FUTURE OF

Healthcare Ecosystems

ARUP

Healthcare Ecosystems

Preventive

The scope of healthcare services looks likely to shift to a more preventive model that accounts for the wider determinants of health. This change is driven by a rise in chronic illness, environmental risk factors, personalised approaches to life-long health and economic pressures. New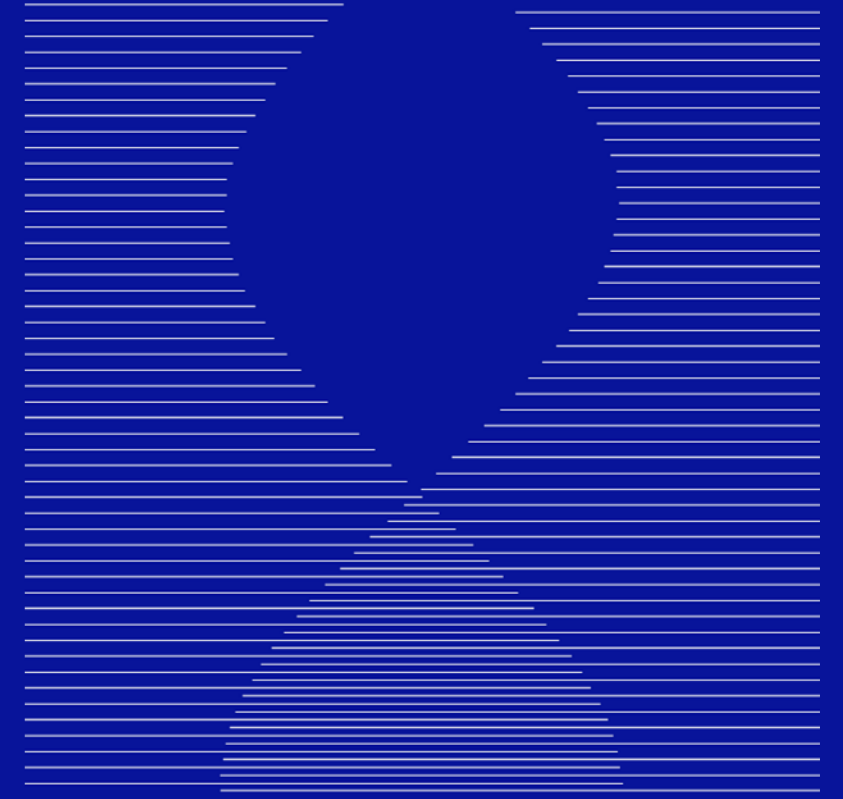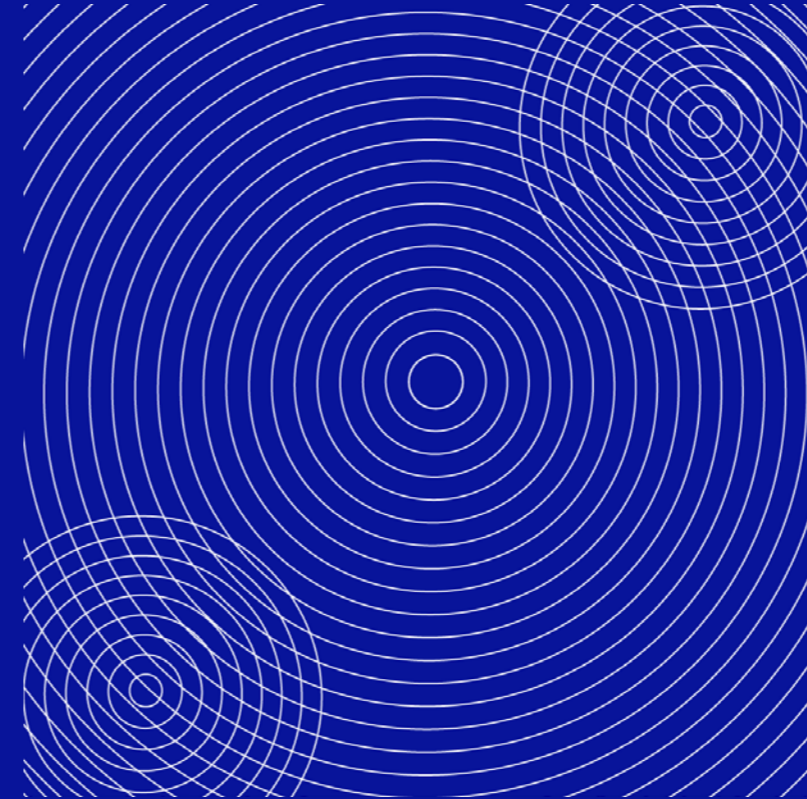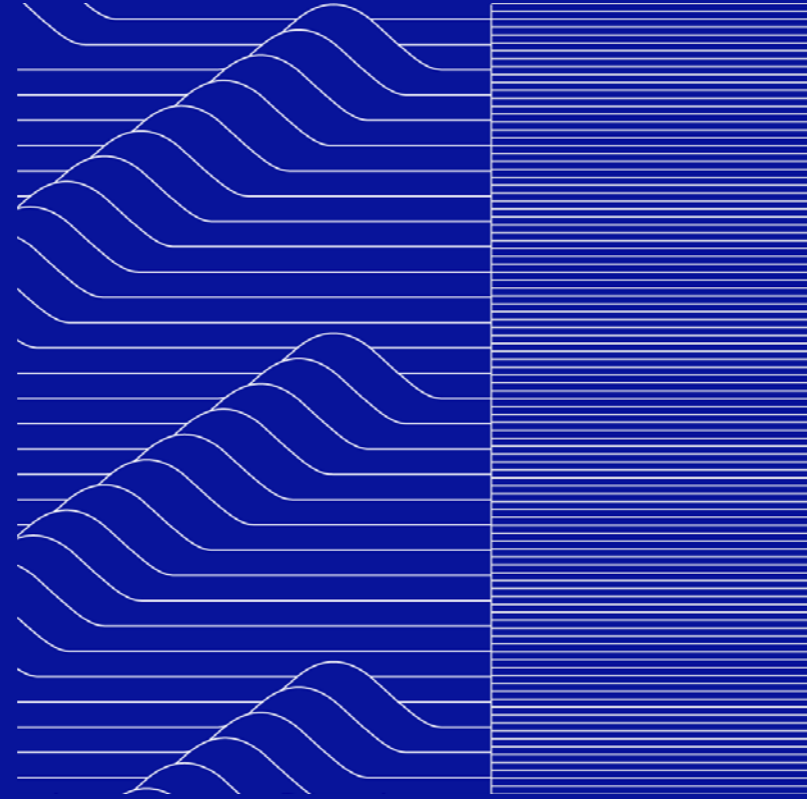 approaches to healthcare will seek to achieve health by or through design, with a greater emphasis on mental health and wellbeing, a balance of physical and digital solutions and better understanding of the role of green urban spaces.

→ *Read more*

Anytime, Anywhere

Technology is transforming the ways in which healthcare professionals provide their services and how patients access them. Rapid advances in mobile as well as wearable and hearable technology, the increased emphasis on operational and cost efficiency, shifts in behaviour and lifestyle patterns, and changing business models are redefining when, where and how healthcare services are delivered and accessed.

→ *Read more*

High Tech, High Touch

As healthcare becomes embedded into almost every aspect of our lives, technology will continue to drive increased convenience and better outcomes. Physical and emotional needs remain as strong as ever, so digital advances will need to be met with increasingly inclusive and human-centred solutions and experiences.

→ *Read more*

Bespoke for All

Improved access to both physical and digital information and a better understanding of individual health needs means that the days of 'one-size-fits-all' healthcare solutions are over. Revolutionary new medical approaches and a greater appreciation of demographic and cultural needs are supporting the delivery of bespoke solutions. At the same time, tailored services in intelligent, adaptable spaces have the potential to deliver better outcomes whilst reducing costs.

→ *Read more*

Catalyst for Urban Regeneration

By 2030, 1 billion more people will be living in urban areas than in 2020 . While rapid urbanisation poses a challenge for the operational capacity and efficiency of healthcare and city systems, the opportunities it provides to embed health and wellbeing into new urban developments are two-fold. Better-designed buildings, spaces and places can improve resident health and wellbeing and overall quality of life. At the same time, hospitals and healthcare facilities can support the long-term economic growth and social cohesion of local communities.

→ *Read more*

Diffusing the Monolith

In a future when healthcare systems in cities will be characterised by the need to provide on-demand, high tech, high-touch, bespoke and preventive services, the role of the built environment and its buildings will be more important than ever. The 'monolithic' physical form of conventional hospitals will need to adapt to an increasingly health-aware population, and an urban context where traditional boundaries between modes and activities, public and private, and inside and outside are no longer fixed. At the same time, they will need to remain equipped to respond rapidly and locally to health crises.

→ *Read more*

Behind the Scenes

The operation of future healthcare systems will inevitably become more complex, driven by the demands of personalised medicine, greater numbers of touchpoints – both on- and off-line – climate change-driven environmental extremes, and global health crises that will make safe, accessible and consistent services more challenging. The human and digital systems that underpin healthcare systems' performance will evolve to deliver improved access and outcomes while the capacity to respond to sudden demand will surge, enabled by advances in logistics, resilient infrastructure, automation and communication technologies.

→ *Read more*

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Foreword

Healthcare affects us all. For many, the events of 2020 have made the threat and consequences of ill health more apparent than ever; for others it has underlined the importance of staying healthy, and the support networks we all need to do this.

Pandemics like COVID-19 are part of the new normal, accelerating a changing approach to healthcare that accounts for the wider determinants of health and follows a more preventive model. The breadth of challenges we face – whether adequate nutrition, antimicrobial resistance or the effects of climate change – is daunting, and change will take time, investment and coordinated effort. Yet philosophically and financially there can be no going back.

This report considers the long-term future of healthcare as a collaborative, multi-disciplinary endeavour – one that extends far beyond physical healthcare assets to include transport networks, public spaces, residential and commercial design, urban planning and more. Our research focuses on the built environment, but considers a broader set of drivers, trends and innovations that could support more efficient, effective and inclusive healthcare systems.

Recent Arup projects indicate this emerging approach, and the pace of innovation. These include patient-centred environments at the Alfred Hospital Intensive Care Unit, Melbourne; guidelines for 'plug- in' modular hospital capacity, developed by our team in Dublin; and our work with Matternet to create an effective drone logistics system for healthcare facilities.

Our environmental projects, whether providing new renewable energy or water treatment systems, also reflect our commitment to the UNSDGs and the unequivocal link between planetary and human health.

With its global outlook, we hope this report illustrates the potential for inclusive, sustainable and efficient healthcare across multiple contexts, and the opportunities within our grasp. It is intended for developers, architects and designers as much as policymakers and healthcare providers, managers and operators – indeed, anyone with a stake in the future of healthcare.

DAVE PITMAN
Director, UKIMEA Healthcare Business Leader, Arup

MAGGIE'S CENTRE
Leeds, UK

This recovery centre offers a calm space for cancer patients and visitors. Natural materials, bespoke amenities and plants embedded into the structure create a respite from clinical spaces. Click to read more on Arup Inspire.

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Introduction

The first half of 2020 showed in stark terms the direct relationship between human health and human settlements, and the defining influence of different economic, social and political contexts. Our understanding of health and wellbeing has evolved significantly as a result, along with our expectations of healthcare systems.

Healthcare systems globally were under growing pressure to change and innovate even before the COVID-19 pandemic. In many countries affordability of healthcare services in relation to national healthcare spending, ageing populations, and a rise in lifestyle-related and chronic diseases have forced a rethink about how and where healthcare services are delivered. This is set against a backdrop of global urbanisation and climate change, as well as the pursuit of social value and inclusive growth.

Future of Healthcare Ecosystems explores the trends, drivers and contexts shaping the future of healthcare, and the innovations affecting change. Fundamental to this is a shift towards preventive models, and a philosophy that accounts for the wider determinants of health.
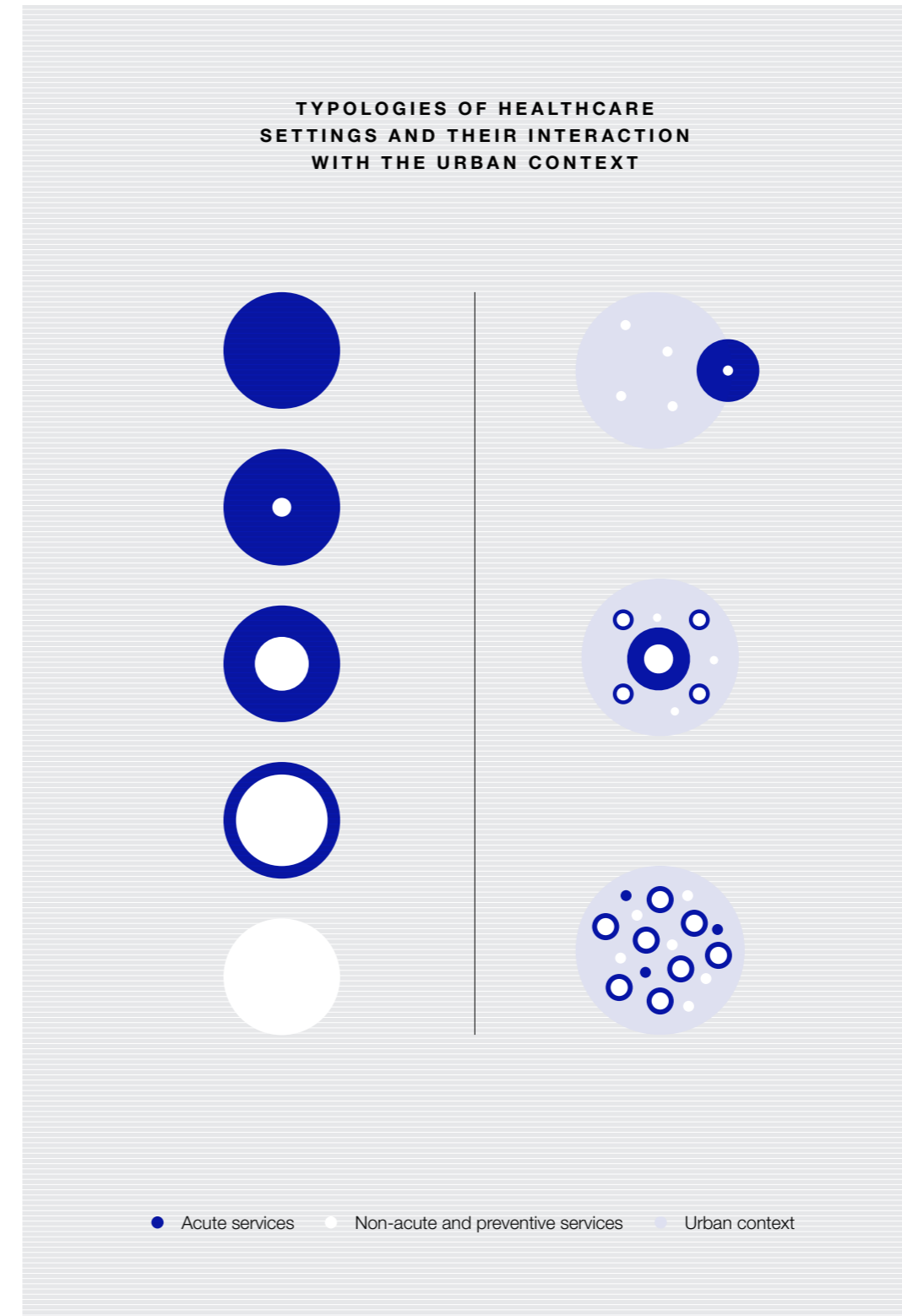
Critically for the built environment, the adoption of preventive approaches must go hand in hand with the evolution of the hospital from a hermetic space for diagnosis, treatment, healing and recovery to one that is diffused across its urban context. This report considers how

healthcare environments can positively contribute to local people's physical and mental health and wellbeing, as well as galvanising economic and social benefits.

Addressing innovation, it explores how convenience, cost and efficiency pressures are driving greater digital adoption – including Artificial Intelligence (AI), telemedicine and wearables – at the same time as strategies that account for and engage human emotions and senses. It also considers the potential for services and spaces to engage with the needs of different demographics and cultural groups.

Future of Healthcare Ecosystems addresses these themes across seven chapters, exploring a variety of scales from the urban to the individual. The report ends with a focus on the outlook for systems that underpin the smooth operation of healthcare environments, before concluding with the overarching implications of the research. Each section contains best practice case studies and a plausible vision for the future.

Planning, designing and building future healthcare ecosystems will require an integrated, multi-disciplinary approach – one that considers healthcare as a diverse and dynamic ecosystem of actors, from the microbial to the planetary. This report considers what a sustainable and effective healthcare ecosystem could look like, our prognosis for the future of the sector and the vital services it provides to all of us.

TYPOLOGIES OF HEALTHCARE SETTINGS AND THEIR INTERACTION WITH THE URBAN CONTEXT

● Acute services   ○ Non-acute and preventive services   ● Urban context

The graphics in this report aim to convey some key themes within the future of healthcare. Blue was chosen for its associations with trust and stability, key ingredients for healthcare in a digital age. This becomes gradually lighter chapter by chapter, indicating the future decentralisation and diffusion of healthcare.

Each chapter is represented by a simple abstract gif using universal shapes and a sound effect, intended to immediately convey the chapter's focus. Lastly, the use of linework suggests the increasingly DIY and self-made nature of healthcare, a deliberate move away from polished impersonal-style renders or vector graphics.

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DIAGRAM
Typologies of healthcare settings and their interaction with the urban context

Hospital buildings are moving from an inpatient focus towards more balanced space typologies as healthcare services shift to prevention-based models. These sites can accommodate a wider range of acute, non-acute and preventive services and activities. At the same time, hospitals are moving away from the urban fringe to become prominent city-centre structures, activating their surroundings and diffused across the city.

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Preventive

The scope of healthcare services looks likely to shift to a more preventive model that accounts for the wider determinants of health. This change is driven by a rise in chronic illness, environmental risk factors, personalised approaches to life-long health and economic pressures. New approaches to healthcare will seek to achieve health by or through design, with a greater emphasis on mental health and wellbeing, a balance of physical and digital solutions and better understanding of the role of green urban spaces.

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CHANGING EMPHASIS

Healthcare is typically considered a reactive system, serving to cure or treat an issue rather than preventing it from occurring in the first place. Yet the precursor of Western medicine, the ancient Greek 'Asclepeion', acted as a space to promote healthy living rather than somewhere to treat patients.[1] Today, with 40% of premature deaths in the developed world occuring due to unhealthy behaviours, poor diet, and inactive lifestyles, governments are recognising that such conditions are avertable.[2]

This comes at a time when costs of treatment are increasing, and it would be cheaper to pay to stay healthy rather than being treated. Yet currently only 3% of healthcare budgets are attributed to preventive services.[3] However, initiatives including the Well-being of Future Generations Act in Wales, and New Zealand's 'wellbeing budget' suggest a new approach, one that encourages and enforces more preventive models. Launched in 2019, New Zealand's wellbeing budget aims to leverage advances in technology that empower people to lead healthier lifestyles as well as use design and planning to facilitate and encourage new choices.[4]

AN APPLE A DAY?

The role that technology plays in preventive healthcare is double-sided: on the one hand the proliferation of technology has resulted in a widespread adoption of digital and 'on-the-go' lifestyles across generations. For some, this has contributed to a wider issue of reduced time for exercise, self-care, or physical social interaction. Further, the constant flow of information provided by smart devices has fuelled instant gratification, which can both positively and negatively impact people's lifestyles as they begin to favour convenience. The absence of instant gratification and convenience, however, can also trigger anxiety and contribute to poor mental health – an issue that has been shown to exacerbate physical and chronic illness and is costing the UK's National Health Service (NHS) an estimated £8 billion a year alone.[5]

While technology is responsible for some of the negative impacts on people's physical and mental health, it can be used to reverse these effects by offering responsive care services both physically and digitally.

Only 3% of healthcare budgets are attributed to preventive services. This comes at a time when costs of treatment are increasing, and it would be cheaper to pay to stay healthy rather than the cost of being treated.

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CASE STUDY
Forward Health
San Francisco, USA

Launched in 2017, Forward uses AI to help patients manage their health, focusing on preventive and proactive care and using powerful user-experience design. Operating like a gym membership, the monthly subscription gives members unlimited visits to the clinic as well as the necessary equipment to track their own health, including a health app and in-clinic equipment. When attending an appointment, a body scanner measures an individual's height, weight, body temperature and heart condition in 45 seconds. Blood and genetic testing, wellness and nutrition counselling and ongoing monitoring from wearable sensors are also available. Data and results collected are displayed on a large digital screen during each consultation, emphasising the value of the data and fostering dialogue between doctors and members. Forward demonstrates the demand in the US for clinics that incentivise on-going health – a cheaper alternative to being treated after falling ill.[6]

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CASE STUDY

*Marmalade Lane
Cambridge, UK*

→

Co-living has been put forward as a potential solution to the housing crisis, providing communal space and amenities that also foster interaction between people. Such schemes might offer a viable alternative at a time when younger people are struggling to make ends meet due to expensive city rent for minimal space, and with some experiencing the effects of isolation. The Marmalade Lane co-housing scheme in Cambridge is a mix of varied size homes ranging from one- to four-bedroom houses and apartments. The scheme also prioritises wellbeing and socialising, with a central common area that offers a space for gathering and eating. Amenities are also shared, including a communal laundry, gym, meeting rooms and garden – all managed by residents.[7]

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Some tools can also give individuals the power to monitor and opt into healthier everyday choices, as well as affecting how people navigate through spaces, such as diet apps or exercise trackers. In the last few years, several tools have also incorporated 'gamification', using rewards and instant gratification to encourage more physical exercise. For example, studies of Nintendo's AR app PokemonGo showed that the game increased the proportion of people who walked over 10,000 steps a day (4km) from 15% to 28% and reduced sedentary behaviour of its players by 30 minutes a day.[8]

Technology has the potential to empower people to take control and co-create their health. This is also visible in the way digital technology is driving the emergence of more preventative health clinics. In the US, such schemes can fill a gap in provision, improving avoidable health problems through lifestyle changes before more costly doctors' appointments are needed.

PLACES OF PREVENTION

Digital-led approaches alone however are not enough to drive healthier lifestyles, but rather need to work in tandem with physical infrastructure, urban space and carefully designed buildings to deliver a truly preventive model. The average US citizen spends 90% of their life inside buildings,[9] making it essential for designers, architects and planners to create environments that can sustain mental and physical wellbeing. Consideration needs to be given to indoor air quality, sound and lighting to alleviate levels of stress and poor mental health, while more active design and provision of facilities such as gyms at work can reduce barriers to exercise. The physical distancing guidance and hygiene recommendations for workplaces in the wake of COVID-19 likewise emphasise the spatial impact of a preventive approach.

500 metres
those living within 500m of accessible green space are 24% more likely to do 30 minutes of physical activity per day.

£8bn/year
the cost of poor mental health on the UK's National Health Service (NHS).

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CASE STUDY
Xiamen bicycle skyway
Xiamen, China

This 8km cycle skyway in Xiamen, China, was completed in 2017 by Danish architects Dissing + Weitling. Hovering five meters above street level and the congested roads, it connects five key residential quarters and three business centres in the middle of the city. This has promoted greener, more sustainable and active transport. In turn, more users have consciously decided to ride a bike to avoid traffic jams and have also noticed health benefits. The majority of the 8km skyway is positioned vertically between ground level and an existing elevated bus rapid transit (BRT) expressway. The BRT route provides shelter for the skyway, further encouraging its use as an alternative to private vehicles. Shared and dockless bicycle pick-up points are also positioned along the route to encourage casual use by visitors as well as residents. The skyway also connects urban districts to green spaces surrounding Xiamen, providing additional health benefits.[12]

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Additionally, with 11 million deaths attributable to dietary risk factors, studies have suggested that aspects of built and food environments have a role to play in shaping healthier eating habits to prevent chronic illnesses.[10] Identifying and redesigning such obesogenic environments,[11] for example where unhealthy food options predominate or where walking is impeded, should be at the heart of preventive healthcare.

The role of recreational outside spaces is another significant factor, given that interaction with the outdoors is an increasingly important aspect of healthier lifestyles. A study by the UK Heritage Fund shows that living in greener areas and close to forests is associated with less sedentary time and reduced risks of obesity.[13]

Other studies have shown that green environments help prevent disorders and speed up healing, with countries including Japan adopting therapeutic practices such as forest bathing (Shinrin-yoku). It is more important than ever – particularly for those living in cities – to reconnect with nature where green space is limited.
Yet proximity to urban parks or gardens is uneven, a factor that became apparent in the UK during the initial lockdown phase of the COVID-19 pandemic.
In addition, the way people transition between spaces, their commutes or other journeys could become daily opportunities to improve fitness and wellbeing by dedicating more and better connectivity for active forms of transport, such as cycling and running.

The built environment is perhaps best positioned to play a significant role in alleviating mental and physical strains on people through the design and planning of urban spaces to encourage healthier lifestyles, which – like the Asclepeion – support a holistic approach that individuals can choose and shape.

Digitally-led approaches alone are not enough to drive healthier lifestyles, rather they need to work in tandem with physical infrastructure, urban space and carefully designed buildings to deliver a truly preventive model.

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PARSLEY HEALTH
New York, USA

Parsley Health offers its members 24/7 access to medical practitioners, personalised care and nutrition plans and personal medical data, and includes lifestyle factors as part of a preventive approach. Click to read more on Arup Inspire.

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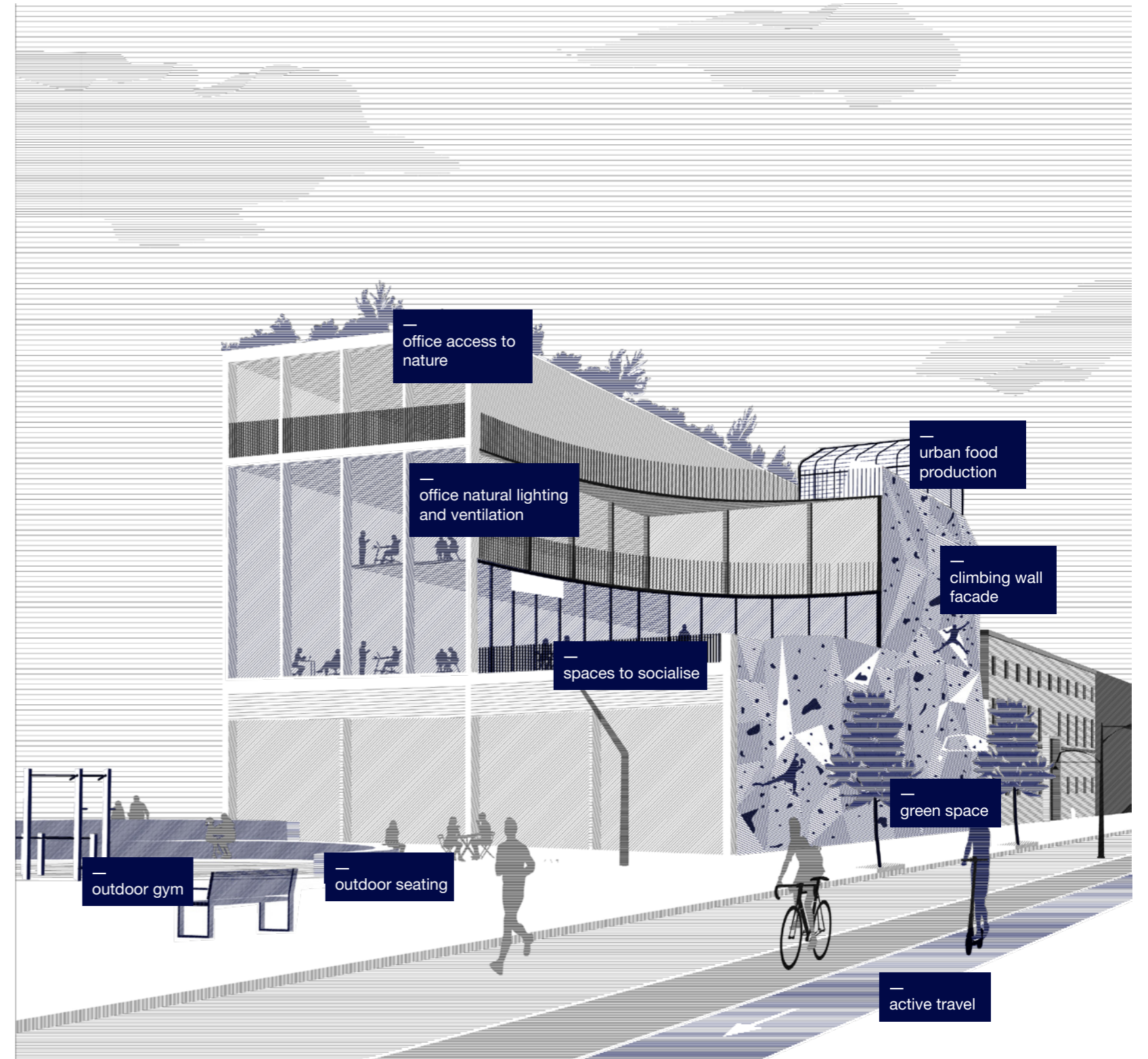
A vision for an incentivising healthcare ecosystem

Truly preventive healthcare will go far beyond the traditional model of a single designated space for reactive medical treatment. Instead, our future healthcare ecosystems will tackle the maintenance of health and wellbeing in the context of where we eat, work, how we sleep, play and travel – rendering health and all our immediate environments inherently linked.

The built environment will be recognised as having the power to prevent illness and promote healthier lifestyle choices, experiences and outcomes. This will be enabled by design decisions that consider everyday experience and with an understanding of mental processes, augmented by wearable devices. Buildings and their urban context will

integrate nature, introduce more natural light, softer sounds, more communal spaces for events and eating to encourage interaction, and quiet areas or furniture that encourage breaks.

Streets will promote active lifestyles by creating mobility routes for cycling or running, hand-in-hand together with cleaner urban air. Building facades will remove pollution while also hosting urban climbing walls. Being healthier also calls for more personalised and targeted spaces that foster a sense of community and belonging. These emerging trends will drive healthcare beyond the walls of hospitals and care facilities – bringing treatment to the community instead of the patient seeking it. This increases access and convenience and unlocks the true potential of preventive healthcare.
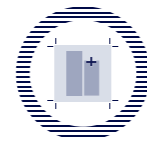

— office access to nature

— office natural lighting and ventilation

— urban food production

— climbing wall facade

— spaces to socialise

— green space

— outdoor gym

— outdoor seating

— active travel

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Key recommendations

**HEALTHCARE PROVIDERS
AND OPERATORS**
Explore digital platforms and tools, such as gamification, and devices, such as wearable and hearables. These will connect patients outside the hospital and promote and monitor healthy lifestyles through regular exercise, self-care and nutrition.

**DEVELOPERS, ARCHITECTS
AND ENGINEERS**
Adjust building programmes and masterplans to prioritise access to nature and natural light as well as activities and modes that promote physical and mental health and wellbeing – from walking to conversation.
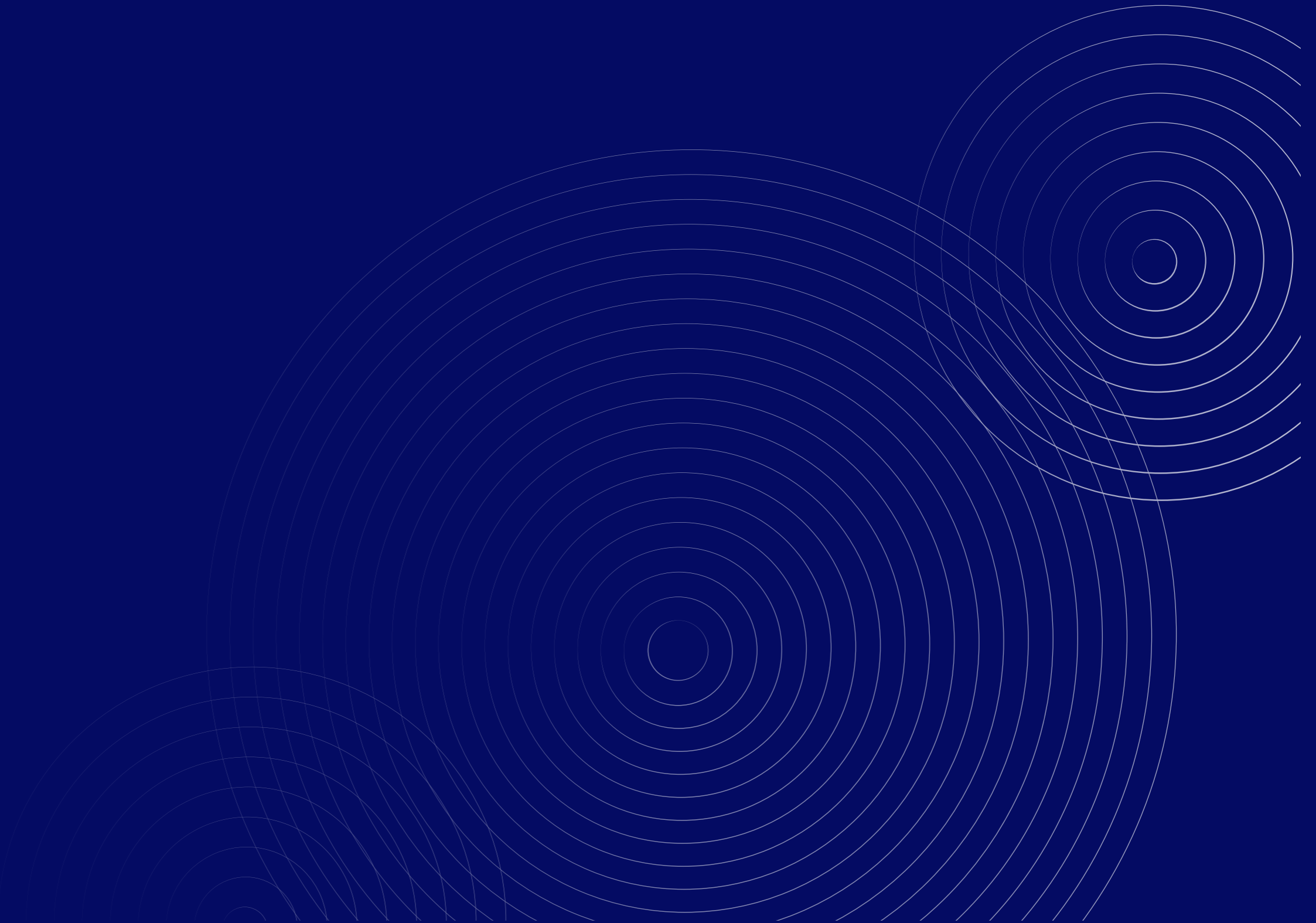
POLICYMAKERS
Regulate towards lower emissions and acoustic levels in urban centres and increase the requirements for active transport infrastructure in existing and new spatial plans.

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Anytime, anywhere

Technology is transforming the ways
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Rapid advances in mobile as well as wearable
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TELEMEDICINE

In the UK, NHS doctors and nurses are using Skype to help older people get faster care, reduce avoidable ambulance call-outs and help people stay out of hospital.[14] Between 2017 and 2019, solving problems via Skype resulted in 2,000 fewer GP appointments, prevented 3,000 avoidable visits to A&E and saved the NHS £1.3 million, signifying the huge potential of using Skype and similar telemedicine tools to connect patients with healthcare professionals.[15] The integration of smart speakers and artificial intelligence (AI) is also making it easier for those who are unable to search for health advice on the internet, including the elderly and blind, with specific new services designed to be accessed by virtual assistants.[16] Some medical devices integrate the technology directly, such as the Livio AI hearing aid connecting to Amazon Alexa.

In addition, advances in voice recognition technology including speech and vocal pattern analysis are used for earlier diagnosis and treatment of diseases like Parkinson's disease. By reducing diagnosis and treatment times, these advancements can improve patients' quality of life and help professionals understand more about diseases and their evolution.[17]
In the US, Care, a telemedicine platform also developed by Amazon, functions via virtual or in-person care as a 'first stop', covering most of the situations

that would make someone visit their primary care physician. Through the app, users can also get their medicine prescriptions delivered directly to them.[18] While the app is currently only being piloted for Amazon employees in the Seattle area, it is a sign of what a just-in-time delivery model for healthcare services could look like.

THE MANY FACES OF WEARABLES

In recent years, the popularity of wearable devices has opened many possibilities for healthcare applications. In the UK alone, the number of wearable users is expected to rise to 7.1 million by 2024 – a steady increase from 6.6 million in 2020.[19] From smartwatches monitoring heartbeat and rhythm, physical activity and sleep patterns, to wireless earbuds filtering noise and doing near-instantaneous translation of foreign languages, wearables have the potential not only to collect physical and mental health data but also record it straight into medical records. This can reduce the need for hospital or GP visits by helping doctors spot 'early warning' signs and act as personal assistants helping people live better. With the number of connected wearable devices worldwide expected to rise to 1.1 billion by 2022 (compared to 325 million in 2016),[20] the opportunity to form a first line of patient testing and monitoring without requiring physical interaction is significant.

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£1.3m

saved for the NHS between 2017 and 2019 from offering healthcare services via Skype, signifying the huge potential of using similar telemedicine tools to connect patients with healthcare professionals.

90%

the uptake in electronic medical records nationally by the Australian Digital Health Agency.

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Changi Airport
Contactless immigration trial   ⟶

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CASE STUDY
3D-printed Polypill
Nottingham, UK   ⟶

A 'polypill' is a single tablet or capsule that combines different types of medication in order to treat or prevent chronic conditions. Combining different pharmaceutical ingredients into a single pill reduces the number of tablets that a patient needs to take, simplifying treatment and reducing the medical administration associated with multiple prescriptions. Researchers at the University of Nottingham have taken the polypill concept a step further by 3D-printing a pill to treat cardiovascular disease. The printed 'multi-active tablet' contains five compartmentalised drugs with two different release times: immediate for some and sustained for others. The 3D-printed polypill approach could open the way for more complex illnesses to be treated by a single pill, improving administration efficiency in locations where access to medication is limited. It could also improve outcomes, with the increased ease of a single pill improving drug adherence by patients.

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CASE STUDY

5G Surgery, Hainan, China

In 2019, a patient with Parkinson's disease received 5G-based remote surgery in the Chinese city of Hainan while his surgeon conducted the operation from the city of Beijing, 3,000km away. Leveraging the benefits of fast connectivity (zero video lag and remote-control delay), the surgeon managed to acquire all the necessary visual, auditory, tactile and other real-time information, manipulate the surgical instruments with micron precision on a computer and successfully implant a deep brain stimulation at the optimal target site.[21] This breakthrough operation signified the beginning of the next step in Chinese telemedicine, moving from just remote monitoring and consultation to operation. In the future, advances in telemedicine and telesurgery will further augment the capabilities of doctors and surgeons allowing them to offer specialist services from anywhere in the world. At the same time, they will allow access to operations for patients who live in remote areas, away from specialist hospitals.[22]

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CASE STUDY

*Livio AI
Minesota, USA*

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Livio AI is a hearing device that combines sensors with AI. Functioning as a hearing aid, Livio AI can improve the clarity of speech through selective noise filtering and by reducing or eliminating sounds that cause annoyance. It can also carry out near-instantaneous translation of 27 languages and transcribe live conversations. Beyond hearing and speech, the device tracks physical activity and cognitive health, such as how much the user is talking and engaging with others and the wearer's heart rate, and features a fall detector and an alert system in case the user does not respond after a fall. It can also connect directly to an audiologist who can provide real-time remote adjustments and updates. By connecting to Amazon Alexa and other devices on the Alexa platform, the device is also part of a bigger ecosystem of hardware and software. Livio AI demonstrates how hearing aids and other wearables are gradually turning into personal assistants that not only augment users' senses but also help them live better.[23,24]

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HEALTH ON THE GO

But this is not the only first line of healthcare tracking, testing and monitoring that technological advances are able to contribute to. During healthcare emergencies, leveraging the ability of mobile devices to function as powerful health tools will allow fast and efficient health checks and tests on the go, including remote temperature checks, biometric monitoring and contact tracing. This becomes increasingly important during a pandemic, particularly in spaces with high volumes of pedestrian activity such as public transit hubs or sedentary environments (offices, retail stores, waiting rooms, etc.). The experience of the COVID-19 pandemic highlights the role of this technology; from temperature mass screening in transit areas such as airports and stations, to biometric wristbands tracking the emergence of potential cases,[25] to contact tracing using built-in features of smartphones like location data and Bluetooth Low Energy.[26,27] Mobile digital devices and systems can act as an additional measure for pandemic outbreak preparedness and control.

Alongside the many opportunities that technological advances bring to the healthcare ecosystem there are inevitable challenges, including digital infrastructure and system interoperability, data privacy and the ability of physical space to adapt.[28]
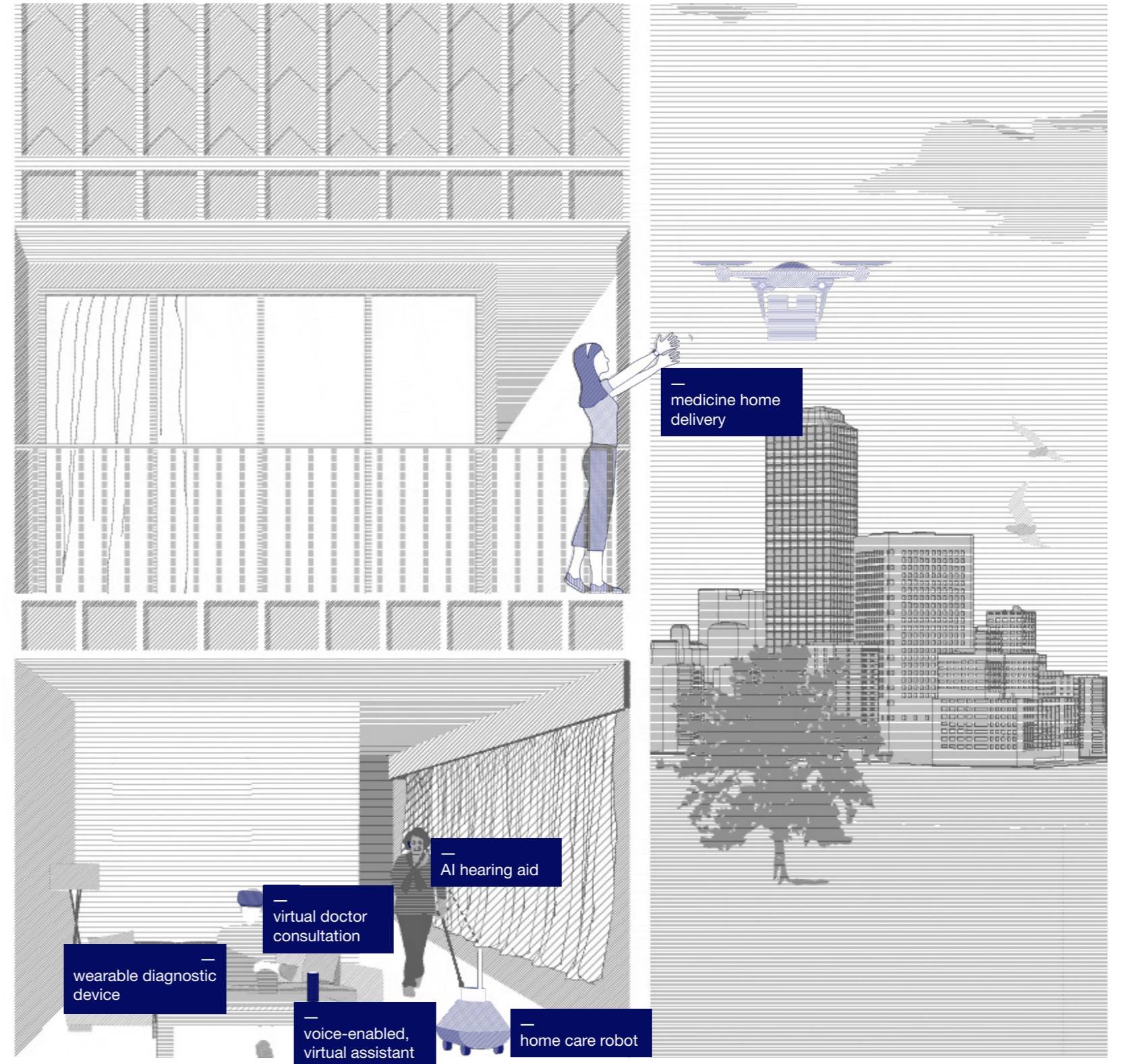
Australia has made headway with the first of these challenges, with the Australian Digital Health Agency leading a 90% uptake in electronic medical records nationally, the world's highest participation rate for a novel national health record system.[29] In Singapore, the Government Digital Service works to produce and improve online access to government services, including healthcare. Its products have included the 'TraceTogether' contact tracking app designed to prevent the spread of COVID-19 while protecting user privacy,[30,31] as well as tools to improve access to local public health clinics.[32]

> During healthcare emergencies, leveraging the ability of mobile devices to function as powerful health tools allows fast and efficient health checks and tests on the go, including remote temperature checks, contact tracing and biometric monitoring.

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A vision for a ubiquitous healthcare ecosystem

The ever-evolving role of technology as an enabler of access to healthcare will enhance existing and create new digital solutions and systems which, when integrated into and supported by physical infrastructure platforms, will allow patients to access care services without having to visit the hospital or leave their home. Faster, 5G-enabled connectivity will result in an even more seamless interaction between patients and doctors, allowing the expansion of VR technology from education and training to immediate care purposes. At the same time, faster connectivity will drive the next phase of telemedicine and telesurgery aiming to tackle the inefficiencies (surgery waiting times, staff shortages, etc.) which many healthcare systems face.

Wearable and hearable technology will further augment human senses and act as a personal assistant that helps people live better[33,34] by empowering them to take control of their physical and mental health and wellbeing. In addition, advances in robotic technology will drive the next generation of care robots and proliferation of 3D printing, while self-test home kits will add care to the list of activity modes a home will accommodate (care from home). AI, Machine Learning (ML) and cloud computing will allow pharmaceuticals and technology companies to develop drugs and vaccines faster and more efficiently.[35] This omnipresent layer of technology will result in increased and better prevention and quicker responses at scale – especially during health crises – while underpinning a light-touch, pervasive model of health-monitoring and surveillance.

— medicine home delivery

— AI hearing aid

— virtual doctor consultation

— wearable diagnostic device

— voice-enabled, virtual assistant

— home care robot

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Key recommendations

HEALTHCARE PROVIDERS AND OPERATORS
Ensure digital infrastructure interoperability between public, private and third-party platforms and systems to maximise speed, convenience and data value.

DEVELOPERS, ARCHITECTS AND ENGINEERS
Future-proof building assets through support of multiple digital layers, such as 5G-ready hardware and software, alongside physical spatial design.
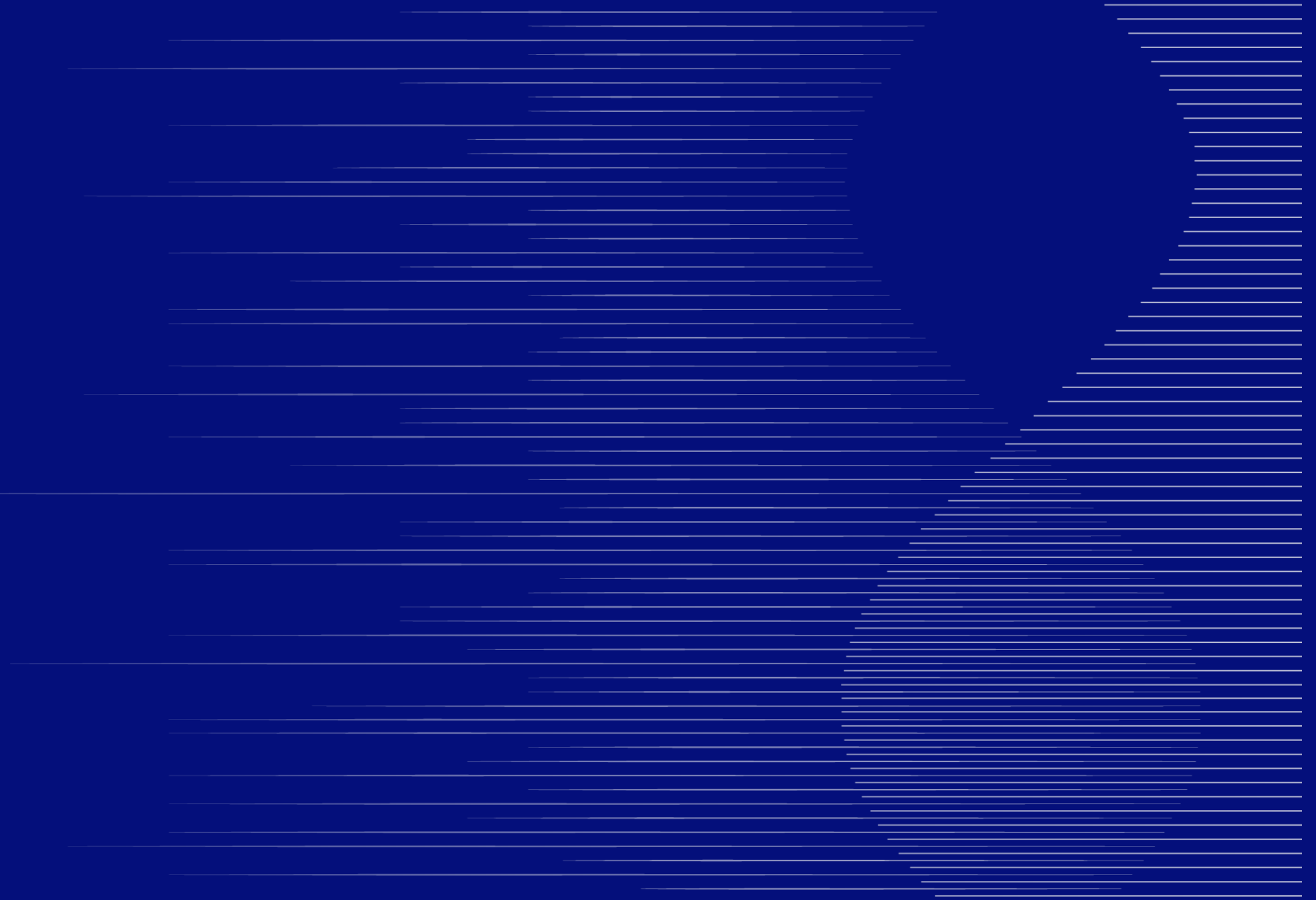
POLICYMAKERS
Legislate transparency in the recording, storing, sharing and management of user data, both by government and private platforms, especially during pandemic outbreaks or other healthcare crises.

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High tech, high touch

As healthcare becomes embedded into almost every aspect of our lives, technology will continue to drive increased convenience and better outcomes. Physical and emotional needs remain as strong as ever, so digital advances will need to be met with increasingly inclusive and human-centred solutions and experiences.

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Advances in user-experience and user-interface design, as well as the evolution of new wearable, hearable, implanted and ingestible devices, will make personal health management seamless, adaptable and embedded in our everyday lives.

DIAGNOSING DEMAND

The possibilities created by ubiquitous access to healthcare information, advice and services combined with the rapid increase of personal health data from smart devices, wearables and sensors will fundamentally change the relationship between healthcare professionals and patients, supporting increased autonomy and control.

Driven by increasing preference for participatory and preventive care, patients are asking to be part of medical decision-making, empowered by easily-accessible online information and new opportunities for self-health 'DIY' management.[36,37] This information will need to be interpreted and evaluated in dialogue with healthcare professionals to agree upon the most effective treatment for the patient.

Alongside this growing awareness and quantification of personal health data is a rise in long term illness. Currently almost half the US population, 133 million, have at least one chronic disease, which are responsible for seven out of every ten deaths.[38] Yet this is not restricted to wealthier economies and will increase as populations grow and age globally. In the developing world, urbanisation and a growing middle class are also expected to lead to a steep increase in sedentary and unhealthy lifestyles, and subsequently a rise in chronic and lifestyle diseases.

WATCHING OUR HEALTH

A rise in chronic diseases will pose significant challenges for healthcare systems worldwide. Monitoring and prevention could be critical to improving health outcomes and reducing costs: 88% of healthcare providers in the US are investing in Remote Patient Monitoring (RPM) technology to support the management of high-risk chronic patients.[39] Current RPM solutions have been shown to reduce hospital re-admissions, emergency department visits, and overall healthcare utilisation, benefitting patients with conditions including diabetes, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), asthma and hypertension.[40]

The promise of the next generation of RPM technology, enhanced by AI with machine learning, is to make treatment plans that are personalised to the individual and increasingly effective. In the form of AI health and wellbeing assistants (or coaches), and together with a connected healthcare provider, these advances can empower patients to proactively manage their own health, effectively shifting traditional healthcare towards a more preventive model (see chapter 1). Advances in user-experience and user-interface design, as well as the evolution of new wearable, hearable, implanted and ingestible devices, will make personal health management seamless, adaptable and embedded in our everyday lives.

Avanti Architects for Sheffield Children's Hospital © Simon Kennedy

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CASE STUDY

Sheffield Children's Hospital
Sheffield, UK

The Sheffield Children's Hospital uses art and child-friendly interior design to improve children's hospital experiences. Through Artfelt, the Children's Hospital Charity art programme, the hospital provides free art materials and music, art and craft workshops for patients aged 0-16. These sessions help to provide entertainment, creative expression and distraction for the young patients during what can be a stressful time, as well as helping them to make friends with other patients. Artfelt, in collaboration with Avanti Architects, designed the interior of the hospital's new Safeguarding Support Unit, which provides space for assessment, treatment and play. Combining high tech with high touch elements, it includes interactive light installations, digital projections, and brightly coloured artworks. Other spaces in the hospital are suited to specific age groups and are designed by specially-commissioned creatives. The design strategy and programme as a whole are intended to provide an engaging, welcoming and safe environment for young people, helping patients feel calm and reducing anxiety.

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In diabetes management, for example, systems like Abbott's 'Freestyle Libre' use smart sensors on the skin to continuously monitor blood glucose, with data accessed and shared in real-time for discussion with healthcare professionals. Similarly, ingestible sensors embedded into pills can reduce the consequences of mismanaged drug intake: only 25-50% of patients globally take medication correctly, errors which cost the US health system US$300 billion annually, or 16% of total US healthcare costs.[41,42] Sensor-embedded pills developed by Proteus Health can monitor medication intake and effect; and compartmentalised, low-power microchips by etectRx can transport messages to and from sensors located in the body and manage drug release, significantly reducing human error.

Today, smart health devices are predominantly enabled by GPS trackers, heart rate monitors and our smartphone cameras. In the future, interfaces, monitoring and interactions will be driven by voice technology, smart contact lenses, implantable chips, sensor embedded clothing, and even smart nanodevices circulating in our systems will both monitor and treat health conditions, proving increased autonomy and improved health outcomes. This 'Internet of Bodies'[43] will provide a rich source of health data, supporting preventive rather than reactive approaches, albeit privacy concerns will need to be addressed.

The emergence of AR/VR and gaming-based interventions is also opening-up new medical possibilities for assessment, rehabilitation and therapy. Game-based VR interventions with stroke survivors showed a significant advantage of 10.4% over standard treatment methods.[44] In the field of traumatic brain injury, the number one cause of neurodisability with no current available pharmacological therapy, VR is seen as a game changer.[45] VR and AR interventions have also been effective as a distraction technique, for example in chemotherapy or to reduce anxiety in stressful hospital environments.[46,47] During the COVID-19 pandemic, AR was also used by doctors at Imperial College London to reduce the number of medical staff needed on the coronavirus ward. A Microsoft HoloLens headset allowed a single doctor treating patients to interact with remote colleagues' holograms, as well as medical notes and X-rays.

Beyond improved treatment efficacy and patient experience, these new technologies can reduce cost and staff time in the care of acute and chronic patients by enabling independent therapy at home. In buildings, sensing environments could support nursing, care and assisted living by monitoring vital signs and physical and mental wellbeing amd detecting falls, meaning family members and healthcare providers could be more connected and remotely involved in the care of their family members despite living far away, with incidents detected and addressed in real-time.

88%
of healthcare providers in the US are investing in Remote Patient Monitoring (RPM) technology to support the management of high-risk chronic patients.

50-75%
of patients globally take medication incorrectly, errors which cost the US health system US$300 billion annually, 16% of US healthcare costs.

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CASE STUDY
National Academy for Social Prescribing London, UK

Social prescribing is advice given by medical professionals to their patients to engage in organised social events and community activity to alleviate symptoms. Rather than a conventional prescription for medication, social prescribing might include volunteering, art classes, or cultural or outdoor sporting activities, and are intended to help with mental health and psycho-social problems such as loneliness, anxiety and stress. By utilising existing local assets and groups to improve outcomes, the approach ultimately reduces the cost of treatment. The concept has seen uptake in the UK, The Netherlands and Ireland, with the UK Government establishing the National Academy for Social Prescribing in October 2019. The independent, non-profit organisation aims to create a network of social prescribing partners, fund community-based programmes, coordinate research, and develop a network of advocates to better embed social prescribing nationally.

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CASE STUDY

*Chelsea and Westminster Hospital
London, UK*

The redeveloped labour and maternity wards at Chelsea and Westminster Hospital in London are designed to create a welcoming, calm and natural space. A key part of the scheme is its lighting strategy, researched and designed by Arup, which aims to reduce fatigue and improve sleep. The bespoke system eliminates flicker and glare, as well as providing dimmable lighting so that patients can control the brightness of their own environment. This human-centred approach forms part of an overall strategy to improve experiences and comfort levels. This includes brightly-coloured mosaic tiling, bespoke artwork and the use of natural materials such as wooden furniture and textiles. In addition, recliner chairs in each room can lie fully flat to provide a temporary bed for birth partners. Combined, these tactics help to provide a more personalised, adaptable and home-like hospital environment.

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THE HUMAN CONDITION

The expansion of the Medical Internet of Things (MIoT), automation and robotics in healthcare to support mundane and repetitive tasks could see the reallocation of human staff to more high-value, 'high-touch' roles. A focus on core responsibilities and uniquely human competencies will see healthcare professionals spending more time directly interacting with patients, improving productivity, quality of care and enhancing patient and visitor experiences.[48]

The tactile and physical nature of healthcare professions, as well as the increasing need for valuation and interpretation data, will make healthcare jobs less susceptible to full automation. Instead, healthcare professionals will be supported in their roles by robotic and AI assistants.[49] VR applications such as 'We are Alfred', which put the user in the place of an extremely ill elderly individual, will help medical and nursing students develop interpersonal competencies by learning to empathise with patients and conditions.[50]

Further, the reallocation of resources more broadly could help to meet demand for 'high-touch' mental health services where demand far outstrips the supply of care.[51] This shift to a more human-centred role of the healthcare professional also manifests in new approaches to healthcare environments

and patient experience. Functionality, strict hygiene requirements and efficient operation have been driving decision-making, but a greater understanding of the interplay of patient wellbeing, comfort and experience and patient recovery are reshaping priorities. A market shift towards 'value-based healthcare' and the (debated) 'patient as a customer' models is further influencing the transformation of the design and operation of hospitals and practices to focus on quality and patient experience (see also chapter 4).

At its most basic this includes the ability for patients and healthcare professionals to communicate. Language barriers can be common in cities with diverse communities, where many – often vulnerable – patients may be unable to speak the local language, presenting a serious risk to patient safety. In healthcare facilities the provision of translators and materials in multiple languages can reduce barriers, as well as training on non-verbal communication tactics. Communicating in the communities themselves is also key. In the early stages of the COVID-19 pandemic the translation team of the Western Sydney Local Health District, where 49% of residents speak a language other than English at home, produced resources in 26 languages so that residents were aware of the latest information and guidance.[52]

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A ROOM WITH A VIEW

An increasing body of research is showing the impact of environmental and design factors in improving patient outcomes and staff performance, including a reduction in medical errors, falls and infection rates.[53] The level of control over and reduction of environmental stressors by improving acoustic and visual comfort, orientation, a sense of privacy, view and exposure to nature and daylight can significantly improve patient wellbeing and shorten recovery times.[54] A greater consideration of these design factors in hospital and care environments has the potential to significantly improve quality and efficacy of treatment and patient recovery, leading to shorter duration of stays and reduced medication and operating costs.

For example, patients with a window with a view of nature compared to those with a view of a brick wall had shorter post-operative stays and took fewer potent pain drugs.[55] Natural materials such as timber used within interior spaces have also been shown to reduce stress.[56]

Hospitals are leveraging these benefits by adopting light and open design approaches and by integrating natural landscapes such as parks into the architecture of their buildings to ensure ample natural light, fresh air and open views throughout all spaces.[57]

The approach taken by San Diego Medical Centre has been to focus its improvements of patient experience around the element of control and customisation: temperature and room microclimates can be adjusted to medical requirements and patient preferences, and lighting is designed around circadian rhythm while allowing for individual adjustments by the patient. Nurses' stations have been relocated outside of patient rooms to make care more patient-centric and accessible.[58] This approach blends integrated technology with a sensitivity to emotional experiences, supporting human-centred healthcare.

A greater consideration of design factors in hospital and care environments has the potential to significantly improve quality and efficacy of treatment and patient recovery, subsequently leading to shorter duration of stays and reduced cost of operation and medication.

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HOSPITAL CABINS
Oslo, Norway

Two woodland cabins work as extensions of local hospitals, allowing patients to spend rehabilitation time around nature and in a therapeutic space. Click to read more on Arup Inspire.

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A vision for a humanised healthcare ecosystem

Technology promises to improve our health, whether through embedded devices that will monitor and treat chronic conditions, richer data analysed by AI to inform personalised treatment, or by the use of gamified VR and AR treatment. But this ecosystem will also benefit from the increased one-on-one personal care we will receive as a result of automation and the reallocation of previous human resources, as well as more sensitive and therapeutic medical spaces. If challenges posed by the security of technology innovation, data ownership, ecosystem partnerships and funding can be overcome, future healthcare ecosystems will be digitally enhanced, centred around the patient experience and will incorporate environmental design elements to improve patient wellbeing and recovery.


— natural materials

— welcoming artwork

— view of nature

— human interaction

— Augmented Reality (AR) interface

— natural light

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Key recommendations

**HEALTHCARE PROVIDERS
AND OPERATORS**
Integrate intelligent, digital technologies
and automation in hospital operations to
free staff from mundane tasks to focus on
quality, human-centred patient interactions.
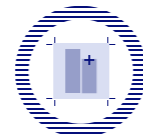
**DEVELOPERS, ARCHITECTS
AND ENGINEERS**
Include environmental design elements
in the design of healthcare spaces with
known positive effects on patient wellbeing
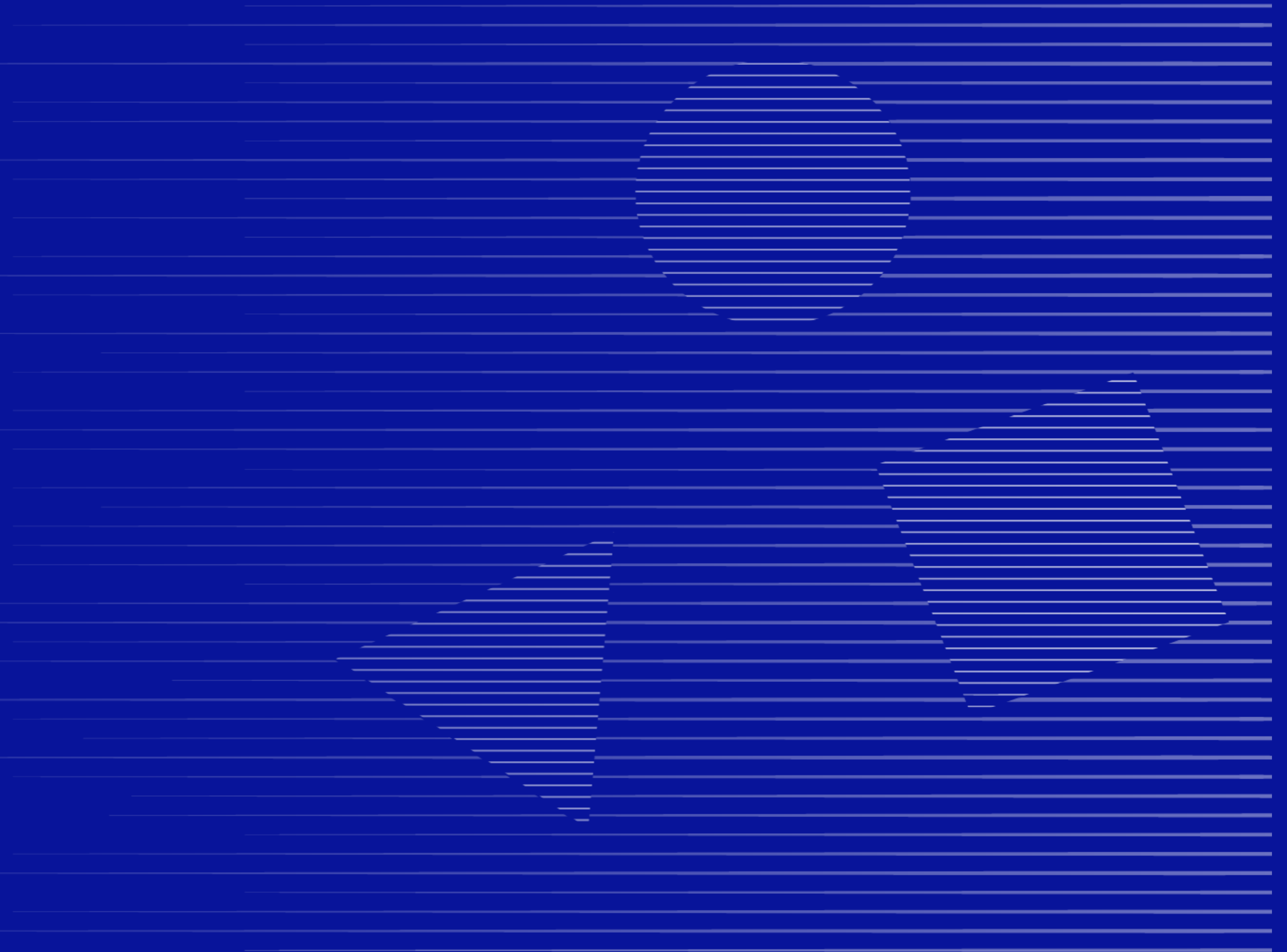and recovery and staff performance.

POLICYMAKERS
Maintain inclusive age-friendly access
to digital healthcare to support ageing
populations by humanising user interfaces
and experiences.

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Bespoke for all

Improved access to both physical and digital information and a better understanding of individual health needs means that the days of 'one-size-fits-all' healthcare solutions are over. Revolutionary new medical approaches and a greater appreciation of demographic and cultural needs are supporting the delivery of bespoke solutions. At the same time, tailored services in intelligent, adaptable spaces have the potential to deliver better outcomes whilst reducing costs.

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PRECISION MEDICINE

New AI-enabled processing technology combined with a greater quantity and accessibility to genetic data have kickstarted a wave of genomics research and personalised treatment. A genome is an individual's complete set of DNA: understanding this can reveal a person's risks to specific diseases and likely response to drugs. As the cost of technology continues to fall, it will place genomic sequencing technology at the heart of realising more precise, affordable and outcome-based care.[59] It is anticipated that by 2040 all new-borns will be DNA sequenced,[60] presenting huge opportunities for how an individual's health is managed across their lifetime and supporting precision medicine with treatments tailored to a person's specific genomic makeup. The impact of these shifts on medical facilities could be to prompt a more spatially-distributed healthcare model with smaller, cheaper and specialised local clinics equipped to diagnose and administer therapies less often, rather than individuals needing regular or acute treatments at larger facilities.

Newly-developed unbiased treatments that account for differences in patient gender and ethnicity alongside shared patient data will result in more informed decisions and vaccines that could eliminate unnecessary treatment, combatting the current estimate suggesting that 20% of healthcare spending is wasted on ineffective interventions.[61]

As well as better patient outcomes, this would free up significant time and money for more research and innovation, commercialisation and diffusion initiatives, creating an overall positive feedback loop delivering further improved health outcomes and costs savings and, ultimately, a more sustainable system.

In addition, an individual's increased access to their health data, including their genetic sequence, could support a greater degree of autonomy, DIY care and choice. This would further bolster emerging outcome-based healthcare models, which prioritise patient autonomy and end results rather than interventions. Given the financial crises of public healthcare systems and the looming insurance challenge of ageing populations with multiple chronic illnesses, this presents the possibility of both a more cost-effective and personalised ecosystem.

HUMAN-CENTRED SPACES

To manage life-long health holistically, the future of bespoke care must look beyond conventional understandings of 'outcomes' and be more sensitive to the broader needs and experiences of individuals. This is already manifesting in varied spatial approaches to different demographic needs, such as age or gender: Kindbody, a US network of women's clinics, responds to women's experience of healthcare environments with spaces and specific material choices that prioritise security, comfort and trust.[62]

To manage life-long health holistically, the future of bespoke care must look beyond conventional understandings of 'outcomes' and be more sensitive to the broader needs and experiences of individuals.

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CASE STUDY
*Kindbody
New York City, USA*   →

Kindbody aims to provide more affordable and holistic women's health services. For US$10 a month, members have access to services including annual gynaecology check-ups, same-day urgent care, contraceptive counselling, on-demand virtual appointments, and pre-conception counselling. Services like these provide members with the peace of mind they need, but which they may be unable to receive from multiple conventional clinic visits due to cost barriers. Members also have access to discounted general wellness care as well as bolt-on services for fertility testing, egg freezing and IVF. Targeting women aged 25-45, the clinics' interiors challenge conventional medical environment design, creating a sense of security and comfort with warmer lights and materials, organically-shaped interiors as well as integrating abstract art. Above all, the space aims to create a sense of place that fosters conversation and gives women a sense of companionship not found in traditional clinics.

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CASE STUDY

*St. Michael's Hospice
Hereford, UK*

The design of St Michael's Hospice seeks a balance between the necessary requirements of a professional healthcare environment and the sense of a warm, more domestic space that integrates nature-based solutions. The design team engaged early-on with patients, practitioners and hospital teams to help create bespoke spatial configurations that satisfied their respective needs and aspirations. Nurses' stations, for example, are positioned to provide full visibility of the rooms they are caring for while also ensuring privacy and comfort for patients. This discreet observation is enabled by a spatial configuration that moves from the current model, whereby rooms are positioned adjacent to corridors, to a layout where clusters or wards of rooms are connected to the main axis of the building. The design team also satisfied patient needs by maximising outdoor connections: each patient room has an external view and private patio, providing a sense of place and comfort rather than of clinical treatment.

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SEE ALSO

Urban hospice
Copenhagen hospice for palliative patients

Maggie Centre Leeds
Charity centre for cancer patients

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In Chiba, Japan, a clinic for elderly patients is designed to be informal, with bright but discreet treatment rooms contained in house-shaped buildings that provide a domestic alternative to hospital visits;[63] and in the grounds of Oslo University Hospital, Norway,[64] Snøhetta-designed 'cabins' are sited close to woodlands (see chapter 3). These respond to patient needs for space that respects everyday life by providing an informal environment for family visits, as well as the therapeutic benefits of outdoor space. Palliative and end-of-life care too have their own practical and emotional needs, with hospices and organisations such as Maggie's providing space beyond the hospital that balance observation, privacy and comfort.

Healthcare systems and spaces that are tailored to demographic characteristics of age or gender may still be at odds with an individual's cultural characteristics. This includes spiritual beliefs and language (see chapter 3), but also extends to the medical approach as a whole, for example Traditional Chinese Medicine. Such factors are not restricted to geography or ethnic group, with increasing global connectivity, migration and travel supporting a greater awareness of different cultures and religious practices and their varied therapeutic approaches. Indeed, between 65-80% of the global population uses holistic naturopathic medicine as a primary form of health care.[65] Adoption of such practices globally is increasing, with

the value of the complementary and alternative medicines market expected to reach US$271.8 billion by 2024, up from US$192 billion in 2018.[66] Non-Western approaches are often underestimated, especially with applications in the prevention and management of lifestyle-related chronic diseases, in meeting the health needs of ageing populations, and managing the psychological aspects of pain. Some countries and insurers are slowly expanding coverage of such services amidst rising patient expectations and costs. In Hong Kong, the first Chinese medicine hospital is set to open by 2024 providing the city's first space where Western and Chinese healthcare practices co-exist and complement each other.[67]

The emotional effect of alternative therapeutic spaces is already influencing the design of healthcare environments, with the potential to complement the more technology-led approaches explored in chapter 3. This includes the greater integration of daylight, natural materials, planting and an awareness of the impact of sound. Likewise, smaller, domestic-scale spaces are part of this shifting focus. A more physically-distributed spatial model that prioritises patient experience could be supported by a centralised data infrastructure, enabled by 5G. Combined, these trends suggest a healthcare system that will need to be more flexible and accommodating to differences, supported by diverse smaller spaces that enable shorter, tailored and varied forms of treatment.

65-80%
of the global population use holistic naturopathic medicine as a primary form of healthcare.

US$271.8bn
the value of the complementary and alternative medicines market by 2024.

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CASE STUDY
Hospital of Traditional Chinese Medicine Weihai, China

Situated on the coast and within a black pine forest, this hospital offers comprehensive healthcare, including space for healing and preventive care. The architecture reflects traditional Chinese typologies and is imbued with and surrounded by nature (trees and waterscapes) offering patients and visitors calming and picturesque scenery. Multiple courtyards and gardens connect various sections of the building and feature unconventional programmes, including showrooms, gymnasiums, eating areas and classrooms. The two axes running north-south and east-west choreograph patient and visitor journeys across the site, creating a sense of layers and routes through the hospital. This facility demonstrates the changing nature of hospital typology, shifting from a processing 'machine' into a rich spatial experience.
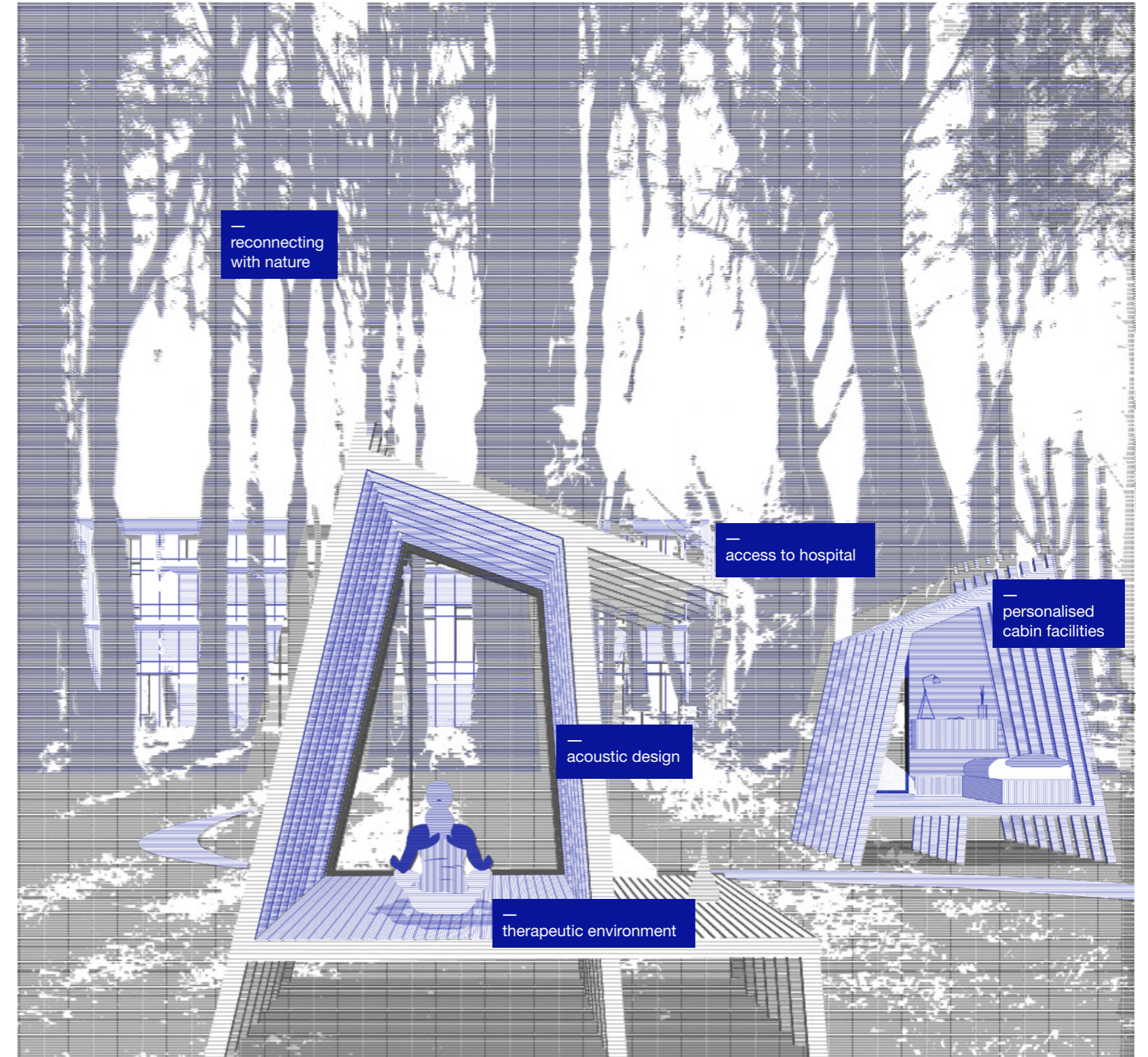
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A vision for a personal healthcare ecosystem

People's experience of healthcare will be increasingly personal, with a large proportion of the world's population collecting and knowing their own health data and genetic make-up, aiding diagnosis and personalised treatments. Rapid access to this data and to individual medical histories by healthcare professionals will also increase the effectiveness of interventions, resulting in fewer hospital visits and time spent in healthcare facilities.

Large acute hospitals will complement a growing number of smaller, tailored and alternative healthcare facilities not previously included in standard insurance or health system coverage. These will use design and nature to foster bespoke experiences that challenge medical facility design conventions

without hindering the risk of infection and quality of care. Spaces will be more domestic, creating a place people feel more comfortable in, improving conversations between practitioner and patient. These accommodate individual lifestyle and demographic factors, as well as patients that are empowered to choose their care based on greater knowledge.

These smaller facilities will also help create a community, where people don't feel alienated by the spaces they visit to get treated in or to prevent illness. This combined with new business models where healthcare will operate increasingly as a service or as an outcome-based system will ensure that services are more affordable, with greater focus on the outcomes of the patients.


—
reconnecting with nature

—
access to hospital

—
personalised cabin facilities

—
acoustic design

—
therapeutic environment

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Key recommendations

**HEALTHCARE PROVIDERS
AND OPERATORS**
Address the patient data privacy and
protection challenges of personalised
medicine with early investment in data
infrastructure and security protocols
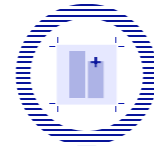
**DEVELOPERS, ARCHITECTS
AND ENGINEERS**
Consider a more holistic understanding
of healthcare, with the emotional impact
of materials and design a key component
of therapeutic spaces, particularly
as they become more culturally- or
demographically-tailored.

POLICYMAKERS
Explore different organisational forms
and delivery models that will be needed
to respond to demand for a more
personalised and preventive healthcare
ecosystem, including subscription models
and DIY care.

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Catalyst for urban regeneration

By 2030, 1 billion more people will be living in urban areas than in 2020.[68] While rapid urbanisation poses a challenge for the operational capacity and efficiency of healthcare and city systems, the opportunities it provides to embed health and wellbeing into new urban developments are two-fold. Better-designed buildings, spaces and places can improve resident health and wellbeing and overall quality of life. At the same time, hospitals and healthcare facilities can support the long-term economic growth and social cohesion of local communities.

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Real estate developers recognise that consumers who visit a medical clinic will also be shopping, eating and drinking, and seeking entertainment nearby. The next decade will see developers building upon this momentum to attract development to complement healthcare.

MIXED-USE DEVELOPMENTS

With preventive care models bringing healthcare directly to communities, hospitals are no longer the only way to access healthcare. Instead, they become places that attract people from surrounding communities to come in for regular check-ups, empower them to take control of their own personal health and promote behaviours that favour prevention, not intervention.[69]

This new model of healthcare service and delivery will transform healthcare infrastructure. Hospitals will be transformed from monolithic, secluded structures within the urban fabric (see chapter 6) to hubs of economic activity that generate further investment for adjacent uses and spaces (residential, commercial, leisure, etc.). At the same time, they place healthcare at the heart of a wider economic ecosystem, components of which are human health research and development institutions, healthtech and biotech start-ups, and pharmaceutical and high-precision manufacturing companies and facilities.

Hospital-anchored mixed-use development in cities that put medical facilities and campuses at the forefront of their offering highlight the potential of health-centred placemaking. These spaces not only serve the medical needs of their patients but also suit the diverse needs of a multi-generational demographic, elevate the user (patient, visitor, employee) experience, drive local growth and regenerate areas.[70,71]

RETAIL HEALTH ON THE RISE

The healthcare sector is taking lessons from retail and hospitality, engaging with patients in innovative and meaningful ways by connecting with them where they live, work and play.[72] Retail health clinics are gradually becoming the physical embodiment of this delivery model, resulting in decentralised, flexible and accessible urban healthcare facilities, the strategies of which (both online and offline) resemble those of a retail shop. These urban facilities also help to alleviate some of the challenges that national healthcare systems face related to access, quality and cost.[73,74] Retail clinics are a popular first-stop choice for patients and a valuable extension to, rather than replacement of, primary care services for traditional healthcare systems.[75,76,77] At the same time, in low- and middle-income countries with few or no pharmacies or retail drug stores have, they have been a major source of healthcare and medicines.[78,79,80]

While healthcare providers recognise the need to treat patients as consumers, real estate developers recognise that consumers who visit a medical clinic will also be shopping, eating and drinking, and seeking entertainment nearby. The next decade will see developers building upon this momentum to attract development to complement healthcare.

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CASE STUDY
*New Ground Cohousing
London, UK*

New Ground Cohousing is the UK's first senior cohousing project for women. Located in Barnet, London, the complex comprises 25 apartments arranged around shared facilities including a garden, cooking space and a laundry room. One third of the units are social rent with the remainder being leasehold. The majority of residents – women between the ages of 50 and 90 – were actively involved in the design process and played a major role in determining the sustainable and community-driven character and layout of the project. The development is completely resident-run, and through mutual support and inclusivity aims to keep its residents healthy, happy, independent and active. It also aims to reduce demand for social and healthcare services. The site layout allows direct interaction between the housing development and the adjacent main street. This helps to reduce isolation by connecting the project and its residents with the surrounding community and enabling them to forge meaningful local relationships.

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CASE STUDY

The Balozi Project
East Africa →

North Star Alliance is a non-profit, public-private partnership developing a network of roadside health clinics at major transportation hubs across Africa. The organisation has established 90 locations in West, Southern and East Africa, of which 19 operate as 'Blue Box' clinics that target the health of mobile workers. Within this, an initiative in East Africa called the Balozi Project aims to build a strong knowledge base and a community-driven approach to improving education, health and safety at a local level. Long-distance truck drivers are trained to act as peer health outreach workers, creating a valuable network of health advice, with the Bridge the Gap project further expanding this programme to include the sex worker community. By engaging with target groups and community champions, the Balozi Project works to facilitate overall community development, delivering services that are inclusive and fostering processes and partnerships that empower people and benefit long-term community growth.

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Cavendish Square
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wellness commercial centre →

Ohio Urban Healthcare Campus
Steam plant redeveloped as
medical headquarter →

Elderly Housing in Norway
Housing scheme that encourages
community interaction →

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UNLOCKING THE VALUE OF UNDERUTILISED ASSETS

At the same time, the changing nature of healthcare delivery in cities leaves behind underutilised medical facilities, often centrally located. For building owners and operators, patients, users and surrounding communities, this presents a unique regeneration opportunity.[84] Through adaptive reuse and redevelopment, legacy healthcare infrastructure can be renovated or repurposed to house workplace, residential, hotel or other healthcare uses and continue delivering value to their communities.

The redevelopment of Chicago's Cook County General Hospital is a characteristic example. After sitting vacant for 17 years, redevelopment on the 1914 building started in late 2018 following the announcement of a transformation scheme which includes a mixed-use complex containing office space, a hospital museum, retail space and two hotels.[85]

CO-LIVING AND REVITALISATION

The potential of inter- and intra-generational co-living to galvanise community-led regeneration in cities is also significant. Beyond the immediate health benefits that co-housing has on residents, especially with regard to isolation and wider mental health

and wellbeing (see chapter 1), such schemes can contribute positively to local economies by maintaining their residents' economic activity, either by employing them in community-related jobs or through community-organised, re- and up-skilling initiatives. One example, the Humanitas care home in The Netherlands, offers students free rooms in return for 30 hours of volunteering per month, to be spent engaging with the 160 elderly residents of the nursing home. The types of engagement vary and include regular conversation and connection to reduce isolation and loneliness as well as teaching of new skills.[86]

As the global population ages, the ability of communities to accommodate the needs of senior residents will play an increasingly important role in shaping local societies and economies. Senior co-housing projects, such as the New Ground Cohousing project in Barnet, London, for people who do not wish to move into a care home, have the potential to support their members in ways that ensure that they find meaning and purpose through old age, feel socially connected with their local community and included in the long-term prosperity of the places that they feel happy living in.[87]

Through adaptive reuse and redevelopment, legacy healthcare infrastructure can be renovated or repurposed to house workplace, residential, hotel or other healthcare uses and continue delivering value to their communities.

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CASE STUDY
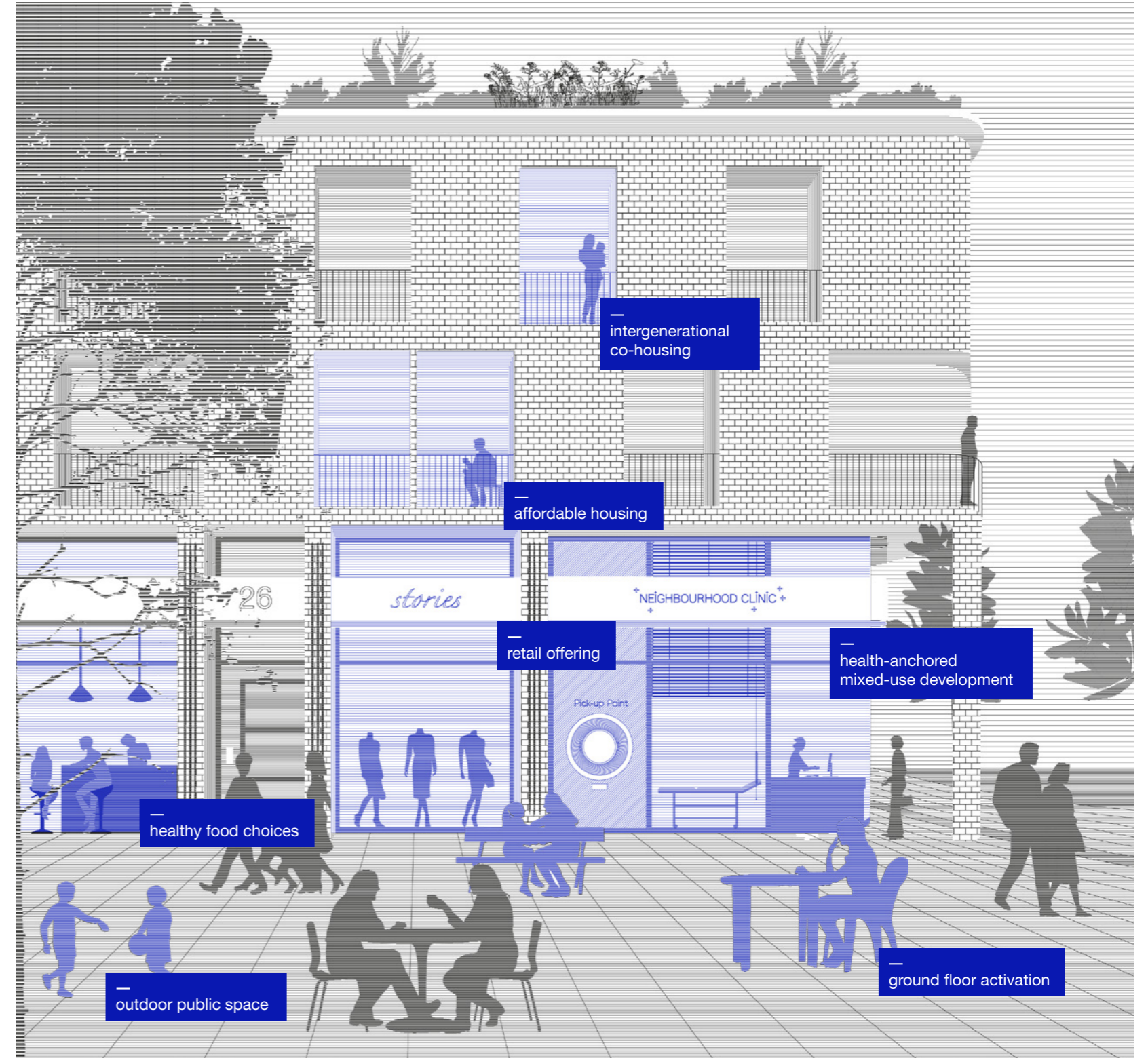*Illinois Medical District*
Chicago, USA

The Illinois Medical District comprises 2.3km^2 of medical research facilities, labs, a biotechnology business incubator, four hospitals, two medical universities and more than 40 health-related facilities. With 29,000 employees and 50,000 daily visitors, it generates US$3.4 billion in economic opportunity.[88] The District is surrounded by some of Chicago's most deprived communities and is engaged in diversifying the character of the area, reducing the existing health and income disparities and strengthening the surrounding communities. One of these initiatives is the redevelopment of Cook County General Hospital, which had stood vacant for 17 years. Past failed redevelopment attempts sought to develop the surrounding area first before tackling the hospital building; this latest initiative focuses on unlocking the value of the underutilised former hospital first in order to catalyse the regeneration of the surrounding area. The 32,000m^2 mixed-use development will provide office and retail space, a hospital museum and a 210-room hotel, as well as employment opportunities for local residents.

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A vision for a regenerative healthcare ecosystem

The future healthcare ecosystem will galvanise the economic and social benefits of its diverse spaces, as well as their medical function. Supported by greater preventative care and patient autonomy, such spaces will become hubs of regular, casual activity, supporting active, healthy and prosperous communities. Old and new hospital buildings, retail clinics, inter- and intra-generational co-living schemes and buildings will act as anchors for mixed-use developments and agents of urban regeneration.

To achieve this, healthcare providers will need to act in a complementary and unified way, building on the variety and diversity of physical healthcare entry points in neighbourhoods to maximise access, optimise efficiency and improve overall quality of service.

Simultaneously, developers, planners and designers need to keep putting healthcare uses at the forefront of mixed-use urban (re)development masterplans and leverage the potential of both existing and new assets. In the future, a healthy neighbourhood will be the pillar for social cohesion, economic prosperity and cultural resilience.

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Key recommendations

HEALTHCARE PROVIDERS AND OPERATORS
Build on integrating physical healthcare access points (hospitals, retail, urgent care clinics) to maximise reach, quality and efficiency.
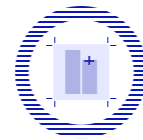
DEVELOPERS, ARCHITECTS AND ENGINEERS
Use healthcare facilities at every scale as springboards for community revitalisation and transformational change of areas and their surroundings.

POLICYMAKERS
Enhance socio-economic policy frameworks that allow health-centred development initiatives to emerge and thrive as hubs, boosting the economic activity of areas (through employment, innovation, medical tourism hubs, tax revenue generation, etc.).

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Diffusing the monolith

In a future when healthcare systems in cities will be characterised by the need to provide on-demand, high tech, high-touch, bespoke and preventive services, the role of the built environment and its buildings will be more important than ever. The 'monolithic' physical form of conventional hospitals will need to adapt to an increasingly health-aware population, and an urban context where traditional boundaries between modes and activities, public and private, and inside and outside are no longer fixed. At the same time, they will need to remain equipped to respond rapidly and locally to health crises.

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As well as rethinking the typology of existing and new hospitals to better align with emerging healthcare delivery models, diffusing the monolith means changing the distribution of healthcare beyond the boundaries of single hospital buildings.

RETHINKING THE HOSPITAL

Medical and surgical processes usually determine the form of hospital buildings; loyal to the architecture principle of 'form follows function', hospitals have allowed flows and procedures that saved lives to shape their spatial configuration. A general focus on in-patient wards, while responding to clinical and technological developments, was and still is prominent in hospital building layouts.

In the future, developments in preventive care and telemedicine will transform usage patterns and reduce the number of people requiring treatment in traditional hospital environments. At the same time, utilising the benefits of AI, bespoke care and treatment plans will result in faster, more effective therapies that reduce the time patients spend in hospitals.

While the number of patients treated in the UK has increased significantly over the past 30 years, the number of NHS beds has more than halved, from around 300,000 in 1987/88 to 141,000 in 2018/19,[89] the result of strategies to reduce hospital admissions and faster release times. The same trend is observed in national healthcare systems worldwide and calls for corresponding design strategies that target the mismatch between current hospital infrastructure and the type of activities taking place in them.[90]

The Woman Mother Child Centre in Maxima Medical Centre in Veldhoven, The Netherlands, uses an integrated model of care covering all stages of pregnancy and childbirth (prenatal, labour and delivery, postnatal, breastfeeding support and discharge). In practice, this means all stages of the process take place in one room, reducing the hospital footprint and freeing up space for other medical and non-medical uses. This patient-centred approach also keeps families together and connected throughout the process.[91]

In London, Guy's Hospital Cancer Centre (see case study) also follows a patient-centred design strategy. Its 14 storeys are split into three 'villages' each with their own medical focus, clinical and non-clinical spaces, and discrete stairs and lifts helping to bring a human scale.

HEALTHCARE EVERYWHERE: THE NEW LOCALISM

As well as rethinking the typology of existing and new hospitals to better align with emerging healthcare delivery models, diffusing the monolith means changing the distribution of healthcare beyond the boundaries of single hospital buildings. Future healthcare assets and infrastructure will be smaller, better connected and strategically dispersed in cities, with a stronger local presence and identity;

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CASE STUDY
*Arup CareBox
Dublin, Ireland*

→

CareBox is a series of design guidelines for scalable, modular and rapid solutions to solve the problem of intensive care and ward bed shortage during a pandemic outbreak. It can be quickly transported, deployed and implemented to provide additional capacity in a range of settings. These include healthcare campuses, where CareBox can be attached to existing infrastructure to provide a 'plug-in' hospital, connecting healthcare practitioners with medical gases and other vital treatments and services. It can also bring health services to buildings such as convention centres or sports halls, converting them into efficient-to-operate healthcare venues. It could likewise enable additional wards in vacant commercial premises in city centres, locations where there is limited external space for conventional field hospital solutions. CareBox can be particularly effective in developing countries or countries with limited existing healthcare infrastructure. Once implemented, it can continue to provide value to local communities as an ongoing medical facility or by being redeployed to neighbouring locations.

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CASE STUDY

Guy's Hospital Cancer Centre London, UK

(→)

Guy's Hospital Cancer Centre, London, applies a human scale and patient-centred design strategy to improve spatial utilisation and patient experience; its 14 storeys are clustered into three stacked 'villages', each related to a patient need (chemotherapy, radiotherapy, one-stop clinic). Intuitive wayfinding and local lifts and staircases within each village optimise patient movement, while design interventions maximise access to nature and natural light. The boundaries between care and treatment spaces are flexible, varying from blurred to clearly separated, in contrast to traditional hospital buildings. This flexible spatial approach also allows the building to adapt to future care or treatment needs.

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their design and execution will effectively blur the boundaries between architecture and urban planning.

A broader understanding of healthcare that considers the full spectrum of health – from strengthening and preserving health to acute and emergency interventions, and the treatment of illnesses and long-term care – will lead to the diversification and decentralisation of healthcare spaces tailored to the levels, type and location of provision required. Parts of the healthcare pathway can be provided in community settings, for example outpatient appointments, diagnostic tests or chronic disease management.[92] Likewise, our understanding of healthcare assets could be expanded to include the likes of parks, active transport infrastructure and community centres (see chapter 1).

Deinstitutionalisation, a shift in the treatment of patients from the hospital into the community, has already transformed mental health provision in some countries, with the aim to improve the patient experience and recovery shown to be impeded by the hospital environment. In the US, Ascension, a healthcare organisation focusing on community-centred care provision closed the acute services of its Providence Health System in Washington DC. Since most people spend only 15% of their life in acute healthcare settings, Ascension aims to shift the focus of Providence towards community and population health and wellbeing initiatives and services such

as care coordination, virtual health and telemedicine, home and senior care as well as behavioural change.[93] In the future such private/public provision models will be enhanced by centralised medical records, securely accessible to all practitioners, with care – particularly at its primary stages – coordinated with local doctors to improve patient outcomes.

POP-UP CARE

Beyond the physical and digital decentralisation of healthcare into non-traditional settings and embedded across cities and into lifestyles, the possibilities of targeted data-driven interventions promise a transformation of public health delivery across cities and nations.

AI and advanced data analytics are opening up new opportunities for more targeted population health management programmes. Where providers used to target broad groups defined around health conditions and basic risk factors, advanced and intelligent analytics now allow the granular segmentation of individual and small groups of patients based on complex risk and health data. The analysis of the interaction of multiple health factors combined with the wider social determinants of health such as isolation, affluence and digital fluency, allows the prioritisation of interventions for patients at the highest risk.[94] Predictive analysis of such data combined with spatial mapping can furthermore support strategies for prevention among future risk groups.

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This could include spatial interventions at a neighbourhood scale, such as access to parks, walking and cycling infrastructure, or screening or education programmes delivered in the community.

For example, a mobile screening unit deployed into neighbourhoods identified as high risk in Leeds, UK, delivers lung cancer screenings at the doorstep of target groups. The initiative aims to detect cancer early to increase the chances of survival.[95]

In addition, mobile and pop-up healthcare services and facilities can support underserved and remote communities where health infrastructure is insufficiently available. This has the potential to alleviate health inequalities and can provide flexible interim and permanent solutions in service deserts and areas of peaking demand, while informing longer-term development strategies for health infrastructure.

Pop-up clinics and mobile units also play a key role in disaster and emergency situations where they can provide a fast and targeted response. An example for use during a pandemic outbreak is a concept for a mobile testing unit developed by M-Rad, a Californian architecture and design studio. The design features a repurposed trailer fitted with antiviral materials (copper) to minimise disease transmission while bringing testing capacity into communities.[96] This facilitates testing in target areas and during lockdowns with minimised contact and travel beyond local areas.

Retrofitting existing transport systems can also help to alleviate local pressure.[97] In response to the COVID-19 pandemic, authorities in France and India converted train carriages for medical use, supporting patient transport as well as isolation and treatment.[98,99] Such hybridised systems have the potential to play a longer-term role in distributed healthcare ecosystems as part of a more resilient approach, helping to better distribute demand as well as providing additional capacity quickly in emergencies. 'Healthcare on wheels' could be further advanced through automation, with autonomous vehicles and robotics facilitating provision into high-risk areas and alleviating the pressure of staff shortages.

RISING TO THE CHALLENGE

Designing urban healthcare facilities that can scale, flex, morph and adapt in response to temporary demand surges will be a key component of the future urban healthcare ecosystem. Recent experience from the COVID-19 pandemic shows the need for this to be integrated across both healthcare and non-healthcare facilities to ensure overall resilience.

For hospitals, this means that the ability to repurpose internal spaces to increase capacity as well as the ability

>50%
reduction of NHS beds in the last 30 years - from 300,000 in 1987/88 to 141,000 in 2018/19 - as a result of strategies to reduce hospital admissions and accelerate release times.

15%
of a person's life is spent in acute healthcare settings.

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SEE ALSO

Patient Hotel Rigshospitalet
Accommodation for long-term care patients

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CASE STUDY

Ghana District Hospitals
Ghana

Part of the country's District Health Programme, the seven campus-style district hospitals were created to respond to the growing demand for healthcare services and hospital facilities. Featuring a nimble construction model and responsive design based on a modular system, the hospitals can adapt to meet local conditions and needs as well as budgetary constraints. Each hospital comprises steel-framed, single-storey buildings and is organised around a central clinical building with a network of interconnected wards and covered walkways. The hospitals are energy efficient and their spaces can be used as accommodation for staff and for education purposes for the community, focusing on preventive care, child nutrition and sexual health.

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to plug additional infrastructure into existing buildings will be necessary requirements for future design.

Depending on the intended use, converting existing facilities (such as operating theatres, wards and support areas) into temporary pandemic wards includes a series of considerations related to construction disruption and safety during modifications, patient traffic flows and circulation, as well as logistics flows and waste management, with recent examples of hospitals repurposing their spaces to respond to COVID-19 highlighting the importance of designing hospital facilities with extreme events in mind.[100]

The hospital tower of the Rush University Medical Center, Chicago, was specifically designed to provide treatment in the case of infectious disease outbreaks. Following the 9/11 terrorist attacks, the need for a specialised area that could expand to handle large-scale, natural or man-made emergencies was key. The building includes 40 negative pressure rooms and three 20-bed units which can be isolated from the rest of the building with separate air handling. Any wing of the hospital can also be converted into a negative pressure ward within two hours.[101,102]

Beyond internal spaces, hospitals are also repurposing areas such as car parks to increase their capacity during

demand surges and to prevent other patients from contracting infectious diseases. In Seattle, University of Washington (UW) Medicine turned one floor of a multi-level car park in one of its medical centres into a drive-through COVID-19 testing clinic for employees.[103] The clinic used medical tents to benefit from the airflow of the non-enclosed car park and basic signage to help drivers navigate the facility. Similarly, a floor of a military hospital car park in Bahrain was converted into a makeshift Intensive Care Unit (ICU) with 130 beds for COVID-19 patients, part of a wider scheme to increase overall hospital capacity through similar field units across the country.[104]

It is important to note that the success of conversion and expansion examples such as these lie in the ability of the hospital system to accommodate 'plug-in' solutions, either within or adjacent to existing building infrastructure.

However, finding space within the building footprint of a hospital is not always possible. In this case, modular, flexible and mobile solutions have the potential to increase hospital capacity. Self-contained, mobile operating theatre and ward units can be repurposed to isolate virus-infected patients, decant existing internal space, maintain critical day surgery operations away from pandemic treatment zones[105] or to function as ICUs.

Deinstitutionalisation, a shift in the treatment of patients from the hospital into the community, has already transformed mental health provision in some countries, with the aim to improve the patient experience and recovery shown to be impeded by the hospital environment.

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SEE ALSO

Paris '15 minute City'
Urban planning initiative for neighbourhood reorganisation

Mobile dental surgery
Refurbished trailer providing dental care

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CASE STUDY

Airbnb 'Open Homes'
San Francisco, USA

Airbnb's Open Homes initiative provides short-term free or subsidised housing for those in need, including medical stays, disaster relief, and refugees and asylum seekers. Hosts can either open their homes for free or have their charges subsidised by Airbnb and participating organisations. Airbnb waives its fees for Open Homes participants. The initiative includes a partnership with Cancer Support Community, a global professionally-led charitable network of cancer support, to facilitate free accommodation for low-income patients and carers travelling over 50 miles to receive treatment. Although organised and validated through the Airbnb platform, Open Homes effectively works as a decentralised, local solution to short term accommodation needs. For hospitals where capacity is available nearby it effectively acts as an extension of a facility's physical space to support improved access to treatment.

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In Italy, CURA, an open-source design solution, converts shipping containers into plug-in ICUs with biocontainment abilities; the plug-in units can easily be transported and quickly installed near to existing medical facilities or field hospitals.[106,107]

Non-medical spaces also have the potential to be repurposed to increase healthcare capacity during emergencies. The first quarter of 2020 saw many countries and national healthcare systems adapting stadia, sports facilities, dormitories and other community facilities, conference centres, hotels and even airports into efficient-to-operate healthcare sites. Examples include the conversion of Glasgow Airport's 17-acre car park into a drive through testing facility;[108] and the use of the runway at Istanbul's Atatürk Airport as a COVID-19 field hospital.

Significantly, any rapid transformation of space for medical use requires an equally rapid expansion of supply chains and labour supply. Even temporary adaptations to the built environment must consider these fundamental systems – whether pharmaceutical production, PPE, or staff – in tandem to avoid creating new capacity that is unusable.

Future planning for healthcare crises like COVID-19 which cause temporary demand surge and are likely to be periodical should involve both medical and non-medical facilities and spaces. In every case, the right infrastructure for the right space, at the right time will determine the efficiency, effectiveness and overall success of such projects.

Mobile and pop-up healthcare services and facilities can support underserved and remote communities where health infrastructure is insufficiently available.

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EIR MEDMODULAR
New York, USA

These competitively priced modular hospital rooms can be used upon arrival and focus on workflow optimisation, the use of new medical technologies, and customised design to improve patient experience. Click to read more on Arup Inspire

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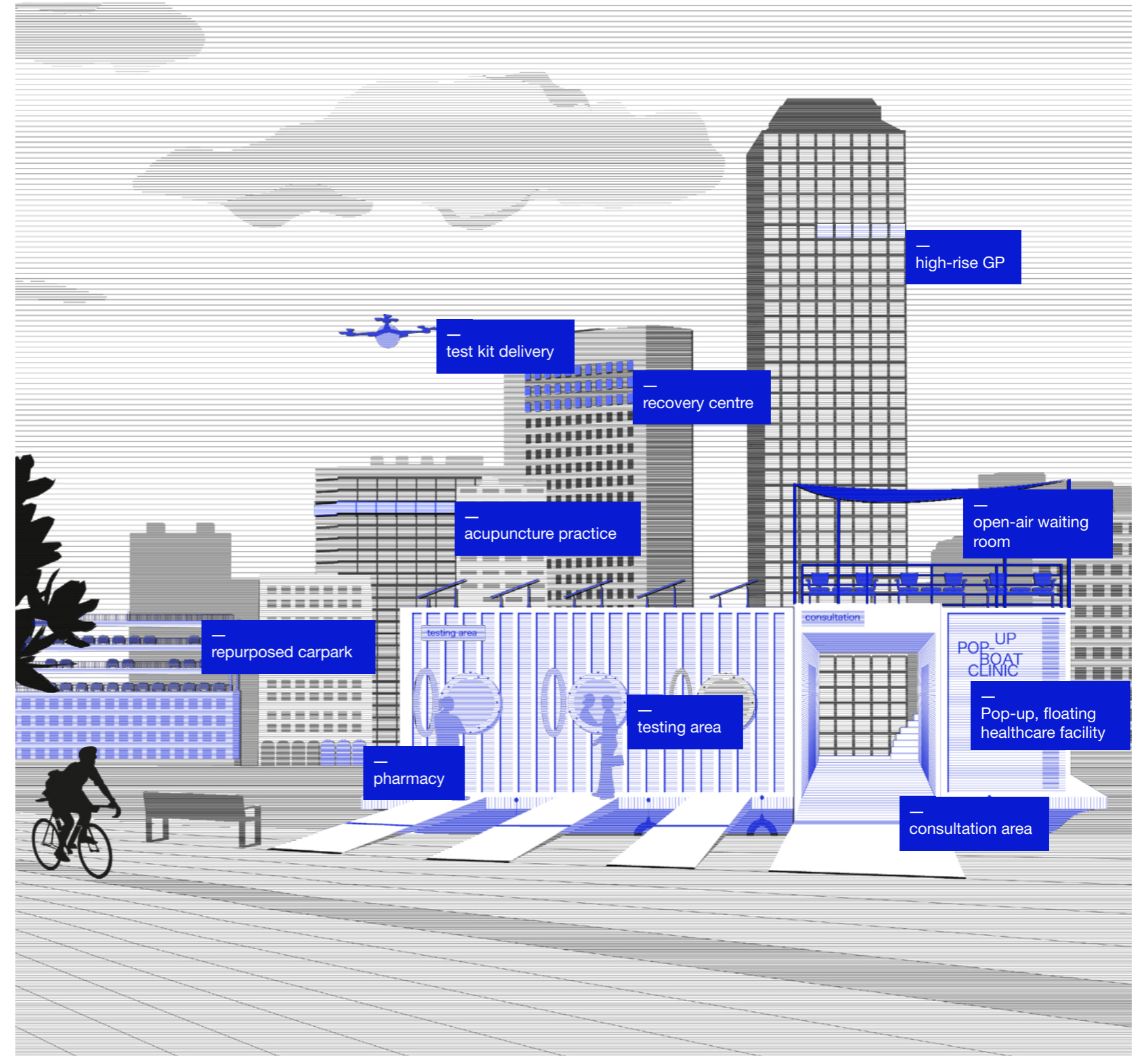SCENES   CONCLUSION

A vision for a permeable healthcare ecosystem

Future healthcare systems will be characterised by a distribution of services, both within healthcare facilities and across the communities and cities these facilities serve. This transformation will be driven by preventive healthcare modes, lifestyle and behavioural changes, technological advances and urbanisation, as well as temporary and periodic climate and global health crises.

In this new landscape of healthcare delivery, hospitals will adapt their spaces and infrastructure to align with patients' needs, match care and treatment functions, elevate the user experience and optimise operational efficiency. Hospitals will be agile, flexible, interconnected units that can scale up and contract to respond to demand surges.

Healthcare delivery will permeate the urban fabric and care access points will be embedded into communities and non-traditional settings and spaces. Retail health clinics will keep strengthening the capacity of national systems and pop-up, mobile healthcare touchpoints, underpinned by AI and advanced data analytics technology will reach patients and vulnerable populations in their communities.

— high-rise GP

— test kit delivery

— recovery centre

— acupuncture practice

— open-air waiting room

— repurposed carpark

testing area

consultation

POP-UP BOAT CLINIC

— testing area

— Pop-up, floating healthcare facility

— pharmacy

— consultation area

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Key recommendations

HEALTHCARE PROVIDERS AND OPERATORS

Diversify built asset portfolios with buildings, infrastructure and spaces that are modular, flexible and able to scale through plug-in solutions to enable lower-cost adaptability and resilience.
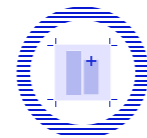
DEVELOPERS, ARCHITECTS AND ENGINEERS

Make healthcare professionals, local communities and patients integral to the design and decision-making process to strengthen the human-centric approach of healthcare facility design.

POLICYMAKERS

Establish a flexible policy framework to enable local and central governments to facilitate mobilisation and coordination between public and private sector stakeholders for mutually beneficial use of space and functions across an expanded 'site'.
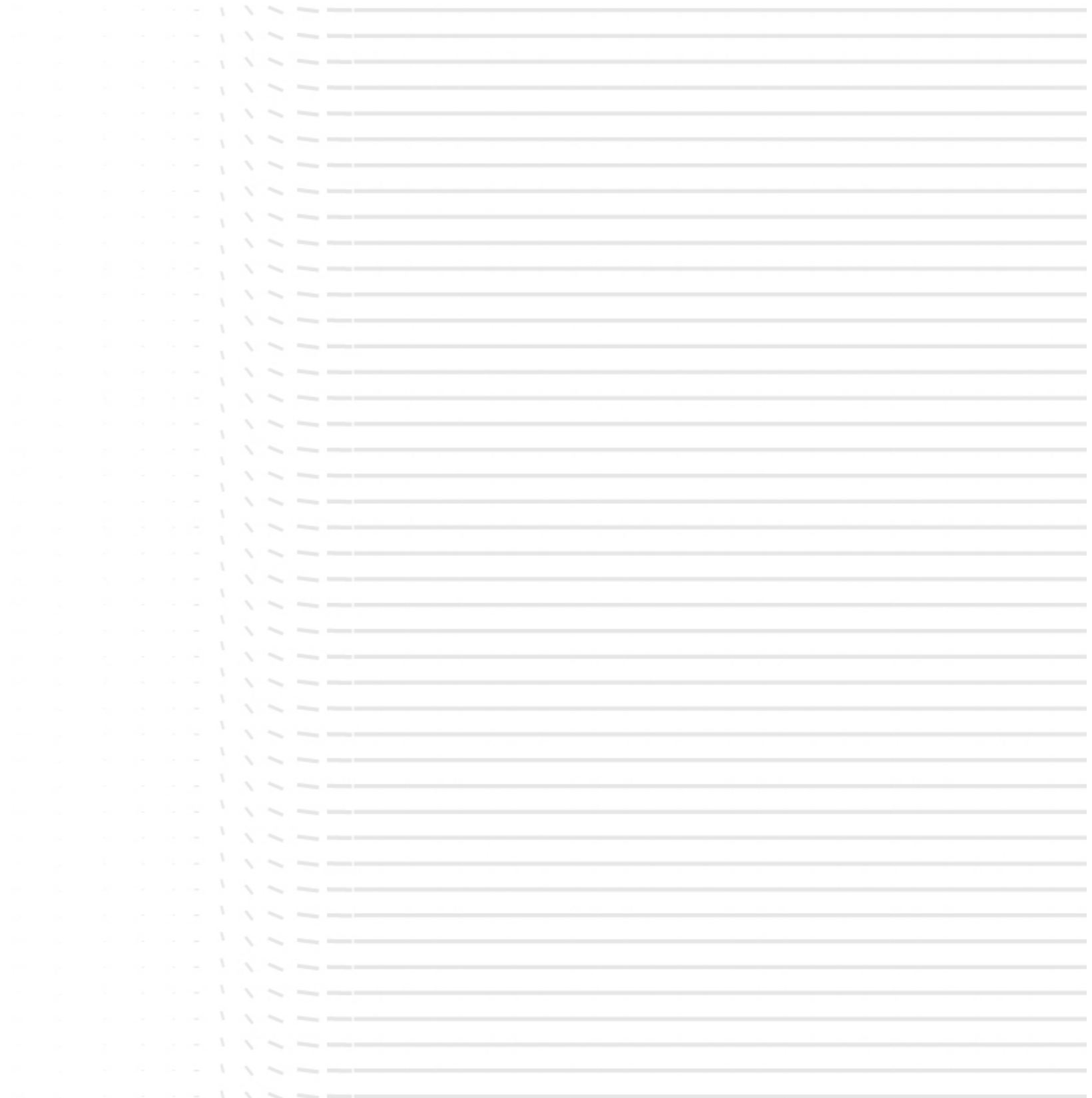
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Behind the scenes

The operation of future healthcare systems will inevitably become more complex, driven by the demands of personalised medicine, greater numbers of touchpoints – both on- and off-line – climate change-driven environmental extremes, and global health crises that will make safe, accessible and consistent services more challenging. The human and digital systems that underpin healthcare systems' performance will evolve to deliver improved access and outcomes while the capacity to respond to sudden demand will surge, enabled by advances in logistics, resilient infrastructure, automation and communication technologies.

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MEDICAL DATA

The digitisation of healthcare will support improved health outcomes through personalised treatments, the automation of services, and the application of AI to achieve medical breakthroughs from dementia to cancer (see chapter 3), and schemes such as the UK's £250 million National Artificial Intelligence lab will have as much impact on the efficient operation of hospitals and healthcare infrastructure as on the health of patients.[109]

Behind every anticipated medical breakthrough will also lie the aggregation and analysis of medical data, a process that is being accelerated massively by AI with Machine Learning, seen recently in the hunt for a COVID-19 vaccine.[110] New York-based digital platform Owkin is applying Machine Learning to patient data at multiple medical institutions. This 'federated' approach means that data remains secure within each institution while allowing Machine Learning models to work at scale, identifying target patient groups and predicting their response to treatment. Such national and international networks of medical data and intelligent processing promise to reduce the human resource burden of medical research, increasing capacity and speed of discovery, while also lowering the costs of drug development.

On the ground diagnosis and treatment will also see the benefits of a networked approach through the use of online treatment guides informed by machine learning and collective medical experience. These systems work by encoding thought processes and decisions as clinical data. International schemes such as the Human Diagnosis Project or 'Human Dx' show the potential for a common frame of reference and step-by-step treatment maps to treat any patient.[111] Such tools could radically democratise specialist knowledge, with implications for medical centres in remote or rural locations, under-resourced healthcare systems, and in the diagnosis of rare illnesses.

CURING INEFFICIENCY

Individual hospital funding mechanisms clearly vary, with capital budgets and operational budgets managed separately in many cases. A more holistic approach is needed to realise future operational improvements, whereby design and capital spend allow for reduced operational expenditure over the long term, for example through layout flexibility and low or zero-energy buildings.

Much has been made of the potential for Digital Twins – virtual models of physical entities – to improve the efficiency and smooth operation of physical assets from power stations to transport infrastructure by integrating data from multiple sources including BIM and real-time sensor networks.[112]

400,000

sign-ups to the GoodSAM pandemic volunteer support scheme within 24 hours of launch.

30%

of a nurse's time in the US is currently spent on non-value-added tasks.

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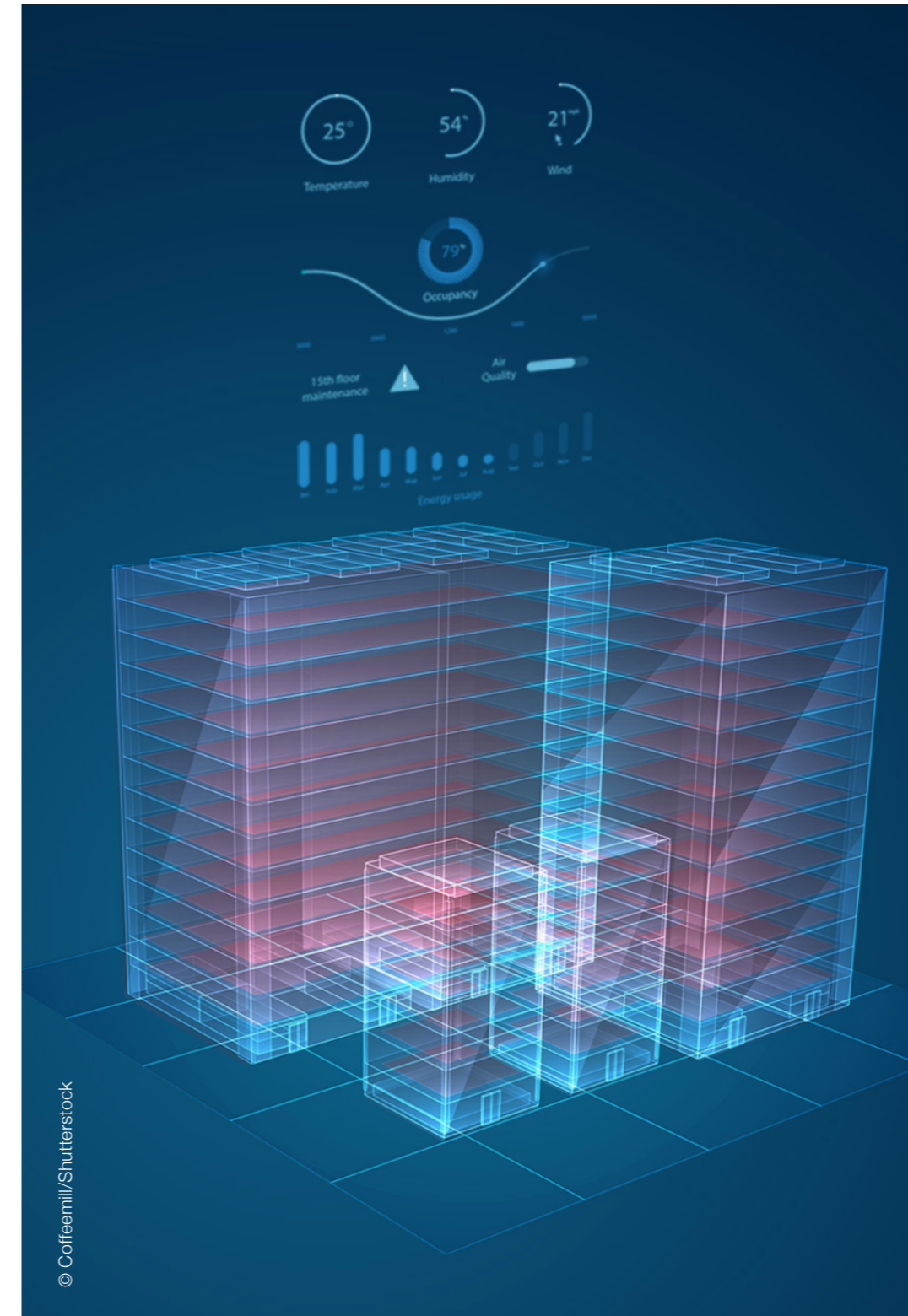
CASE STUDY

Digital Twins for Hospitals Boston, USA

A hospital Digital Twin combines live data on performance and patients, ward configuration, equipment and resource use into a digital model in order to test scenarios, inform decisions and improve efficiency. Various companies, including Siemens and GE Healthcare, are now providing these systems, combining the spatial configuration of a hospital and its wards with real time data from its associated systems, including ambulances, energy use and medical supply levels. Hospital managers are able to understand present and future capacity, staff flows, optimal floorplan arrangements and care approaches. The use of Machine Learning and AI also supports scenario development, modelling the real impacts of potential changes or shocks to inform the redesign and reconfiguration of existing hospitals and the design of new ones.

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CASE STUDY

*Matternet Station
San Francisco, USA*   →

Autonomous drone logistics developer
Matternet has designed a new delivery
port for use by medical facilities that
promises faster turnaround times for
blood samples, pathology specimens and
medical supplies. The 3m-tall Matternet
Station includes a hatch for loading and
unloading of consignments, a raised
landing platform, and a segmented
canopy that opens and closes for take-off
and landing. Once a drone has landed, the
station automatically replaces its payload
and battery, while remote operators use
a dashboard to schedule collection and
delivery. As well as reducing the cost and
time associated with medical logistics,
the system also allows the greater
centralisation of laboratories, reducing the
space and cost requirements of smaller
medical facilities.

© Matternet

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INTRODUCTION PREVENTIVE ANYTIME, ANYWHERE HIGH TECH, HIGH TOUCH BESPOKE FOR ALL CATALYST FOR URBAN REGENERATION DIFFUSING THE MONOLITH **BEHIND THE SCENES** CONCLUSION

Digital Twins are particularly suited to the complexity of hospitals, combining multiple systems and spaces in order to inform decision-making and strategy without risking ongoing hospital operation or patient wellbeing.

Managers of hospitals and healthcare facilities will be able to use a Digital Twin of their facility to understand capacity, resource flows and optimal ward arrangements and how they interrelate in real time. Further, integrated AI will allow operators to test alternative scenarios – from floorplan reconfiguration to supply shortages – with integrated outcome predictions. Analysis suggests that the use of hospital Digital Twins could result in 900% of cost savings, and an almost two-thirds reduction in medical emergencies,[113] the result of faster patient turnaround, capacity increases and reduced costs. Spatially, scenario modelling within a Digital Twin will support decision making around new configurations, furthering the argument for flexible layouts and support systems.

ADAPTIVE STAFFING

While we have seen the potential role that robotics can play in patient care (see chapter 2), their presence will also affect hospital workflow and staffing requirements. Automated logistics systems and medical assistance robots, such as US-based 'Moxi', are designed to only execute non-patient facing tasks, including delivering samples or

retrieving supplies. This could increase nursing capacity, with estimates suggesting that nurses currently spend up to 30% of their time on non-value-added tasks.[114] Deployed at scale throughout a hospital, or even individual units in smaller medical centres, robotic assistants could improve the utilisation rates of valuable human medical professionals. Their increased use may however be contingent on, or even drive, robotically-accessible hospital design, for example laboratory or storage facilities.

For healthcare professionals, a new wave of smartphone apps and digital platforms is already disrupting established staffing models. Their greater proliferation and development could support a more agile and resilient hospital workforce. One example in use across England and Wales, Patchwork, matches healthcare organisations with workers to fill temporary staffing vacancies, from admin roles to qualified doctors and nurses. The tool integrates pre-employment checks, compliance and payroll, acting as a digital 'staff bank', challenging the conventional agency model and reducing associated costs.[115]

Greater integration and normalisation of digital marketplaces for staff and volunteers will support flexible healthcare systems, better able to reach surge capacity both locally in the event of emergencies, or across a

To realise future operational improvements, a holistic approach is needed whereby design and capital spend allows for reduced operational expenditure over the long term, for example through layout flexibility and low or zero-energy buildings.

© Lifebank

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CASE STUDY

LifeBank
Lagos, Nigeria

LifeBank is designed to tackle the shortage of essential medical supplies in hospitals across Africa, including blood, oxygen and vaccines. Created in Lagos, Nigeria, the digital platform encourages individuals to register to donate blood, and subsequently connects them to their local blood bank. Supplies are then couriered by motorbike in response to real-time hospital demand. The system is effective as it can respond rapidly, with a decentralised network of donors, blood banks, medical suppliers and hospitals. Central to the organisation's mission is its belief that poverty should not be a barrier to healthcare access. As such, it provides free blood and oxygen to those that cannot afford to pay hospital bills, funded by private sector funding partners. LifeBank has already moved over 21,000 products across 1,000 hospitals, saving more than 7,100 lives.

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CASE STUDY

GoodSAM
London, UK

The UK's 'GoodSAM' digital platform coordinates the sign-up and deployment of NHS volunteer responders. The public volunteer scheme was established to support the health service and care sector during the early stages of the COVID-19 pandemic and received 400,000 sign-ups within 24 hours of launch. Healthcare professionals can directly refer individuals needing assistance, while volunteers must complete a series of checks, including identity and health status, before being offered local tasks via the app. These include driving patients to and from appointments, delivering medicine from pharmacies, and making regular phone calls to check in on people self-isolating or shielding. These tasks support vulnerable or isolated people potentially cut off from friends and family, and those most at risk from contracting COVID-19. The platform has been shown to enable the rapid, crowd-sourced expansion of support networks, and support healthcare system resilience.

© CC0 Sallie

whole network for prolonged periods.[116] Their greater use could also support a better life-work balance by giving individuals greater control over shift times and encourage greater utilisation of older workers through shorter and less frequent shifts. However, issues around precarity and skills will need to be addressed to avoid exploitation and maintain safety.

HEALTHY ASSETS

Pharmacies and medicine sellers more broadly are an integral part of healthcare networks that should complement rather than compete with formal providers.[117] Indeed the greater willingness of consumers to buy medicines online and the increase in diversity of distribution points, such as retail clinics, will support greater decentralisation and thus system resilience.

For the operation of hospitals themselves, diversifying supply-chains, increasing self-sufficiency and reducing resource-use where possible will leave them better able to cope with extreme weather events and disruption as well as reducing their environmental impact. Schemes in developing economies have demonstrated how to remain agile with fewer resources, including 'LifeBank', a blood and medical products collection and delivery scheme that responds in real-time to hospital demand through a decentralised network of suppliers, donors and delivery vehicles.[118]

Incorporating drone delivery into the building's fabric, for example with drone ports built into the windows of wards or patient rooms, could reduce the need for road traffic as well as limiting on-site storage and distribution needs.[119] Further, it would ensure ongoing delivery of vital food and medicines in the event of road closures, power outages or non-availability of logistics workers – requirements that are crucial to medical centres in rural sites or areas prone to natural disasters. Indeed, while the global COVID-19 pandemic is front of mind, the prolonged instability and likely disruption caused by climate change must not be forgotten.

The use of rainwater harvesting for use in greywater systems, as well as on-site power generation, for example through solar PV, will increase site resilience as well as reducing carbon emissions. Yet on-site renewables must come hand-in-hand with reliable and efficient battery storage to ensure the system as a whole is resilient, particularly given the risks inherent in spaces and systems across hospitals, such as operating theatres and ventilators.

More broadly, the health sector must recognise and take responsibility for its climate footprint. Health Care without Harm's report, *Health Care's Climate Footprint*, delivered in collaboration with Arup, estimates a climate footprint of 4.4% of global

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net carbon emissions due to the healthcare sector – equivalent to 514 coal-fired power plants.[120] Seventy-one per cent of emissions are attributable to its carbon-intensive supply chain, including the production transport and disposal of goods and services. As well as reducing emissions from healthcare facilities themselves, the sector must invest and support the decarbonisation of local and national energy systems and zero-emissions procurement. Given their additional impact on air quality and associated health impacts, the use of electrified transport and renewable energy sources over diesel and petrol fuels must be an immediate goal.

Lastly, healthcare facilities also have a responsibility towards low or net-zero construction and to acknowledge the environmental impact of the materials they build with. Materials such as blended cement, concrete that stores CO_2, and timber can reduce the carbon impact of new hospital buildings, the latter seen in the UK at the Dyson Centre for Neonatal Care at the Royal United Hospital in Bath.[121] Here, large cross-laminated timber (CLT) panels comprise the main structure, providing an efficient and clean construction process, as well as substantially reduced embodied carbon compared to steel and concrete.

4.4%

of global net emissions are due to the healthcare sector – equivalent to 514 coal-fired power plants.

71%

of healthcare emissions are attributable to its carbon-intensive supply chain, including the production transport and disposal of goods and services.

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ZIPLINE
San Francisco, USA

A drone delivery system dispatches critical medical products in underserved areas, complementing or replacing existing delivery methods, speeding up deliveries and increasing supply-chain resilience. Click to read more on Arup Inspire.

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A vision for an efficient healthcare ecosystem

Future healthcare ecosystems will have to operate in an unstable environment – both physically, in terms of extreme weather events and natural disasters associated with climate change, and man-made critical events including terrorism and infrastructure failure – as well as socio-economically, due to changing demographics and the varied fallout from the COVID-19 pandemic. Yet the application of technology, whether to design new therapeutics or improve hospital efficiency, alongside supply-chain and resource strategies that encourage a networked approach, will support system resilience.

Larger healthcare assets, like hospitals, will see the biggest shift with automation and flexible layouts increasing operational capacity and improving outcomes. However, the contribution of healthcare systems to climate change must not be overlooked, with the potential to become a beneficial actor with cost and self-sufficiency benefits as well as for human health.

- on-site renewables
- lights-out operation
- low carbon supply chain
- medical drone delivery
- FM room control panels
- cleaning bots
- delivery bot
- automated logistics
- Digital Twin dashboard

PATIENT WARD

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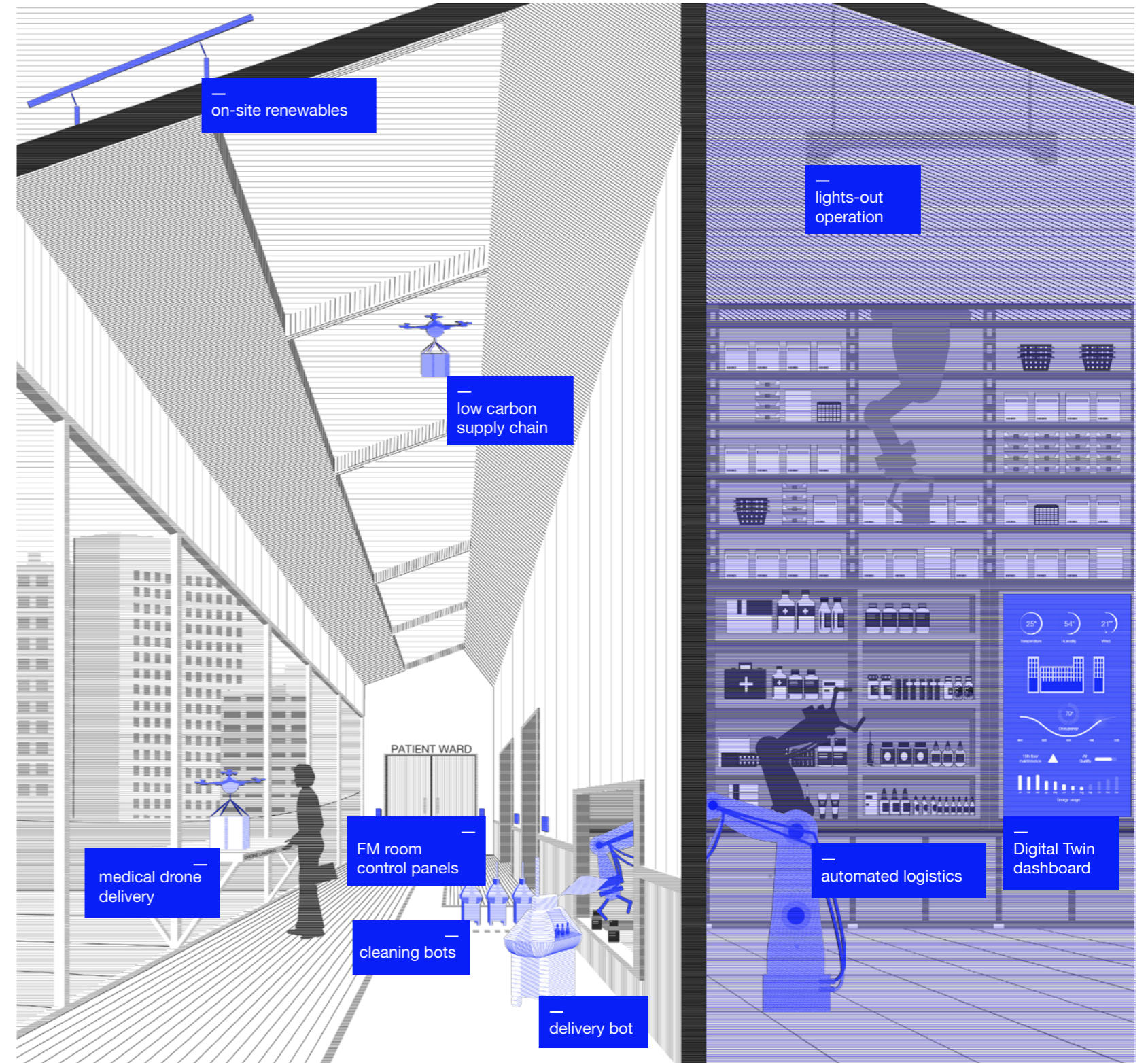
Key recommendations

HEALTHCARE PROVIDERS AND OPERATORS
Invest in national, cross-organisational digital systems enhanced by AI to help monitor, predict and plan everything from supply levels and floorplan layouts to clinical trials.

Larger healthcare asset operators should reduce building resource needs to increase resilience and self-sufficiency and cut carbon emissions.
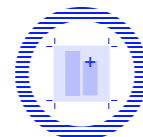
DEVELOPERS, ARCHITECTS AND ENGINEERS
Work to accommodate automation alongside human healthcare professionals, providing flexible and digitally-enabled spaces and networks to increase capacity.

POLICYMAKERS
Incentivise and legislate for more integrated and adaptable supply chains to better cope with uneven and unstable demand and improved system resilience.

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Conclusion

The future of healthcare will be a story written and told outside the hospital. As this report demonstrates, change is already visible in the shift towards preventive care models and the disruptive advances in digital and mobile technology that are leading to new ways of accessing and delivering healthcare services.

It is clear that innovation in healthcare isn't determined by technology alone, nor is it restricted to direct improvements in human health and wellbeing. Advances in biological science, for example, will improve human health through new cell, gene and RNA therapies; but in the coming decades a larger impact is expected in other sectors, including agriculture, consumer products and energy production. This in turn could support improved nutrition, personalised care and a healthier environment.[122]

At the same time, cities will play a major role in keeping people healthy. Spaces such as public parks and community centres as well as infrastructure systems such as active transport networks will function as local or regional health assets promoting an active, healthy lifestyle for all and enabling preventive approaches to healthcare. Asset-based strategies that prioritise healthcare will catalyse the revitalisation of neighbourhoods and districts by connecting strong, but mostly disconnected, sectors delivering economic and social value and strengthening community cohesion and resilience.

The trends which are analysed in this report and which will likely shape the future of healthcare indicate that it will take a convergence of innovations and interventions from various sectors and industries to achieve improved

operational capacity and efficiency in healthcare delivery. Researchers, healthcare professionals, patients, technologists, hospital operators, designers, architects, engineers, planners, real estate developers and policymakers will need to form a common front where healthcare delivery and access is founded on education, inclusivity, equity and resilience.

A common understanding of how the ecosystems outside healthcare – natural, socio-economic, technological, R&D, jurisdictional – function and co-exist will be a key factor of long-term success. Understanding of the connections like those found between biodiversity preservation and human health as well as the wider impact the protection of a natural ecosystem has on nutrition and food security, disease prevention, business and community

prosperity will pave the way to a healthy future from the microbe, to the human, to the planetary level.

A human-centred approach to healthcare means that providers should address the core of patient needs. In a future where healthcare is embedded into all aspects of everyday life, it will be crucial to understand human emotions and behaviour. As care moves away from the hospital, so does the emotional journey of patients. Healthcare systems that cater only for operational efficiency and capacity, but which fail to recognise that the human experience of healthcare extends beyond the hard boundaries of conventional medical typologies, will eventually lack the necessary influence to establish or restore trust with their patients and empower them to take control of their own health.

An integrated, ecosystem-based approach to healthcare will therefore be key in ensuring that trust, equity and ownership is nurtured, whether during a teleconsultation session, during an open, honest discussion with a doctor in a safe, familiar and comfortable environment, or in a variety of settings that span buildings (homes, offices, hospitals), places (community centre, mixed-use developments) and infrastructure networks. Only then will healthcare be able to act as a catalyst not only for total health but also wider socioeconomic, environmental and cultural resilience.

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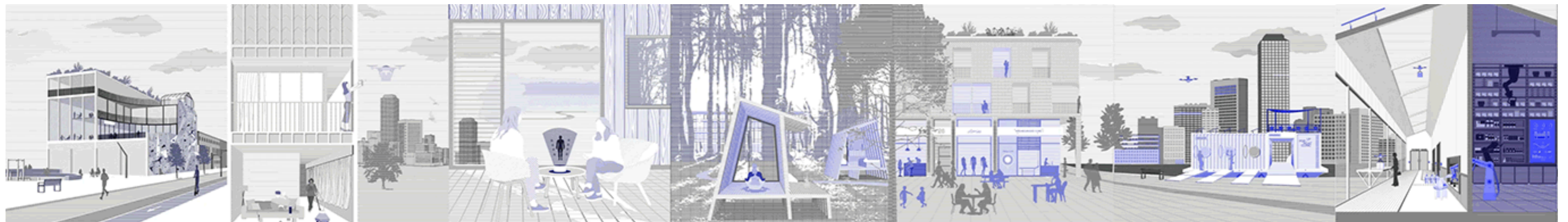
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About

The COVID-19 pandemic has caused immense suffering, disrupted economies and communities and pushed national healthcare systems to their limits. Yet even before its emergence, healthcare systems globally were facing mounting pressure to change and innovate. Affordability, ageing populations and a rise in lifestyle-related and chronic diseases are forcing us to rethink how and where future healthcare services are delivered.

Future of Healthcare Ecosystems explores the trends, drivers and contexts shaping the future of healthcare and the innovations affecting change. It covers a variety of scales from individual to urban, microbial to planetary, supported by global exemplars and emerging best practice. It also considers the long-term future of healthcare as a collaborative and multi-disciplinary endeavour, one that extends beyond built healthcare assets towards ecosystems that include transport networks, public spaces, residential and commercial design, urban planning and more.

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