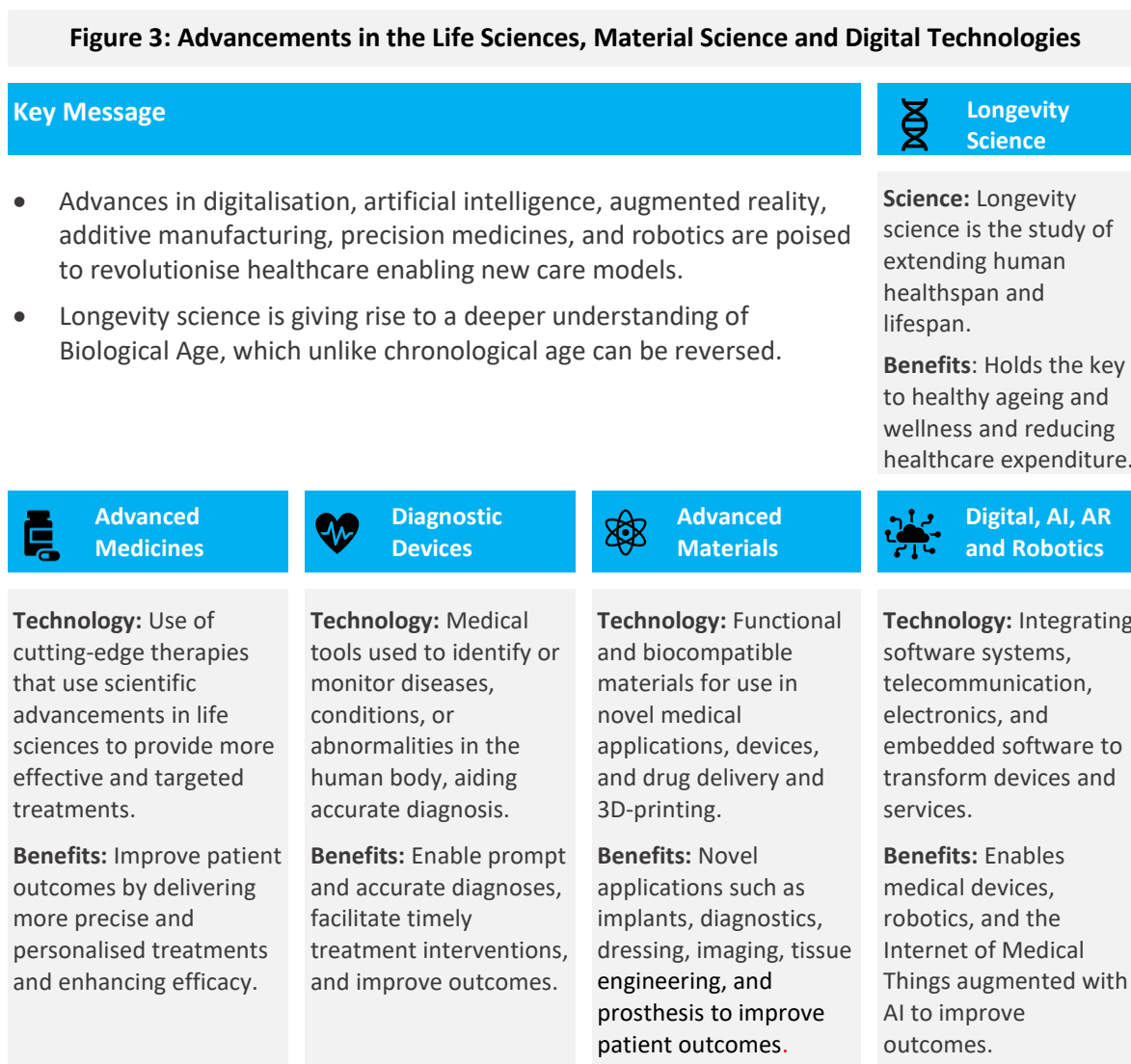


**CPI's RNA-LNP Technology Platform for Vaccines and Therapeutics**

RNA-based technologies are transforming the field of therapeutics, providing scientists and industry with powerful new tools to address a wide range of challenging and elusive conditions such as:

- Vaccines - rapid development to help mitigate future healthcare emergencies.
- Cancer - target specific tumour antigens, enhancing immune system's response against cancer cells.
- Genetic Diseases - conditions such as cystic fibrosis, muscular dystrophy.
- Protein Replacement Therapy - for individuals with certain genetic deficiencies.
- Regenerative Medicine - aid tissue repair and wound healing in various conditions and injuries.
- Autoimmune Diseases - regulate immune system activity and reduce inflammation.
- Cardiovascular Diseases - targeting specific genes in the disease processes, such as lipid metabolism.

## 2. Advancements in the Life Sciences and Exponential Technologies



Five significant scientific developments and exponential technological are reshaping the future of healthcare and our approach to health and wellness.

Exponential technologies are technologies that are adopted at an accelerated pace by industry, often by new entrants and their progression can surprise incumbent businesses. These can material, physical, or digital technologies. The characteristics are discussed in this paper in the section titled “The Future Personalised and Patient-Centred Healthcare System”.

### Development 1: Longevity Science

Longevity science is a new and emerging branch of the life sciences. It is making groundbreaking advancements in comprehending the molecular, cellular, and physiological mechanisms responsible for establishing and preserving health. It delves into the human body's innate bio-chemical mechanisms that maintain health such as how the body prevents the emergence of cancer and how the body repairs damaged cellular structures, proteins, and DNA. This innovative approach diverges from

traditional methods that primarily focus on intervening in biochemical mechanisms after the disease and its symptoms have taken hold. As a result, researchers, industry, and healthcare professionals are gaining fresh insights into unleashing science-based lifestyle and therapeutic interventions that promote healthy aging. Moreover, they are progressing towards interventions to decelerate and even reverse biological aging, ultimately forestalling the onset of diseases and enhancing the treatments.

### **Development 2: Advanced Medicines**

Advancements in the life sciences are opening new doors to targeted and precision therapeutics that consider a patient's genetics and medical history, paving the way for more effective and tailored approaches to combating diseases.

A noteworthy example is the emergence of Messenger RNA drugs, a promising therapeutic category employing synthetic mRNA molecules to generate disease-fighting proteins with exceptional precision. These drugs exhibit high specificity and selectivity, precisely targeting the required cells and tissues. Their rapid development and manufacturing processes further enhance their potential. As a result, the life sciences are empowering healthcare professionals with novel tools to develop personalised treatments that consider individual genetic profiles and pave the way for more effective and tailored approaches to combating diseases.

Moreover, life sciences advancements have unveiled the pivotal significance of the human gut microbiome in the advancement and progression of diverse diseases. It forms around 70% of the immune system, exerts influence over hormone regulation

and aids food digestion and absorption. Microbiome breakthroughs are propelling the development of microbiome-based therapies and lifestyle interventions to tackle arduous conditions such as autoimmune diseases, depression, Type 2 diabetes, and allergies.

### **Development 3: Diagnostic Devices**

The future of diagnostic devices is undergoing a transformative shift, driven by cutting-edge technologies that promise to revolutionise medical diagnostics. Artificial intelligence (AI) is playing a central role, with algorithms analysing vast datasets swiftly and accurately, aiding clinicians in rapid and precise diagnoses. Miniaturisation and portability are enhancing accessibility, enabling point-of-care testing at the bedside or even in homes, particularly benefiting underserved regions. Additionally, advancements in biomarker identification, molecular diagnostics, lab-on-a-chip, biochips, wearables, and imaging technologies contribute to the emergence of personalised healthcare.

Furthermore, companies operating in the wellness sector are also incorporating diagnostic testing services for their customers to help them better understand their health status and act before medical issues arise.

### **Development 4: Advanced Materials**

Advancements in material science are driving the development of future healthcare technologies that could play a crucial role in disease prevention, diagnosis, monitoring, treatment, and even environmental sustainability.

The emergence of new materials will give rise to a wave of cutting-edge customised medical products, including biosensors, imaging systems, personal protective

equipment, drug delivery systems, antibacterial surfaces and patient-specific surgical guides, implants, biodegradable inserts, prosthetics, orthopaedics devices, exoskeleton structures and other mobility solutions, 3D-printed polypills, and tissue engineering scaffolds for organs and regenerative medicine. These advancements in material science will need to take into consideration environmental sustainability challenges to drive decarbonisation of supply chains, products, and services without comprising product performance and patient outcomes as well as supporting a shift towards a circular economy.

Techniques such as additive manufacturing, also known as 3D printing, are enabling near-to-care manufacturing. The key areas where additive manufacturing will transform healthcare are:

- Bioprinting – precisely deposit layers of living cells for tissue engineering
- Surgical instruments – haemostats, surgical guides and more.
- Prosthetics – designed and personalised for individual patient needs.
- Patient-specific products – anatomical models, wearable devices, and organs
- 3D-printed medicines – poly-pills.

#### **Development 5: Digitalisation and Robotics**

Digital technologies, such as Artificial Intelligence, 6G wireless networks, the Internet of Medical Things, robotics, automation, virtual reality, augmented

reality, real-time monitoring, quantum computing, and distributed ledger systems, are reshaping healthcare at an exponential rate. Digital technologies are enabling the seamless gathering, integration, and deep analysis of vast volumes of bioinformatic, clinical trial, and patient data. This includes crucial information like DNA, epigenetics, blood biomarkers, and real-time data.

Patient data can also be augmented by a library of very carefully curated medical research papers, recent discoveries and case studies using Generative AI, to aid medical decision making. The ability to promote responses<sup>11</sup> using an AI interface will be a vital skillset for medical professionals and researchers.

The application of AI and quantum computing to drug development is expected to accelerate the identification of new potential active pharmaceutical ingredients, and better predict their safety and efficacy even before laboratory testing and clinical trials commence. AI is already enhancing cancer diagnosis by scrutinising extensive medical imaging data, swiftly identifying subtle changes, and detecting potential cancerous lesions with precision. AI will give rise to co-pilots for researchers, healthcare workers, patients, and caregivers.

Cybersecurity threats are a barrier to realising the full potential of Digital Healthcare. It will clearly need to be underpinned by robust cybersecurity measures, systems, and regulations to safeguard privacy and build trust.

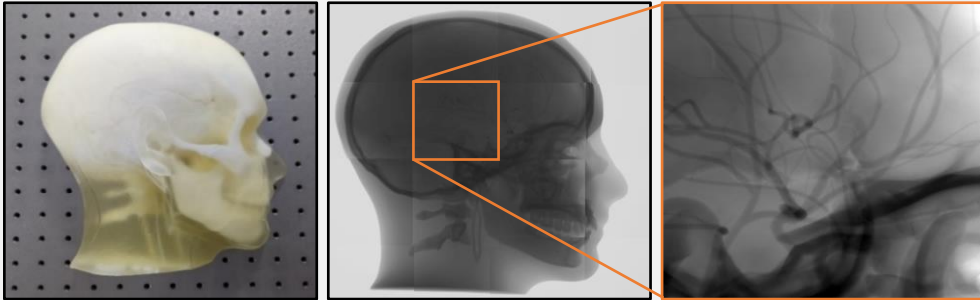
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<sup>11</sup> Prompt Engineering as an Important Emerging Skill for Medical Professionals: National Library of Medicine



**Case Study: Additive Manufacturing for Medical Applications**

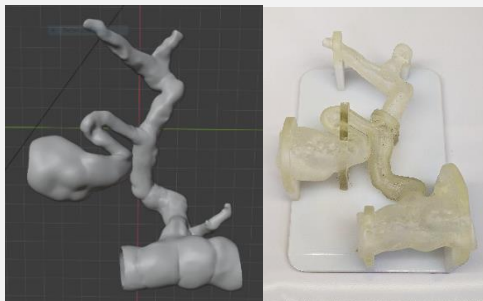
Additive manufacturing is set to change healthcare. Its importance lies in the ability to create complex, customised **patient-specific medical devices** and models with high precision and efficiency based on digital designs and patient imaging data. It is now possible to produce highly detailed and realistic models that replicate the intricate anatomical structures of the body. Drawing on our expertise in materials science and healthcare, at CPI we are building capabilities in additive manufacturing to help industry and healthcare providers to develop novel medical applications.



**With our Digital Anatomy 3D-Printer**, it is possible to manufacture directly from data obtained by medical imaging methods such as CT scanning or MRI Scans. At CPI, we worked closely with imaging specialists at Beaumont Hospital and through careful material selection and parameter optimisation, we successfully demonstrated the radiopacity, like that of the human head by closely emulating the X-Ray attenuation properties of the target tissue. We created a realistic and anatomically accurate model that could mimic the radiological properties of the human head for use in cerebral angiography training, research, and calibration of imaging machines. Traditional methods of producing such phantoms were limited in their ability to accurately simulate the complex structures and radiographic properties required. CPI's solution offered a revolutionary approach to overcome these limitations and achieve the desired level of realism and functionality.



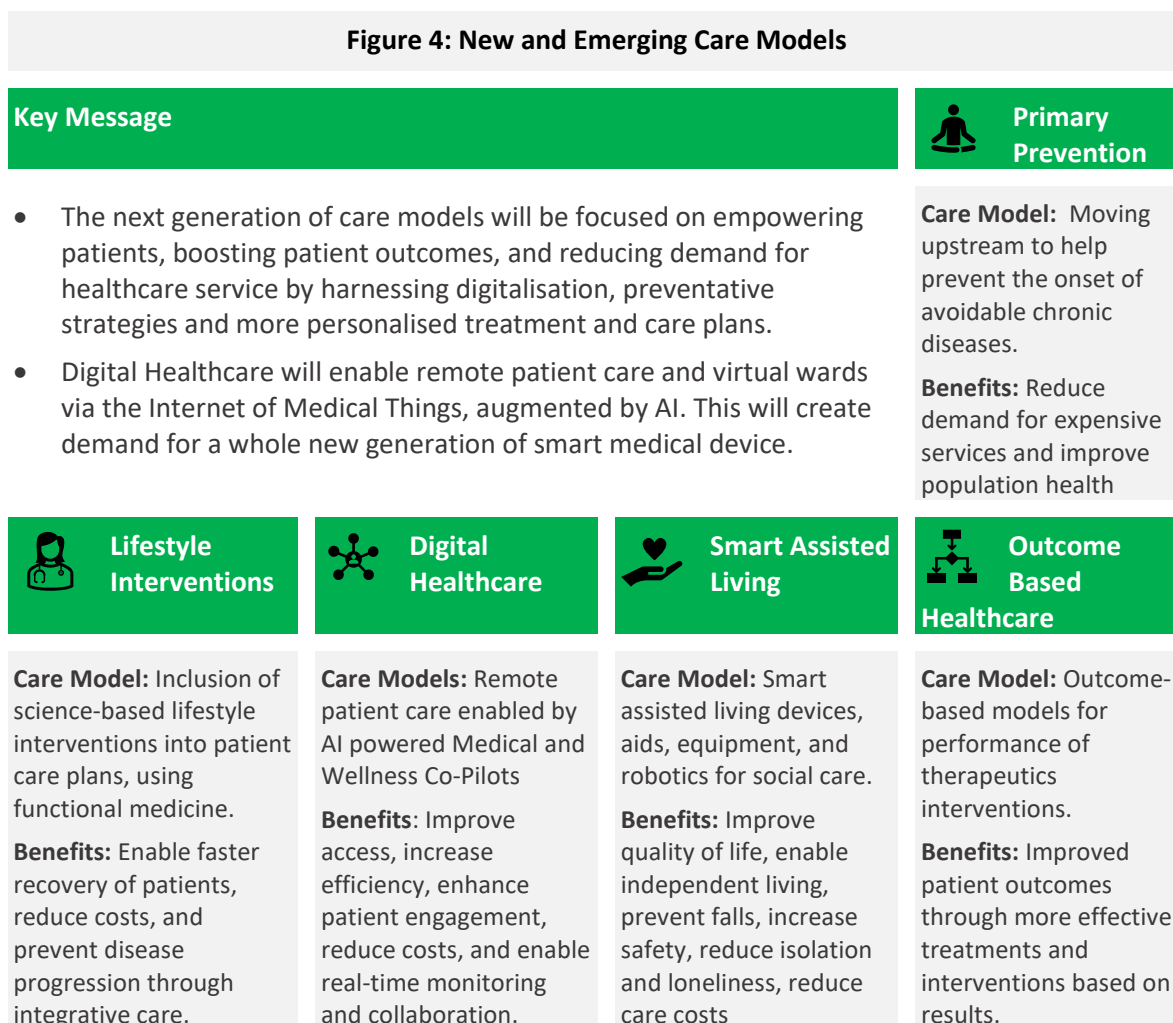
**Patients**, medical students, and healthcare providers can benefit from custom models, helping patients to understand their condition and treatment options and healthcare professions to plan surgical interventions. For patients, they provide a tangible representation of their unique condition, allowing them to visualise and grasp the complexities of their condition. By seeing their anatomical structures and potential treatment approaches, patients can make informed decisions.



3D-models can be printed using a variety of materials, including those that mimic the mechanical properties of human tissues. This allows the models to be used as functional prototypes for pre-surgical simulations or even as guides during surgical procedures. Image on the left shows a 3D-model of a hepatic duct printed for [Nottingham Biomedical Research Centre](#) to plan and test a patient-specific endoscopic intervention.

**Cell, tissue, and organ culture** also make use of additive manufacturing, from bioprinting used to create models of tissues and organs that can be used to study diseases and test new treatments, for example scaffolds that provide a foundation for cells to grow and organise into tissues and organs such as skin, bone, cartilage, and more complex organs. This emerging field is giving rise to the use of tissue engineering and regenerative medicine.

### 3. New and Emerging Care Models



Disruptions often come from new entrants from outside of a given industry, increasingly driven by digital technologies, to address long standing unmet needs and systemic issues. The healthcare sector will be no different. The disruption for healthcare will come from the need to shift from a reactive care model based on symptom management to one that is more preventive to improve outcomes, reduce demand, reduce costs, and reduce environmental footprint of services.

#### Care Model 1: Primary Prevention

In its long-term strategy for the next 10 years, the NHS is planning to go upstream and embrace primary prevention. The

conventional healthcare model has largely been reactive, intervening after diseases have already surfaced. However, the future of healthcare will also prioritise prevention by placing greater emphasis on identifying and mitigating risk factors before they trigger the onset of diseases. This proactive approach involves promoting healthy behaviours, incorporating remote monitoring, self-monitoring practices, conducting regular biomarker and microbiome screenings, and using genetic testing to identify predispositions to disease. By adopting this approach, healthcare providers can potentially reduce the demand for complex healthcare

services, improve the overall health of the population, and alleviate the burden of healthcare costs.

### **Care Model 2: Lifestyle Interventions**

Advancements in longevity science have revealed the profound impact of lifestyle choices on overall health and recovery, including at the cellular, epigenetic and microbiome levels. Future healthcare models would be expected to increasingly incorporate science-based lifestyle interventions, encompassing healthy diets, fasting, physical activity, yoga, stress management, sleep, meditation, hydration, and social support. Collaborating with healthcare providers, patients would receive tailored education, personalised coaching, and behaviour change programmes to empower them in making sustainable modifications to their lifestyles. By addressing the underlying causes of diseases and promoting healthy habits, healthcare systems can achieve long-term improvements in patient health.

Clinical trials undertaken by Dr Dean Ornish has demonstrated that a whole foods plant-based diet can reverse cardiovascular disease. His lifestyle programme has been approved by the FDA and has received MEDICARE coverage as a comprehensive lifestyle intervention for reversing cardiovascular disease. Similar lifestyle interventions are being investigated for their efficacy on other conditions such as Alzheimer. Such lifestyle intervention approaches can also be implemented in the UK to improve patient outcomes.

This will require the adoption of functional medicine. This is a medical approach to healthcare that focuses on understanding and addressing the root causes of illness and disease, rather than just treating

symptoms. It is highly patient-centred, science-based, and integrative approach that considers individual's unique genetic, biochemical, medical history, and lifestyle factors.

Furthermore, in the future smart connected wearables and artificial intelligence will play a pivotal role in helping healthcare providers and patients monitor such interventions, allowing individuals to track and visualise their progress.

### **Care Model 3: Digital Healthcare**

Digital healthcare is expected to disrupt the delivery of healthcare services.

Telemedicine, 6G networks, remote patient monitoring, wearable devices, health apps, virtual wards, surgical robotics, delivery drones, smart ambulances, smart homes, and artificial intelligence could all contribute to an advanced Internet of Medical Things underpinned by Generative AI.

These technologies would enable patients to access virtual consultations, remotely monitor vital signs, and receive personalised health information, empowering them to take an active role in their own care. Artificial intelligence is expected to play a crucial role in digital healthcare, assisting in early detection, accurate diagnosis, and clinical decision-making. AI-driven algorithms will not only aid healthcare providers but also through the data gathered from different devices help determine patient compliance to care plans and medication regimens. This digital integration would capture the entire patient experience, allowing for comprehensive and individualised care.

It will also overtime give rise to Medical Co-Pilots for assisting healthcare professionals, coaching patients, and aiding caregivers.

#### Care Model 4: Smart Assisted Living

Incorporating smart technologies into assisted living environments will give greater independence to elderly individuals and those with chronic conditions. Smart homes equipped with sensors, remote monitoring devices, exoskeleton structures, and assistive robots could work in tandem to monitor vital signs, detect falls, offer medication reminders, enhance mobility, and provide immediate assistance during emergencies. This comprehensive approach would significantly enhance patient safety, improve overall quality of life, and promote greater independence for individuals.

By leveraging the power of smart assisted living models, healthcare providers will be able to remotely monitor the health status of their patients, enabling early intervention and reducing the likelihood of hospital readmissions. This proactive monitoring would allow healthcare and social workers to address potential issues promptly, ensuring that individuals receive the necessary support and care in a timely manner. Furthermore, the integration of smart technologies in assisted living settings

would foster a sense of security and peace of mind for both patients and their families.

#### Care Model 5: Outcome-Based Healthcare

Lack of data has been a barrier to date for the adoption of outcome-based models. The increasing volume of data and AI assisted analysis will help address this, by helping to establish a connection between actual patient outcomes and the interventions prescribed in their care and recovery plans.

This will clearly impact the business models of companies offering products and services to healthcare provider.





## Case Study: Transforming the Care Model for Stroke Rehabilitation

**KnitRegen** is a smart textiles start-up from the Royal College of Art (RCA), who collaborated with CPI to enhance and develop a novel wearable stroke rehabilitation **medical prototype**.

According to the NHS around 100,000 people have a stroke each year in England, Scotland, and Wales. This is approximately one stroke every five minutes. A stroke occurs when the flow of blood to the brain is interrupted or blocked, which leads to death of brain cells. This neurological damage affects movement. There are 1.3 million stroke survivors in the UK, many of whom require physiotherapy to regain movement and restore their quality of life.



- The human nervous system has the amazing ability to continuously recover, rewire and repair itself each day. Today, physiotherapy sessions are limited in terms of frequency and duration. Care models that provide round-the-clock physiotherapy are simply not feasible, yet.
- KnitRegen aims to revolutionise the care model by empowering patients with smart textile garments that enable continual rehabilitation. KnitRegen's UK-patented smart textile technology, delivers state-of-the-art muscle stimulation using novel 'beads' in smart textile components that can be aesthetically stitched into everyday garments or other wearables. The smart 'bead' system delivers timed impulses to selectively activate or suppress muscle activity.
- This controlled continuous stimulation helps to re-train and rewire the brain, enabling patients with moderate-to-severe impairments to regain their movement.
- CPI worked with KnitRegen to develop a wearable stroke rehabilitation prototype. Importantly, to make the technology portable we reduced its bulk from the size of a backpack to a wristband and integrated a rechargeable Bluetooth-enabled battery. We also made it safer and more energy efficient by reducing the power required to stimulate muscles.
- This advanced KnitRegen's stroke rehabilitation technology to make it portable, wearable, safe, and efficient. The prototype also now combines mechanical stimuli with an audible cue. It also gathers data wirelessly on the rehabilitation, relaying information to the healthcare providers and patient via a Bluetooth enabled companion APP.
- Now in the form of a wristband, the technology can be evaluated as a medical device for people with and without mobility following a stroke. After future clinical trials, the technology could become a valuable addition to the treatment options available to those with neurological disabilities. Stroke survivors could wear the KnitRegen wristband throughout the day to enhance and reduce muscle activity for continual rehabilitation.
- KnitRegen's technology will address the health inequities that currently exist for those who have moderate-to-severe impairments following a stroke, enabling them to access rehabilitation and recover lost movement. This has the potential to be life-changing, with positive outcomes for the physical, social, and economic well-being of those affected by strokes.
- KnitRegen's smart textile technology could also be used within **smart wellness wearables** for use by consumers to support muscle training in sports and wellbeing activities.



The Future of healthcare will be characterised by a patient-centric approach, prioritising prevention to lower demand, costs, and enhance patient outcomes.

## The Future Personalised and Patient-Centred Healthcare System

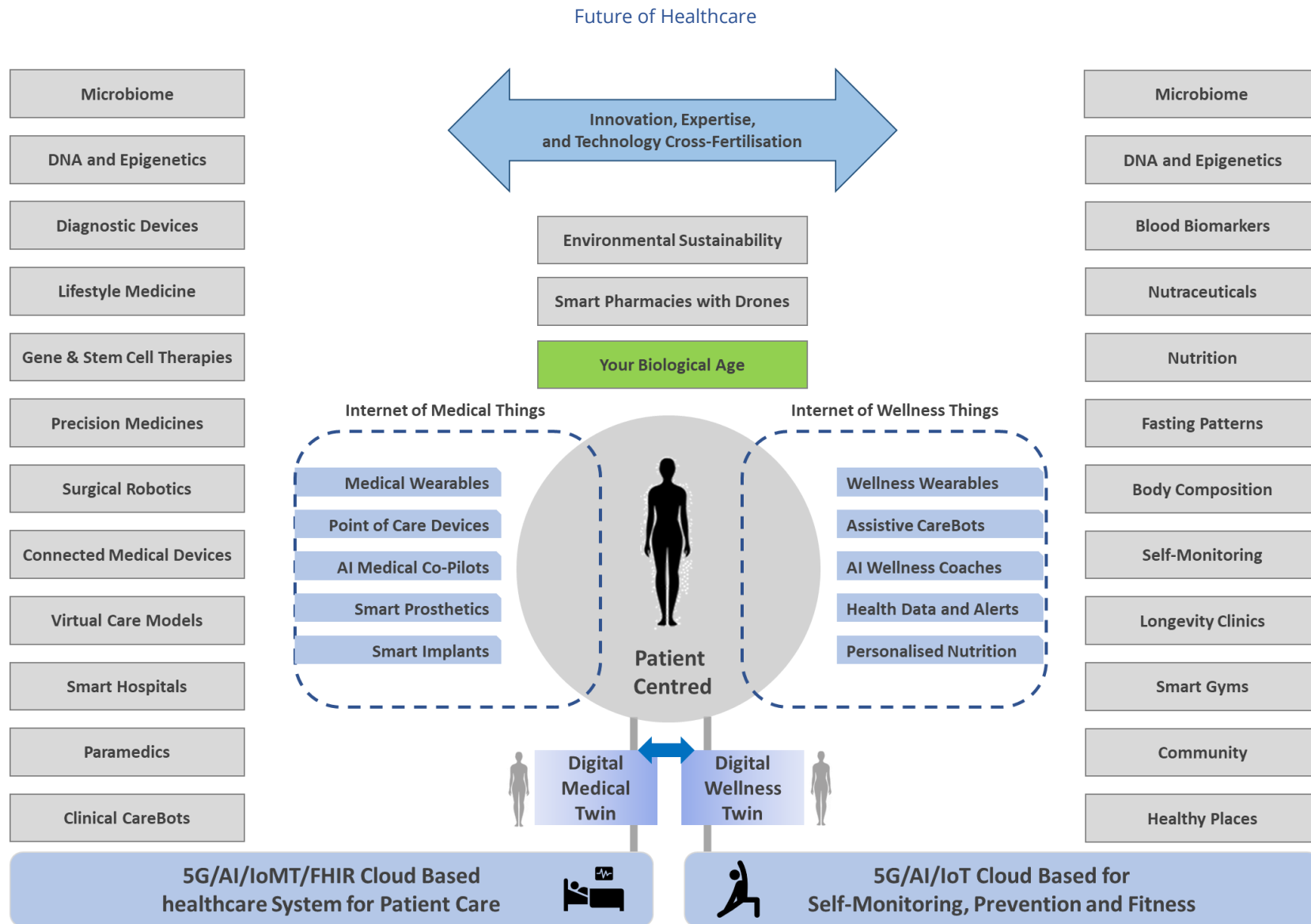
Healthcare is at a pivotal point and poised for transformation that will impact all stakeholders. In the future, healthcare will revolve around sustaining wellness rather than just responding to episodic events and symptom management. It will be highly patient-centred, with an increased use of **personalised care plans for patients** (which focus on prevention and cure), and it will be underpinned by advances in life sciences, materials, and digitalisation.

The forthcoming two decades will be distinguished by a transformation driven by technologies evolving at an exponential rate. Some of these technologies have been discussed earlier in this paper. Before assembling a landscape of what the future of healthcare will look like, it is important to understand the nature and key characteristics of **exponential technologies**:

- **Exponential Growth:** Exponential technologies exhibit an exponential growth trajectory, meaning that their progress follows an accelerating pace. This leads to advancements, which may seem linear at first but with time rapidly surpass linear expectations.
- **Convergence:** Exponential technologies tend to converge with one another, creating synergistic effects. For example, the integration of 3D-bioprinting, lab-on-a-chip, biotechnology, artificial intelligence, and robotics can lead to breakthroughs for healthcare.
- **Disruption:** Exponential technologies have the potential to disrupt established industries and business models, leading to significant transformations. They can render existing technologies, products, or care services obsolete, while simultaneously creating new ones.
- **Democratisation:** Exponential technologies often have a democratising effect, making advanced capabilities and tools accessible to a broader population, including new entrants. As costs decrease and accessibility increases, more people and firms can leverage these technologies to drive innovation and address unmet latent needs.
- **Accelerating Impact:** Exponential technologies have an accelerating impact, meaning that their influence and benefits multiply as their development progresses. As breakthroughs build upon one another and technologies become increasingly interconnected, their collective impact expands exponentially.
- **Ethical Considerations:** Exponential technologies introduce new ethical, social, and legal considerations. The rapid pace of advancement may outpace the ability of regulatory frameworks to keep up, leading to potential ethical dilemmas, concerns about privacy and security, and the need for responsible governance.

The resulting pace of innovation can surprise and exceed the expectations of many traditional incumbents, causing significant disruption in their business models. To thrive in this changing landscape, incumbents must either lead the transformation or risk being replaced by more innovative entrants who prioritise addressing long-standing unmet needs and creating new opportunities for healthcare professionals and patients. However, existing incumbent may lack the disruptive mindset and expertise needed to reshape their business models.

The future healthcare system is depicted below in **Exhibit A**. It depicts a future system that is highly patient-centred and digitally enabled, with a focus on integrated prevention and curative treatments.



**Exhibit A: Landscape for the Future of Healthcare – it will require the mass production of personalised medicines and devices.**

## 11 Key features of the landscape:

### 1) Shift to Healthier Places, Cities, Cultural Norms, and Food System

An analysis of what works globally reveals that lifestyle choices may matter more than expenditure spent or level of technological advancement when it comes to population health and patient outcomes.

The United States, with its substantial healthcare expenditure (\$4.2 trillion in 2021<sup>12</sup>) and cutting-edge healthcare technology, falls behind in performance by international standards. The US ranks 30<sup>th</sup> in terms of its care system and 69<sup>th</sup> in the health of its population, according to the 2023 [Healthcare Ratings](#) by the World Health Organization (WHO).

These rankings demonstrate that merely having a technologically advanced healthcare system does not guarantee optimal patient outcomes or population health. It brings home the crucial connection between health, lifestyle, and their environment, including the role of communities, cities, the food system, and surroundings in supporting individuals' well-being and facilitating faster recovery from illnesses. Deep down, we all recognise that lifestyle and the environment matter.

The study, commissioned by National Geographic, identified regions of the world with the highest concentrations of centenarians. Over the course of a decade, the research team discovered common lifestyle factors that contributed to the exceptional health and longevity observed in

five regions. The following nine key characteristics, known as the "9 Powers," played a significant role in the well-being and vitality of the Blue Zones<sup>13</sup> residents:

- Making movement part of your day.
- Knowing your sense of purpose.
- Prioritising stress relief.
- Eating until you are about 80% full.
- Largely a whole foods plant-based diet.
- Drinking alcohol in moderation.
- Connecting with your community.
- Putting loved ones first.
- Supportive social circles

Whilst the "9 Powers" identified in the study offer few surprises, the challenges of modern living make them difficult to adopt. In the UK, ultra-processed foods account for 57% of total energy intake for adults, 75% for children and 82% for teenagers<sup>14</sup>. Higher consumption of these foods is associated with greater risk of developing chronic conditions and mental disorders.<sup>15</sup> In the Blue Zones, the surroundings, culture, and food system naturally enables healthy living.

Recognising the significance of these findings, the author and investigator Dan Buettner, from the National Geographic, helped to establish the Blue Zone Project. Working with regional government authorities, companies, and communities the project is an ongoing initiative that creates built environments that enable healthy choices and habits.

In the future, similar initiatives will be emerging across the UK embedded in regional development strategies, which will also drive inclusive economic growth.

<sup>12</sup> American Medical Association, Trends in health care spending, March 2023

<sup>13</sup> Blue Zones, Lessons from the World's Longest Lived, NIH, American Journal of Lifestyle Medicine, 2016 September

<sup>14</sup> British Medical Journal, Ultra-processed foods, and excessive free sugar intake in the UK: a nationally representative cross-sectional study, 2019

<sup>15</sup> Ultra-processed people: Why Do We All Eat Stuff That Isn't Food and Why Can't We Stop? Book by Chris van Tulleken, 2023

## **2) Cross-Fertilisation will drive Convergence of the Healthcare and Wellness Sectors, Accelerated by Digitalisation**

The growth of digital health tools — including the Internet of Medical Things, Internet of Wellness Things, smart devices, and interactive digital platforms — will drive the convergence of the healthcare and high-end wellness sectors. This convergence will present huge opportunities for innovation and disruption among industrial stakeholders who are providing solutions to healthcare providers.

Real-time data gathered from wearables (such as smart watches, bands, rings, and vests) combined with biological data — obtained from blood biomarker tests, biological age tests, DNA profiles, MRI scans, breath analysis, urine tests, body composition and microbiome analysis — will be augmented with generative artificial intelligence to establish digital coaches and co-pilots. This will help empower individuals with the information they need to adjust their lifestyle habits and be able to pre-empt, delay or avoid the onset of chronic diseases.

Today, and increasingly in the future, new entrants and companies operating in the wellness sector are configuring these technologies by combining them with science-based lifestyle protocols and AI-enabled digital APPs and platforms to offer consumer wellness services. Healthcare providers will adopt robust “medical grade” digital healthcare tools and platforms that incorporate medical records and deeper clinical functionality. These new tools will include features that support lifestyle interventions and functionality for remote care and virtual wards. They will integrate

medical devices such as smart prosthetics, orthotics, and implants.

As the NHS and the government improve services and reduce costs, cross-fertilisation will accelerate. General Practitioners (GPs) will also adopt platforms for preventing disease onset to reduce the demand for complex treatments and improve the quality of life of their patients.

This collation and aggregation of data will ultimately give rise to the greater use of personalised Digital Twins for better health and wellness. In medicine, a Digital Twin refers to a computational model that can be continuously updated and used to create simulations to inform clinical decision making. With the application of artificial intelligence, the data held within Digital Twin will give rise to Medical Co-pilots for assisting healthcare professionals, patients, and caregivers.

## **3) Use of Biological Age for Assessing Health Status and Recovery from illness**

Biological age refers to the physiological condition and overall health of an individual; it considers various factors such as cellular and molecular changes, genetic factors, lifestyle choices and environmental influences. Unlike chronological age, which measures the number of times a person has been around the sun, biological age provides useful insights into an individual's health status and potential disease risks. It can also be reversed with the right lifestyle interventions.

A person may have a chronological age of say 40 yet have a youthful biological age of 25 or if they are in poor health a much higher biological age such as 65.

**Table A: 12 Hallmarks of Ageing**

Twelve Hallmarks of Ageing		Short Description
1	Genomic instability	Accumulation of DNA damage over time
2	Telomere attrition	Shortening of telomere lengths
3	Epigenetic alterations	Changes in the way DNA is packaged and expressed
4	Loss of proteostasis	Protein misfolding and aggregation
5	Disabled macroautophagy	Impaired cellular recycling and waste accumulation
6	Deregulated nutrient-sensing	Impaired regulation of nutrient intake metabolism
7	Mitochondrial dysfunction	Decline in the function of mitochondria
8	Cellular senescence	Accumulation of dead “Zombie” cells
9	Stem cell exhaustion	Depleted stem cells, required for rebuilding tissues
10	Weak intercellular communication	Breakdown of communication between cells
11	Chronic inflammation	Low-grade, long-term inflammatory states
12	Dysbiosis	Poor quality and poor diversity of gut microbiota

A standardised method still needs to be determined and established for clinical use. Measuring biological age can be done through various methods that assess different aspects of an individual's physiology.

One common approach is based on the analysis of biomarkers associated directly or indirectly with the 12 Hallmarks of Ageing<sup>16</sup> as shown in the table below. These are also essentially the hallmarks of chronic diseases. Furthermore, an individual's biological age is a mosaic: it varies from tissue to tissue within the body.

These hallmarks are not mutually exclusive, and they often interact with each other to promote aging and disease formation. For example, genomic instability can lead to telomere attrition, which can then lead to epigenetic alterations. These changes can then contribute to the development of cellular senescence, which can further promote inflammation and tissue damage.

These Hallmarks of Ageing are also closely associated with the onset and progression of chronic diseases. They are significantly influenced by environmental exposure and everyday lifestyle choices and habits.

Biomarkers for some of these can be measured using advanced laboratory techniques and compared to reference values to estimate an individual's biological age. Additionally, health-related behaviours and lifestyle factors — including physical activity, diet, stress levels, sleep quality and smoking habits — can also contribute to assessing biological age.

Another measure used is VO<sub>2</sub> max, which is the amount of oxygen the body uses during intense exercise, as studies have shown higher levels of VO<sub>2</sub> max are associated with a reduced risk of mortality, greater longevity, and improved overall health outcomes.

[GlycanAge](#), an innovative startup based in Newcastle-Upon-Tyne, UK, has introduced a

<sup>16</sup> Hallmarks of aging: An expanding universe, *Cell*, ScienceDirect, 2023, Carlos López-Otín *et al*

wellness service specifically designed for health-conscious individuals seeking to assess their biological age and understand how lifestyle and/or modifications effect their health status. This assessment is conducted by analysing the state of the immune system and inflammation through a blood test.

GlycanAge focuses on analysing the glycans attached to Immunoglobulin G (IgG), the most common antibody found in the blood. Glycans play a crucial role in maintaining overall health and are closely linked to various chronic diseases. As we age, the balance of pro-inflammatory and anti-inflammatory glycans in our body changes. By evaluating the glycans present in the blood, GlycanAge provides insights into an individual's overall well-being and potential health risks. The company believes this approach enables individuals to gain a deeper understanding of their health and make informed decisions to support their long-term wellness goals.

In healthcare, biological age has the potential to transform how we approach preventive medicine and personalised healthcare. By considering an individual's biological age, healthcare providers can gain a deeper understanding of their overall health and disease risk. This knowledge allows for targeted interventions, early detection of potential health issues, and the development of personalised treatment plans. Using biological age in healthcare can also help identify individuals who may be at higher risk for age-related diseases, such as cardiovascular diseases, cancer, and neurodegenerative disorders.

Biological age assessments can also be used to monitor the effectiveness of interventions and treatments. By tracking changes in an individual's biological age over time,

healthcare providers can assess the impact of lifestyle modifications, medications, or therapies on their overall health and aging process. This information can guide adjustments to treatment plans and provide valuable feedback on the effectiveness of interventions.

Nutra, an innovative US-based company, has achieved a remarkable milestone by obtaining a patent from the US Patent and Trademark Office for their revolutionary Fasting Mimicking Diet® (FMD®), which is now available to consumers, branded as [ProLon](#). This patent signifies the first-ever patented protocol designed to optimise human healthspan and **reduce biological age of individuals**. ProLon, a nutritional product backed by scientific evidence, has shown to reduce biomarkers associated with age-related diseases and stimulate tissue regeneration, including immune cell renewal and generation of new stem cells. Developed by Professor Valter Longo, Director of the Longevity Institute at the University of Southern California, FMD has also been investigated for its potential to help patients with complex conditions such as cancer, cardiovascular, neurological, and autoimmune conditions.

In research settings, measuring biological age provides valuable insights into the effects of different factors and interventions on the aging process and recovery from diseases. By assessing biological age, researchers can study the efficacy of novel therapeutics and evaluate the overall health status of patients during clinical trials. While the concept of biological age shows promise.

#### 4) Use of Microbiome Profiling for Healthy Living and Therapeutics

The microbiome is the genetic and cellular material of all the microbes — bacteria, fungi, protozoa, and viruses — that live on and inside the human body. The number of genes in all the microbes in one person's microbiome have 200 times the number of genes in the human genome. Humans, like all animals, are superorganisms.

Each person is comprised of human and microbe cells, which are synergistically interacting. Without the trillions of microbes in our body, we could not function. While there is some debate about the ratio of microbes to human cells in the human body, the ratio is thought to be at least 1:1.

The human body has outsourced many functions to our friendly microbes. The microbiome is increasingly classed as an organ that produces bioactive substances critical to health. Dysbiosis — or an imbalance in the gut microbiome — is known to produce harmful metabolites. Healthy gut microbiome requires a diversity of plant fibre and polyphenols to thrive.

Recent advancements in microbiome research have unveiled the intricate connections between our microbiome and various aspects of human health. This includes digestion, immune function, mental health, and even the development of complex chronic diseases such as autoimmune conditions.

With the advent of advanced technologies, such as metagenomics and artificial intelligence, scientists are now able to delve deeper into the complexities of the microbiome and its interactions with our bodies. Metagenomics allows for the comprehensive analysis of microbial

communities, providing insights into the diversity, composition, and function of the microbiome. Artificial intelligence algorithms can help process vast amounts of microbiome data, identifying new patterns and associations.

This expanding knowledge of the microbiome has the potential to revolutionise healthcare. It opens possibilities for innovative diagnostics and medical therapies. By understanding how specific changes in the microbiome are linked to chronic diseases or conditions, researchers can develop targeted interventions to restore microbial balance and improve health outcomes. For instance, faecal microbiota transplantation (FMT) has emerged as a promising treatment for certain gastrointestinal disorders by transferring healthy microbiota from a donor to a recipient. The first FMT pill was approved in 2023 in the US by regulators for treatment of bacterial infection *Clostridioides difficile*, a common and deadly infections found in healthcare settings.

Whilst microbiome opens the door to new therapeutic interventions for complex conditions. It also opens the door to healthy living and prevention. Studies have demonstrated that a diet rich in a diversity of plant fibres, polyphenols, and fermented foods promotes a flourishing microbiome. These dietary components serve as prebiotics and probiotics, providing nourishment for beneficial gut bacteria.

On the other hand, a diet high in ultra-processed foods, refined sugars, certain food additives, and unhealthy fats can negatively impact the microbiome, contributing to imbalances and associated health problems.

The growing awareness of the connection between the gut microbiome and health will not only impact the wellness and healthcare sectors, but it will also directly affect the future of the food and drink sector.

Increasingly, people will be adopting services delivered through AI-based apps that will inform and help consumers understand the composition of their gut flora and lead them to make healthier food choices.

Innovative early-stage firms, such as UK-based [ZOE](#), are already offering individuals a personalised nutrition service based on data from continuous blood glucose devices, regular blood lipid tests and periodic microbiome analysis. ZOE uses the data to make personalised food suggestions to customers to improve the diversity and quality of their gut microbiome. Such services empower individuals to make informed choices, helping them to improve their health and reduce their risk of chronic diseases.

As consumers increasingly have access to information about what foods positively affect their health, we should expect a shift in what is being offered by the future food industry to meet these demands. One can imagine a future scenario where similar app-based services integrate their services with online food shopping and delivery.

Furthermore, the gut-brain axis, which refers to the bidirectional communication between the gut and the brain, highlights the influence of the microbiome on mental health. The gut microbiome influences various neurotransmitters and metabolites that can affect brain function and mood. This connection has led to the exploration of specific probiotics or prebiotics that target mental health conditions.

As our understanding of the microbiome continues to grow, it becomes increasingly clear that it holds the key to unlocking a new era of personalised medicine and proactive health management.

### **5) Shift Towards Preventive Lifestyle Medicine and More Curative Treatments and Care Plans**

Historically, healthcare systems intervene once disease has taken hold. Furthermore, chronic diseases have been treated by healthcare providers with a symptom management approach, rather than as something to prevent, reverse and cure. This has meant that chronic diseases and their causes have only been tackled once they have progressed to more complex multimorbidity conditions, leaving patients on multiple medications for life to mitigate symptoms.

The shift will occur on two fronts, towards prevention and a more personalised, curative approach.

#### **a. The preventative approach – connecting functional medicine, lifestyle, and digital healthcare.**

Healthcare will move upstream to prevent disease onset. It is important to appreciate that lifestyle interventions are low-cost, therapeutic interventions that result in changes at the cellular, epigenetic, and biochemical level. Ultimately, these interventions have been shown to reverse biological aging.

Historically, lifestyle interventions have been difficult to implement as healthcare providers could at most only provide education and information to patients. Furthermore, lifestyle medicine has not formed a significant part of the medical training doctors undergo in medical schools.

The combination of functional medicine and advanced digitalisation will enable healthcare providers to increasingly adopt science-based lifestyle programmes.

Functional medicine is an approach to healthcare that focuses on understanding and addressing the root causes of illness and disease, rather than just treating symptoms. It is a patient-centred, science-based, and integrative approach that considers the individual's unique genetic, biochemical, and lifestyle factors.

Advanced digitalisation will provide healthcare providers, patients and caregivers with smart connected devices, collaborative digital platforms, and tools that automatically analyse data.

This will enable not just monitoring but also coaching using Generative AI through the development of AI Medical Co-pilots.

These advances will occur through the cross-fertilisation of lifestyle approaches and digital platforms, which are already emerging in the high-end wellness sector by new entrants.

One example is US-based [InsideTracker](#), an early-stage company offers healthy people various wellness services, including regular screening of 43 blood biomarkers, DNA profiling, body composition testing, biological age analysis, and real-time monitoring using commercially available smart watches, rings, and bands. The system provides personalised lifestyle recommendations to individual users via its digital platform. The system is evolving towards becoming an AI-powered Wellness Co-Pilot for its customers.

When such technologies become economically more affordable, it will become more widely used and adopted by people. Clearly, they will challenge and even

make today's basic health check provided by doctors obsolete!

One can visualise a future where a similar clinically tested system is used by General Practitioners and healthcare professionals to monitor and care for their patients.

The progression of innovation filtering into the mainstream and changing the future of healthcare is illustrated by the past, present, and future patient outcome scenarios for diabetes type 2 explored in Exhibit D. Wellness platforms will aid in disease prevention, reduce the need for expensive medical interventions, and remove the associated need for a lifetime supply of medications and/or the need for amputations and other surgical interventions.

A similar system to InsideTracker could be established and deployed in clinical settings for remote healthcare services, improving the quality of services provided to patients and reducing the demand for complex medical interventions.

**b. The curative approach – using personalised medicines and targeted therapeutics.**

Secondly, future treatments and therapeutics will be targeted and personalised and designed to be “curative” with fewer or no side effects. A curative approach will not only prevent disease progression and complications, but it will reduce ongoing demand for healthcare services. Medical interventions such as gene therapies, epigenetic therapy, stem cell treatments and microbiome treatments hold the potential to be more curative for some conditions. This can be seen in Exhibit C, which looks at past, present, and future patient outcome scenarios for diabetes type 1. Both stem cell therapy and gene therapy

hold promise in the pursuit of a cure for type 1 diabetes, a condition characterised by the destruction of insulin-producing cells in the pancreas. Stem cell therapy aims to replace or regenerate the damaged cells by using stem cells capable of differentiating into insulin-producing beta cells, while gene therapy seeks to address the underlying genetic factors by introducing genes responsible for Insulin production into target cells. The combined efforts of these innovative approaches provide hope for a future where individuals with type 1 diabetes can regain normal insulin production and achieve lasting disease remission.

Artificial intelligence (AI) has the potential to accelerate the development of stem cell therapy and gene therapy for type 1 diabetes by optimising stem cell differentiation protocols, enhancing gene delivery techniques, and analysing complex data to identify patterns and predict treatment outcomes. By leveraging the power of AI, researchers can accelerate the innovation process, improve treatment effectiveness, and ultimately bring the health care sector closer to finding a cure for type 1 diabetes.

**6) Deep Digitalisation and Robotics will Reduce Unwarranted Clinical Variation and Enable Outcome-Based Care Models**

The lack of data collection and the ability to measure outcomes has historically been a barrier for the deployment of outcome-based healthcare models. Deep digitalisation augmented with artificial intelligence is set to change this. Key medical systems, smart diagnostic devices, wearables, implants, and assistive robots will all be fully integrated around the

creation, execution, and monitoring of a patient's medical intervention and recovery plan.

For example, surgeons will increasingly use augmented reality devices and displays while being assisted by surgical robots, helping to prevent unwarranted clinical variation. The whole surgical procedure and the data generated will be captured and linked to the patient's Medical Digital Twin (aka real-time medical records), with real-time recovery and medication compliance remotely monitored, as needed.

Digital healthcare platforms will be able to interface with the healthcare provider's supply chain management system to place orders for repeat prescriptions at the right time and inform healthcare providers of any potential non-compliance issues or difficulties the patient may have encountered. A complete picture of the diagnosis, intervention and recovery will be built and maintained, enabling assessment of the outcome, and hence opening the door to outcome-based healthcare models.

How outcome-based care models are realised in each nation will be very much dependent upon how healthcare is structured and financed in the country. In the UK, healthcare costs are free at the point of need and largely covered by government. The key emphasis would be aligning the cost of treatment with patient outcomes, or at least sharing the risk with the solution providers. Ultimately this would alter the purchasing relationship between healthcare providers and manufacturers of medications and medical devices.

This means manufacturers may need to shift their business models to become far more service-oriented and outcome-based. Performance of medications could be

monitored at an individual patient level and at a larger cohort- or even population-level to help assess its effectiveness and use.

**7) Wellness and Medical Co-Pilots will Aid and Coach Individuals for Healthy Living and Through Medical Recoveries**

In the rapidly advancing era of deep digitalisation, a transformative development is poised to unfold: the emergence of Wellness and Medical Co-Pilots. These intelligent systems will be driven by artificial intelligence, leveraging the wealth of data encapsulated within an individual's Medical Digital Twin or Wellness Digital Twin. The synergy achieved by amalgamating this personal data with insights derived from peer-reviewed scientific research papers is set to redefine healthcare and well-being paradigms.

The concept of a Medical Digital Twin involves a comprehensive and dynamic digital representation of an individual's medical history, genetic makeup, lifestyle choices, and ongoing health parameters. Similarly, a Wellness Digital Twin encapsulates a person's holistic well-being, considering factors such as physical activity, nutrition, mental health, and other lifestyle elements.

By harnessing the power of artificial intelligence, these Co-Pilots will not only navigate through the intricate details of an individual's health data but also interpret and contextualise it with the latest findings from scientific research publications. This fusion of personalised data and scientific knowledge will enable these Co-Pilots to offer highly tailored and proactive insights into both medical conditions and overall wellness.

In essence, the integration of AI-driven Co-Pilots with Digital Twins will empower individuals to take a more active role in managing their health. It promises a future where preventive measures, early interventions, and personalised treatment plans are seamlessly woven into the fabric of healthcare, ultimately contributing to a more effective and patient-centric approach to well-being.

**8) Assistive Carebots, Exoskeletons and Advanced Prosthetics will help Address Social Inclusion and Social Care**

The integration of robotics and digitalisation into healthcare is leading to the development of three remarkable innovations: assistive carebots, smart advanced prosthetics and smart exoskeletons. These advancements hold significant promise in transforming patient care, rehabilitation, and social care, and enable wider social inclusion for people with different conditions and abilities in society and workplaces.

**Carebots:** With an aging population and the increasing demand for personalised care, carebots are emerging as a groundbreaking solution. In the future, these robotic companions will be designed to aid and support to individuals who require aid in their daily lives. The hope is that by helping with activities and routine tasks (like dressing, communicating with others, and participate in workplaces) and offering emotional companionship, carebots can enhance the quality of life for some segments of society who currently are underserved, such as the elderly and those with disabilities. By assisting with essential activities, carebots may not only reduce the burden on caregivers but also enable individuals to maintain their independence

and dignity. Combined with Generative AI, future carebots could become co-pilots and coaches that help individuals through their recovery and with compliance to care plans and day-to-day activities.

**Exoskeletons:** The concept of exoskeletons bridges the gap between human potential and technology. These wearable devices will amplify human strength and mobility, benefiting medical, social, and industrial applications. In healthcare, exoskeletons will aid the rehabilitation of individuals with mobility impairments, enabling them to regain lost functionalities and independence. Meanwhile, exoskeletons will also find utility in industries by minimising physical strain, reducing workplace injuries, and enhancing overall productivity. The fusion of human effort with mechanical augmentation illustrates the power of exoskeletons in redefining human limitations and empowering individuals to achieve personally difficult feats.

**Advanced Prosthetics:** Adding a new dimension to the Future of Healthcare landscape, advanced smart prosthetics is merging cutting-edge engineering with human anatomy. These sophisticated replacements for lost limbs bring forth enhanced mobility and a help restoration of functional abilities. As technology continues to evolve, advanced prosthetics offer a tangible pathway to a more fulfilling and inclusive life for amputees, enabling them to actively participate in society and engage in a wide range of activities with confidence.

The advent of assistive carebots, exoskeletons and prosthetics underscores a new transformative role of emerging technologies in healthcare. These innovations not only cater to immediate needs but also signify the potential to reshape entire paradigms of patient care,

social care and self-sufficiency. The convergence of human ingenuity and robotic capabilities is already beginning to usher in an era where technology enhances the human experience, If the benefits of these capabilities can be harnessed to support those who need it most, these emerging technologies have the potential to foster a more inclusive society.

### 9) Adoption of Sustainable Healthcare Practices and Infrastructure

In the future of healthcare, sustainability will be paramount, with a focus on addressing climate change as an important tenet of holistic well-being. The healthcare system will recognise that climate change poses significant threats to national and global health, influencing disease patterns and necessitating proactive measures. As a result, the future healthcare systems will place a strong emphasis on reducing carbon emissions of their operations and their supply chains for both medicines and medical devices. They will establish eco-friendly medical infrastructure, electric ambulances, and incorporating sustainable practices to mitigate the health risks associated with a changing climate. They will adopt preventative healthcare approaches to help reduce the overall demand for services and hence their environmental footprint.

Moreover, the future healthcare system will prioritise the use of sustainable materials, recognising the impact of responsible sourcing on both individual health and the environment. Medical equipment, packaging, and other healthcare products are crafted from eco-friendly materials to minimise the environmental footprint. Embracing the principles of a circular economy is integral to this vision, where the

healthcare sector actively engages in recycling, reuse, and waste reduction initiatives. By aligning with sustainability, the future healthcare system not only ensures the well-being of individuals but also contributes to the longevity of our planet.

### **10) Population Healthcare Management and Health Data**

As shown in Exhibit B, the use of Medical Digital Twins across a population unlocks a multitude of applications, possibilities, and insights. This vast pool of information (or Big Data) can be mined, analysed, and harnessed by various stakeholders. For instance, government agencies can utilise this data to assess the overall health status of the population and evaluate the impact of rolling out different health campaigns and initiatives to improve the nation's wellbeing. By analysing patterns and trends within the data, policymakers can identify areas of focus and make informed decisions to allocate resources effectively.

Medical researchers can delve into this wealth of data to gain deeper insights into treatments and their effectiveness. By examining the outcomes of various interventions across diverse patient populations, researchers can identify patterns, correlations and factors that contribute to successful outcomes. This knowledge can guide the development of new therapies, the refinement of existing treatments, and the advancement of precision medicine. Moreover, Big Data can fuel innovations in delivery of healthcare services. For example, healthcare organisations can leverage this data to develop predictive models and decision support systems that aid in early disease detection, risk assessment, and personalised treatment planning.

The potential of Big Data in healthcare is vast and ever-expanding. By harnessing the power of data analytics, machine learning and artificial intelligence, stakeholders can unlock valuable insights, drive evidence-based decision-making and identify unexpected demographic, geographic, genetic, and lifestyle-based health trends.

### **11) Stronger Cybersecurity, Privacy, and Trust Frameworks**

Within healthcare and wellness, cybersecurity, privacy, and trust have a symbiotic relationship of paramount importance. The accidental release of health data would have huge implications within insurance, finance, and employment, or it might expose previously hidden connections and relationship secrets.

By embracing robust cybersecurity, transparency, accountability, and responsible data handling practices, healthcare providers can foster a culture of trust and bolster patient confidence in the healthcare system's ability to protect their sensitive information. When patients and consumers trust that their data will remain secure and their privacy will be respected, they are more likely to share information and actively engage in their treatment or services respectively.

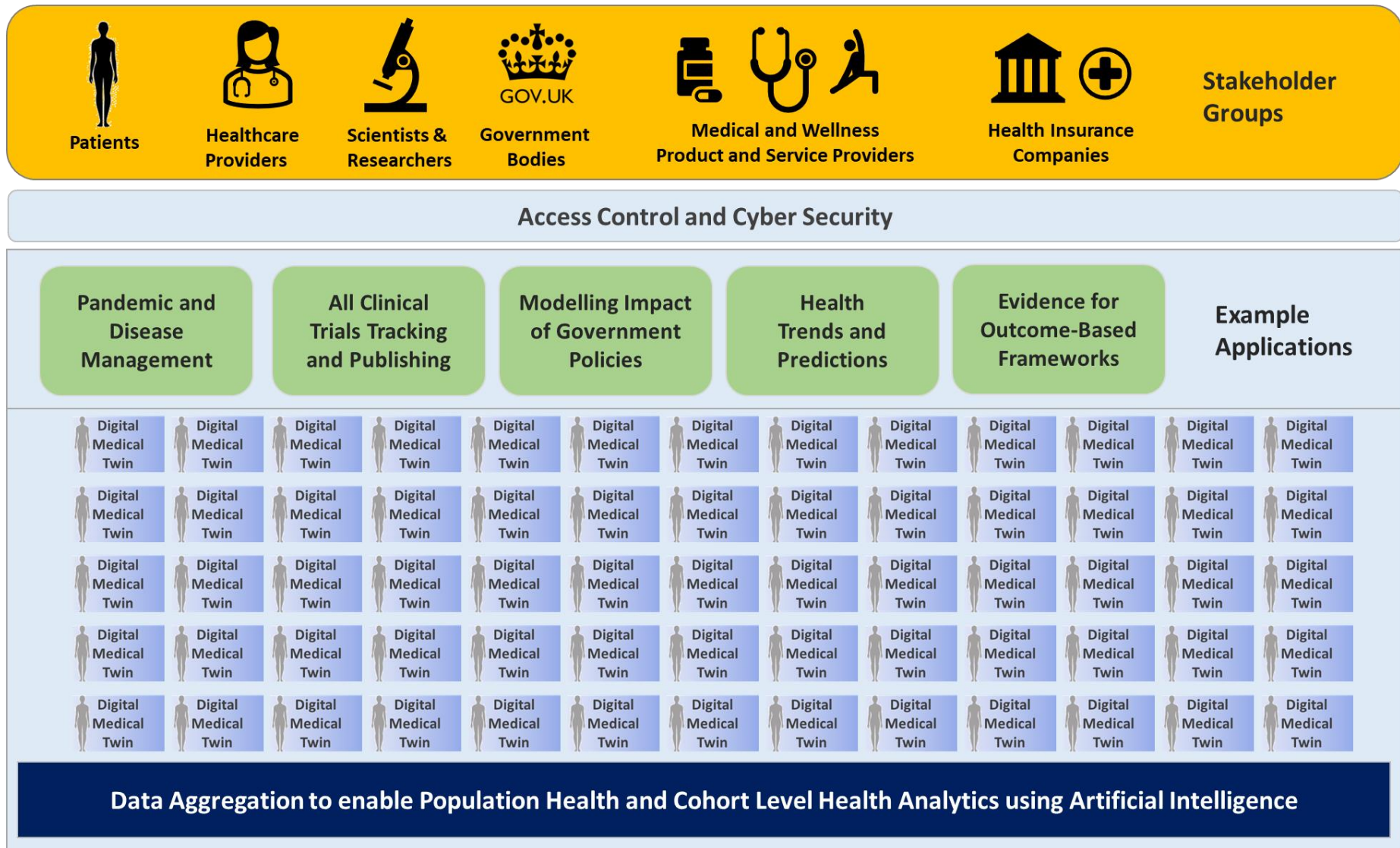
Privacy is an inherent right within the healthcare and wellness sectors. Upholding stringent privacy regulations and adhering to ethical standards while handling sensitive information are fundamental. Employing strong access controls, limiting data sharing to authorised personnel, and obtaining informed consent for data collection and usage are pivotal in safeguarding patient privacy.

Six key barriers that will need to be addressed to fully harness digitalisation of healthcare are:

- Safeguarding against the threat of bad actors looking to break into systems to access data or to take control of important medical devices, and facilities.
- Ensuring consent is obtained from individuals before their data is shared and used by others, and understanding who owns patient data.
- Understanding embedded bias intentional or not in AI Models.
- Foreseeing the implications of what genetic information will reveal about family, relationships, and inheritance.
- Preparing for how health data may impact an individual's future finances, insurance, pensions, and careers.
- Adapting future AI modelling to address the learnings from current neural-network-based AI models, which operate as "black boxes" and can generate uncertain results for certain applications in clinical settings.

These barriers, which can also be found in other sectors adopting digitalisation, will require not only solutions, but also close regulation and even oversight by an independent third party.





**Exhibit B: Population Health Enabled by Advanced Digitalisation and AI**



**Harnessing the power of data and insights, future healthcare services will empower individuals to take charge of their health, proactively avoid diseases, and foster overall wellbeing.**

## Foreseeing Future Scenarios for Patient Outcomes

Exhibit C and Exhibit D below outline scenarios for type 1 diabetes and type 2 diabetes for fictional characters Lyra and Will, respectively. Type 1 diabetes is primarily caused by an autoimmune response in which the immune system mistakenly attacks and destroys the insulin-producing cells in the pancreas. Type 2 diabetes is a metabolic disorder characterised by insulin resistance caused by various factors, including lifestyle choices. Both scenarios look at the individuals' respective experiences and outcomes as it might have been in the past, present, and future. Some important observations include:

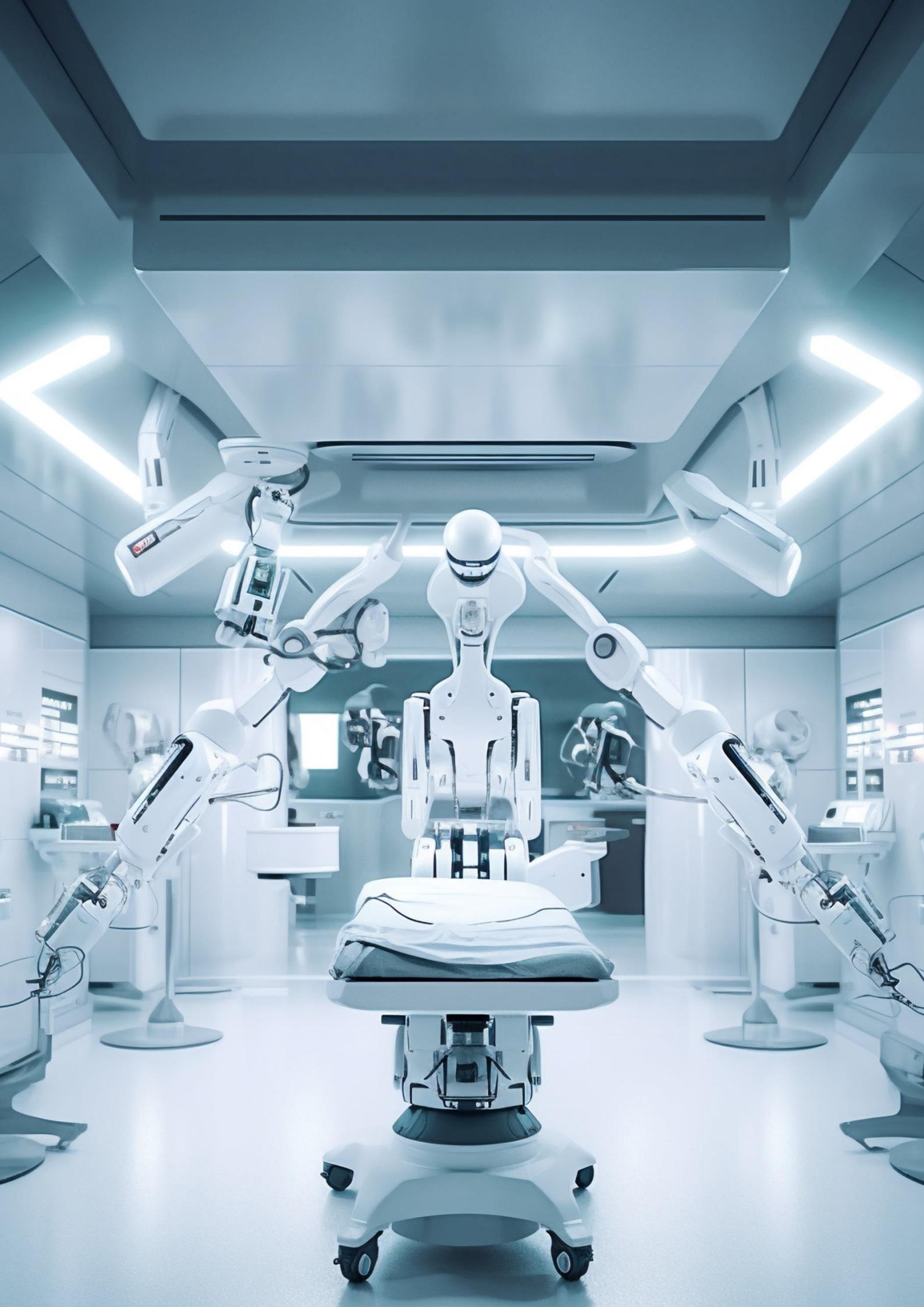
- Historically the prognosis for both conditions, which are generally very progressive, was poor. These conditions would have had adverse impacts on the characters' lifespan, quality of life and participation in work and social activities.
- Overtime, the prognosis for both conditions have significantly improved and will continue to do so, positively impacting healthspan and lifespan. This progress can be attributed to advancements in the life sciences, digitalisations and solutions that empower individuals.
- There is a noticeable shift towards preventive and curative approaches when managing both type 1 diabetes and type 2 diabetes. Whilst the management of both these conditions has improved, individuals still face many difficulties. However, in the future, the emphasis will increasingly be on prevention and finding cures. This will reduce the overall demand for complex medical interventions by addressing the root cause.
- In both scenarios lifestyle interventions are increasingly recognised as vital. In the future, they will be an integral part of the patients' treatment, care, and recovery plans.
- The scenario for type 1 diabetes exemplifies the evolution of personalised, targeted, and curative medicines and therapeutics. In the past, Lyra would have needed to manually inject insulin. However, today she has the advantage of continuous glucose monitoring and an advanced insulin pump, enabling improved insulin timing, quantity, and automated injection. In the future, her condition would be pre-empted, monitored for signs and treated with a curative approach such as gene therapy, eliminating Lyra's reliance on insulin altogether. In such a future, remote monitoring would be required in case her autoimmune condition resurfaces.
- In the case of Will, type 2 diabetes tends to develop today at a much younger age due to the increased consumption of ultra-processed foods. However, in the future, Will benefits from better information and personalised coaching. Using smart wearables and a non-invasive continuous glucose monitor, coupled with his Generative AI Wellness Coach, Will effectively prevents the onset of chronic diseases through lifestyle alone.
- In both scenarios, digitalisation plays a crucial role in transforming devices and treatment, leading to better patient outcomes. However, digitalisation is also accelerating new research and development in the life sciences and enabling groundbreaking innovations such as the use of machine learning in gene therapy.
- The prognosis for both in their respective future scenarios is positive. They both live long, fulfilling social and work lives. Will remains healthy and experiences no chronic disease. Lyra receives Gene Therapy.

## Scenario A: Diabetes Type 1

Exhibit C – Patient with Diabetes Type 1		
In the Past – 1970s	Present Time	In the Future – 2035+
<p>Lyra is on insulin injections for life, her condition is very aggressive, she experiences collapses, uses electrochemical strips, and dies at 60.</p>	<p>Lyra is on insulin injections for life and, whilst better managed with advanced insulin pumps her condition is still difficult and she dies at 76.</p>	<p>Thanks to her Digital Medical Twin, Lyra's risk is pre-empted, she is remotely monitored and undergoes gene therapy. She dies as a centenarian.</p>
<ul style="list-style-type: none"> <li>• Lyra was born a healthy baby. She enjoyed the first 11 years playing with her friends and sister. She was vibrant and full of energy.</li> <li>• Just after her 11<sup>th</sup> birthday party, she started to feel unwell, tired and seemed to lack energy. Lyra started to withdraw and lose weight.</li> <li>• An hour after Sunday lunch, Lyra collapsed, lost consciousness, and was shaking. Panicking, her parents phoned 999. Ten minutes later an ambulance arrived and rushed Lyra to A&amp;E.</li> <li>• Lyra was kept in the Intensive Care Unit for two weeks as she stabilised.</li> <li>• Lyra was diagnosed with diabetes type 1. Her parents were told there was no cure. Lyra's father recalled his grandmother and uncle having diabetes type 1.</li> <li>• From childhood to adulthood, with the help of her parents, Lyra learnt how to inject herself with insulin based on the foods she ate and glucose testing using electrochemical strips. It did not ease. She put a brave face on to the world and made the most of what life had to offer.</li> <li>• Lyra visited her doctor often to have her blood tested. Several times she was rushed to A&amp;E after a collapse.</li> <li>• Lyra grew obese from the insulin injection.</li> <li>• Lyra died young at the age of 60</li> </ul>	<ul style="list-style-type: none"> <li>• Lyra was born a healthy baby. She enjoyed the first 11 years playing with her friends and sister. She was vibrant and full of energy.</li> <li>• Just after her 11<sup>th</sup> birthday party, she started to feel unwell, tired and seemed to lack energy. Lyra started to withdraw and lose weight.</li> <li>• An hour after Sunday lunch, Lyra collapsed, lost consciousness, and was shaking. Panicking, her parents phoned 999. Ten minutes later an ambulance arrived and rushed Lyra to A&amp;E</li> <li>• Lyra was kept in the Intensive Care Unit for two weeks as she stabilised.</li> <li>• Lyra was diagnosed with diabetes type 1. Her parents were told there was no cure. Lyra's father recalled his grandmother and uncle having diabetes type 1.</li> <li>• Lyra quickly learnt to manage her condition with the help of her parents by measuring her blood glucose using continuous monitoring, capturing the reading and injecting insulin. She was provided with an insulin pump to help her more accurately control the level of insulin injected.</li> <li>• Lyra visited her GP for regular check-ups.</li> <li>• Lyra stayed okay, eating healthily and keeping in shape.</li> <li>• Lyra died at the age of 76.</li> </ul>	<ul style="list-style-type: none"> <li>• Before Lyra was born, her parents already knew that diabetes type 1 ran in their family, based on information provided to them by their Medical Digital Twins.</li> <li>• Lyra was born a healthy baby. Just as soon as she was born, so was her Medical Digital Twin. Samples of Lyra's stem cells were taken from the placenta and frozen for future use.</li> <li>• At the age of five, the NHS provided Lyra with a wearable device that monitored over 16 different biometrics, continuously, relaying the information to Lyra's Medical Digital Twin.</li> <li>• Before her eleventh birthday, Lyra's doctor and parents received a message from Lyra's Medical Digital Twin indicating that Lyra was very likely developing Diabetes Type 1 and automatically scheduled an appointment for her and her parents.</li> <li>• After diagnosis, Lyra's doctor with the support of a highly advanced AI system developed a medical intervention plan, which included Gene Therapy to correct the genomic changes.</li> <li>• Following Gene Therapy, Lyra's parents were provided with a lifestyle intervention plan for Lyra.</li> <li>• Lyra enjoyed the whole of her childhood and adult life. With the support of her Medical Digital Twin Lyra never developed Diabetes Type 1.</li> <li>• Lyra died peacefully as a centenarian.</li> </ul>

## Scenario B: Diabetes Type 2

Exhibit D – Patient with Diabetes Type 2		
In the Past ~1970s	Present Time	In the Future – 2035+
<p>At 43, Will is on oral medication for life, his condition is very aggressive, he is put on insulin, receives two amputations, and dies at 57</p>	<p>At 30, Will is on oral medication for life, his condition is progressive, and his GP provides a continuous glucose monitor. Will dies at 72.</p>	<p>Thanks to a low-cost AI-powered wellness service, which Will joined at 20, he remains healthy throughout his life and dies as a centenarian.</p>
<ul style="list-style-type: none"> <li>• Will is 43 years old and feeling unwell, thirsty and attends an appointment to see his GP, which took him a week to make.</li> <li>• His GP suspects Will has diabetes and Will is given an appointment for a fasting blood test.</li> <li>• His blood test appointment date arrives by post after a week. It is in two weeks' time.</li> <li>• Will attends the appointment. A nurse takes a sample of his blood.</li> <li>• Will attends a further appointment with his doctor two weeks later and is informed that he may have diabetes type 2.</li> <li>• After a series of consultations and more blood tests, Will is prescribed an oral medication to help control his blood glucose.</li> <li>• Will is given some education and advice on lifestyle. His doctor informs him there is no cure and he must remain on the medication all his life with regular blood tests.</li> <li>• Will finds it hard to manage and control his blood glucose levels, and his conditions worsen along with his eyesight. He is also put on insulin.</li> <li>• 20 Years later he is suffering from multiple conditions and is on multiple medications. Will undergoes his second amputation.</li> <li>• Will dies before he is 57 years old after much suffering, unable to walk and in pain</li> </ul>	<ul style="list-style-type: none"> <li>• Will is 30 years old and enjoys fast food, sweet snacks, crisps, cakes, and takeaways. He is feeling unwell and thirsty and goes into a walk-in clinic after work. The doctor suspects he has diabetes type 2. He is given an HbA1c test at the clinic on the same day. His GP is informed. Will is told that if there any problems his GP will contact him.</li> <li>• Will received a message on his mobile from his GP. He calls, makes an appointment for the next day and learns he may have diabetes type 2.</li> <li>• After dialogue with his doctor and more blood tests, Will is prescribed an oral medication for life to help control his blood glucose and is given some advice on changing his lifestyle, diet, and activity level. He goes in for regular medical checks.</li> <li>• Will finds it hard to manage and control his blood glucose level. When he is out socialising or at a work buffet there are limited or no healthy food options! He finds all the information on the internet on lifestyle and diabetes overwhelming.</li> <li>• Will is provided with a continuous glucose monitor to help him manage his condition.</li> <li>• 20 years later he is suffering multiple conditions and is on multiple medications and has eyesight problems.</li> <li>• Will dies shortly after he turns 72.</li> </ul>	<ul style="list-style-type: none"> <li>• Will is 20 years old. Like many of his friends, Will decides to join a low-cost wellness service via an app on his new smart watch, which already has a built-in non-invasive continuous glucose monitor.</li> <li>• The following day Will receives a package of devices delivered by a drone, including various wearables and body composition devices.</li> <li>• He is given a wellness clinic appointment.</li> <li>• Within a few days over 50 biometric measurements are gathered and stored securely in the Cloud, including his DNA profile and microbiome profile.</li> <li>• A Digital Wellness Twin of Will has been created. The cloud-based system has a built-in AI Coach looking for trends across all the Digital Wellness Twins and has access to medical research papers.</li> <li>• Will's Digital Twin is updated in real-time via his smart wearables, and periodically via other home devices he owns and via blood tests.</li> <li>• Will turns 30 years old and receives a prompt from his AI Coach, advising him that he is at risk of developing diabetes type 2 later in life (within 10 years-time) and provides him with a personalised lifestyle intervention plan for his nutrition, eating patterns, fasting and activity level.</li> <li>• Will follows the intervention plan with the help of his AI Coach and enjoys a healthy active life.</li> <li>• Will dies as a centenarian.</li> </ul>







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