# FIGHTING A PANDEMIC WITH TECHNOLOGY

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BAILLIE GIFFORD

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*Cover Image: Close up of a Covid-19 coronavirus particle.*

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# FIGHTING A PANDEMIC WITH TECHNOLOGY

*Healthcare is evolving rapidly to save lives. Our investors look at the innovative companies battling the coronavirus*

Three billion people, over a third of the world's population, are currently living in lockdown because of the coronavirus (Covid-19). Pictures from across the globe show deserted streets and the rapid construction of huge, make-shift hospitals. According to the influential epidemiologist, Professor Neil Ferguson, this is the most serious public health threat since the Spanish flu virus in 1918, which is estimated to have killed 50 million people. Thankfully, medical technology and healthcare infrastructure have developed enormously over the past century – particularly so in recent years. Professor Ferguson and others are confident that if governments and societies respond appropriately, we can dramatically reduce both the numbers who contract the virus, and the fatalities.

Healthcare, which has been slower than others to make the transition to become an online data-driven sector, is having to throw its usual caution aside and evolve at rapid speed to combat the spread of the coronavirus. Out of times of crisis comes innovation, and the convergence of technologies, including genetics, machine learning, imaging, sensors and cloud computing, is meaning that we truly are in a period of accelerated change. Here we share some of the technologies at the forefront of the efforts to diagnose, treat and prevent the coronavirus. First, we will look at some examples of technologies that will help us get through the current situation, before turning to explore how the current pandemic will lay the foundations for a new era in healthcare, which is underpinned by data and accessible online.

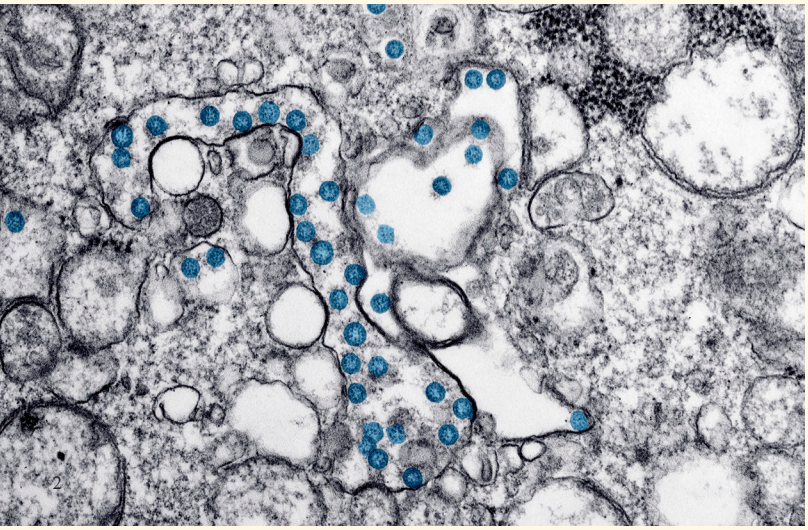
# PART 1 – GETTING THROUGH THE CRISIS

## UNDERSTANDING THE CORONAVIRUS

One of the first steps in tackling a disease is a solid understanding of its biology. This is where gene sequencing technology, particularly Illumina's next generation sequencing (NGS) technology, comes into its own, suggesting avenues for exploration that will help efforts to diagnose, treat and halt the spread of the disease.

Driven by machine learning and cloud computing, Illumina's NGS technology is six times faster than the previous generation of genetic sequencing, enabling scientists to share data and unlock the virus much faster than the 2002–03 SARS outbreak. A week after notifying the World Health Organisation (WHO) of several cases of pneumonia in Wuhan, China on 31 December, Chinese authorities confirmed that it had isolated a novel type of coronavirus. On 10 January, the first novel coronavirus genome sequence was made available online by Chinese researchers. By early February, 80 variants had been mapped, published and shared via the Global Initiative to Share all Influenza Data (GISAID). And, with the cost of sequencing reducing all the time (from circa $750,000 during the 2002–03 SARS outbreak to just above $1,000 today), it will be easier than ever before to collate an ever-larger database of genomes for researchers to study and to track how the disease mutates.

Understanding the virus' genetic blueprint gives health systems a head start on understanding how the disease is transmitted and developing accurate testing, in addition to better informing governments' responses through rapid feedback. There is much still to learn, but we are progressing every day, thanks to the power of NGS technologies.



*Coloured transmission electron micrograph (TEM) of SARS-CoV-2 coronavirus particles (blue).*

# Sequencing the Coronavirus (Covid-19) Genome versus the SARS 02-03 Genome

## Coronavirus (Covid-19) Genome

**8 Dec 19**  First patient with symptoms presents in Wuhan (another patient later found to have had same symptoms on 1 Dec 19)

**31 Dec 19**  Chinese authorities advise World Health Organisation (WHO) of pneumonia cases

**7 Jan 20**  Chinese authorities confirm the novel virus is of the coronavirus family

**10 Jan 20**  The first novel coronavirus genome sequence is made publicly available online by Chinese researchers, the search begins to find a vaccine…

## SARS 02-03 Genome

**16 Nov 02**  First case of atypical pneumonia presents in Guangdong province, South China

**11 Feb 03**  Guangdong health bureau makes first public announcement about disease outbreak

**12 Mar 03**  WHO issues a global alert

**12 Apr 03**  Canadian scientists announce they have sequenced the virus' genome

**14 Apr 03**  American scientists announce that they have also sequenced the virus' genome

**5 July 03**  WHO announces the global SARS outbreak has been contained. After this, interest fades in finding a vaccine

## DIAGNOSTICS

As the UK government's chief medical officer, Chris Witty has said, "the one thing worse than no test is a bad test." That's why companies around the globe are working hard to find a test that provides accurate results quickly, and can also be produced at speed, but we are not there yet.

At present, testing for the coronavirus is based on looking for its genetic sequence in a specialised lab, using throat/nose swabs taken by trained professionals. Results can take three or four days and the efficacy of the test depends on timing – taking it too soon or too late will produce a false negative result – and the quality of the swabbing. Being a new virus, it is difficult to assess how accurate the existing tests are, but as a general guideline, the accuracy of similar tests for influenza is only between 50 per cent and 70 per cent. This is not satisfactory when it is one of societies' main lines of defence against further spread.

Alternatives being developed include antibody testing, which can detect if an individual has had coronavirus by identifying the antibodies produced by the body to fight the virus. These tests require a single drop of blood from handheld machines, with results available in minutes. The kits are currently undergoing testing, with the hope that they can be available in the coming weeks. If they prove successful, the kits will be quickly mass-produced and rolled out across the UK by Amazon and Boots. Another avenue being explored is an antigen test, as the antigens from the virus which trigger the immune response appear in the blood system almost immediately after infection, several days before antibodies do. These are already being rolled out to frontline healthcare workers.

*At present, testing for the coronavirus is based on looking for its genetic sequence in a specialised lab…*

*© Bloomberg/Getty Images.*

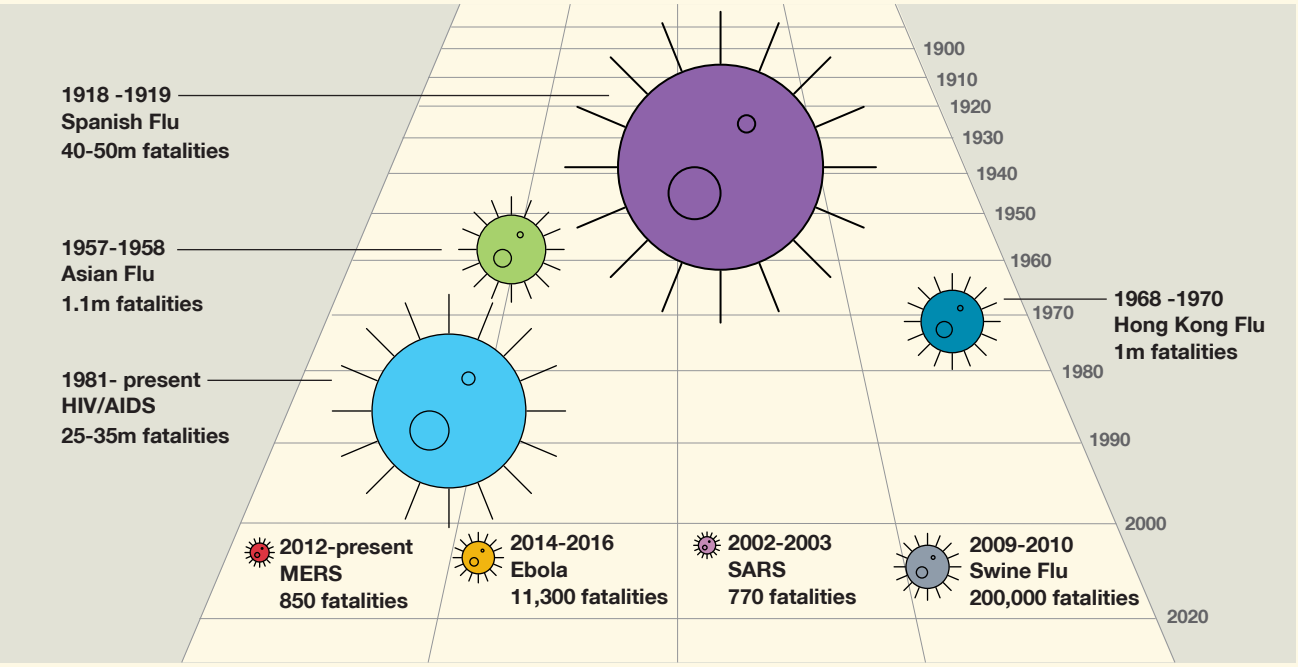
*Thanks to Butterfly Network, the technology is there, it is now a matter of ramping up production over the rest of this year.*

In the meantime, there is some evidence that the lung abnormalities caused by the coronavirus may develop before symptoms present or the virus can be detected from current testing methods. Therefore, some experts have recommended early CT screening for suspected patients. However, there is only limited CT screening capacity and clinicians need to weigh up the risk of radiation exposure. One way around this dilemma is to use portable ultrasound to detect the lung abnormalities relating to the coronavirus, an option which allows for increased capacity and less radiation for the patients. There are reports of a Spanish doctor who has successfully been using Butterfly Network's hand-held smartphone-connected ultrasound device to monitor his lungs.

Thanks to Butterfly Network, the technology is there, it is now a matter of ramping up production over the rest of this year to the point where portable ultrasound is in the hands of every doctor and, thereafter, eventually it might even be made available for patients to self-monitor. The technology is based on a semiconductor chip and powered by machine learning, enabling Butterfly Network to substantially reduce the cost and make the device user friendly for those not trained as radiologists. Over the long term, possibly within the next decade, we may be wearing an ultrasound patch that will continuously monitor our lungs and send an early signal when there is a need for intervention and isolation.

Other technologies are increasing our ability to monitor patients' conditions in real time, not just at pandemic crunch points, but as a matter of routine. Masimo is one such US medical technology company that provides non-invasive pulse oximetry sensor technology. This measures the oxygen level in the blood and is a key component in critical care. The company is the global leader in this market and its good inventory management and limited supply chain exposure to China and Europe means that it is well-placed to respond to increased demand for its sensors as the number of patients requiring intensive care increases.

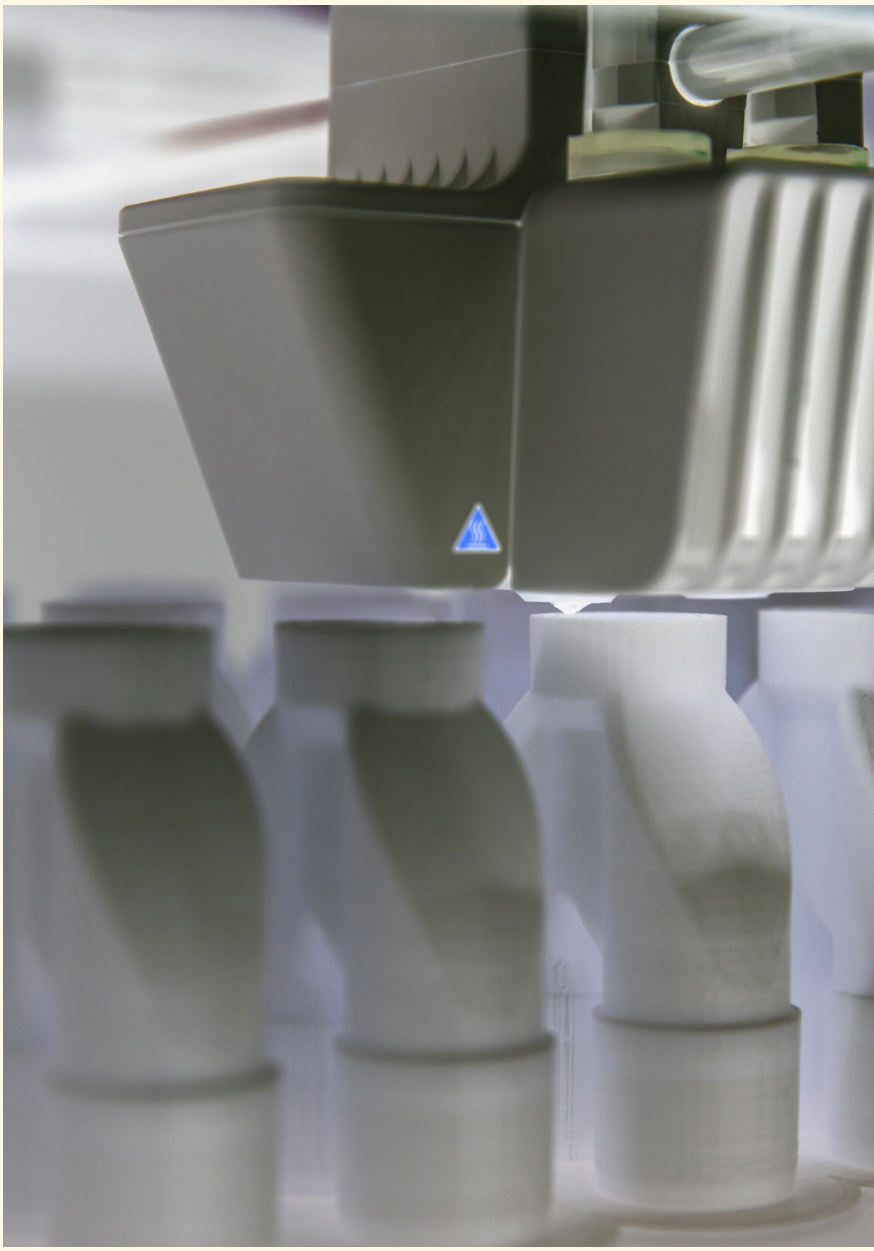
## A History of Pandemics from 1900



## TREATMENTS

As the outbreak increases demand for intensive care spaces, single-use medical products, including those being championed by Danish company, Ambu, are one way to improve the care for coronavirus patients. Single-use products eradicate the risk of cross-patient contamination. They are also readily available, cost less than the hospitals' installed reusable technologies (meaning capacity can be ramped up quickly), and there's no need of significant downtime for cleaning or repair as with traditional technology.

The gravity of the pandemic has brought out the best in many companies. In therapeutics, just as in sequencing efforts and vaccine development, the race is no longer against peers, but against the virus. The news is flooded with stories of consortiums being set up to collaborate on research efforts and therapies, and of companies redeploying existing capabilities from non-healthcare-related fields to help re-design healthcare products. Novartis, for example, has joined forces with 14 of the biggest names in life science, including Johnson & Johnson, Eli Lilly, Merck, Sanofi and GlaxoSmithKline to identify what they can do to scale up the availability of treatments, vaccines, and diagnostics for the coronavirus, with the support of the Gates Foundation. Elsewhere, the emerging technology of 3D-printing is helping to produce affordable tools to meet identified shortages, such as protective gear for healthcare workers, because it strips back the production chain to its bare minimum.



*A 3D printer produces replacement components for medical respirators.*

*...the emerging technology of 3D-printing is helping to produce affordable tools to meet identified shortages...*

Even more complex medical equipment can be improved or re-engineered under time pressure. Under normal circumstances, it takes two to three years to design and produce a new ventilator, but governments hope to speed up the process to meet the anticipated shortfall. In response to the UK Government's plea for help, some of the country's leading technology and engineering firms have been changing their existing operations and partnering with manufacturers to rapidly build existing, modified or newly-designed ventilators, including the vacuum-cleaner manufacturer, Dyson. In partnership with the medical technology company, The Technology Partnership, it is bringing to bear its expertise in air movement, motors, power systems, manufacturing and supply chain to develop a fully regulated medical device.

For patients needing assistance breathing, Continuous Positive Airway Pressure devices can help keep patients out of intensive care by delivering oxygen to the lungs without needing a ventilator. They are in short supply and clinicians and mechanical engineers from University College London and the Mercedes Formula One team created a new device in less than a week. One hundred of the machines are being tested in hospitals. Mercedes has said that, if all goes to plan, it will be able to immediately start producing up to 1,000 per day.

Drugs are one form of therapeutics that will take much longer to develop and deploy in a clinical setting. Because of the long lead times, many drug companies are working on repurposing existing drugs that have been approved for other uses, including drugs that treat malaria, arthritis and Ebola. The advantage of this approach is that the drugs can go directly to being tested in humans for efficacy (Phases 2 and Phase 3), meaning patients should, hopefully, have less time to wait to access these treatments.

There are currently two main types of drugs being investigated: antivirals (preventing the virus replicating) and anti-inflammatories. Clinical trials will take months, and the fear is that the pandemic may have passed in the meantime. For this reason, US companies Alnylam Pharmaceuticals and Vir Biotechnology are looking at an entirely novel way of treating the virus. They are working on developing an anti-viral treatment which, if the technology proves successful, will allow them to treat the whole family of coronaviruses, by targeting the part of the genome that does not mutate. This would mean that we would be better prepared for future outbreaks.

It is unlikely that all the drugs that are being developed will be successful. However, because there are so many different approaches being taken, it increases the chances that one will succeed, and we might be in a much stronger place to deal with a similar pandemic in the future.

## PREVENTION IS BETTER THAN CURE

Advances in technology increase our likelihood of finding a vaccine relatively quickly, or at least a lot faster than previously possible. Historically, developing a vaccine could take up to 10 years. However, scientists are suggesting that new approaches to vaccine development could shrink this to a 12–18-month period. There are at least 70 coronavirus vaccines in development globally, with three candidates already being tested in human trials, according to the WHO. This level of focus and the wide range of technologies being deployed increases the likelihood of finding an effective vaccine. It is also testament to the willingness of research institutions and companies to put aside rivalries and focus on providing solutions in a time of crisis.

Vaccines work by directing the body's cells to produce an antibody – a virus-fighting protein – and so triggering an immune response. Traditional vaccines use small or inactive virus samples, but newer technologies allow scientists to work from the virus' genetic sequence instead, meaning shorter development times and increased immunity. One of the new approaches is based on mRNA (messenger RNA) technology: mRNA transfers information stored in our genes to the ribosome which produces the body's proteins. Companies approaching the coronavirus from this angle include the US company, Moderna. It is engineering mRNA that provides a code for the coronavirus' spike protein, the virus' mechanism for entering the body's cells. The mRNAs are injected into the patient, where the patient's cells take on the mRNAs and produce the spike proteins. These, in turn, will invoke an immune response and trigger the body to produce antibodies.

Progress to date has been rapid and is testament to the recent advances in data science: drug development and manufacturing are fully automated at Moderna, and the company relies heavily on cloud computing and machine learning tools to carry out research and development. Within 42 days of receiving the genetic blue print for the coronavirus, the company went straight to a Phase 1 clinical study to determine whether the vaccine is both safe and provides immunity at the tested dosage. There will be two further clinical phases that, all being well, will test the effectiveness of the vaccine in larger testing pools. While the vaccine might be a year or more away from approval, the company has suggested that under emergency use it might be available for the most vulnerable and healthcare professionals later this year.

*Scientist Xinhua Yan works in the lab at Moderna in Cambridge, MA February 2020.*

*© Bloomberg/Getty Images.*

Others utilising mRNA technology to develop a vaccine include CureVac (due to start clinical trials in early summer) and BioNTech (aiming for clinical trials in late April). If any of these vaccines are approved, the next issue will be producing enough vaccines at speed to provide immunity across the globe. Thanks to the automation of its manufacturing facility, Moderna is well-placed to overcome this challenge.

# Developing a Coronavirus Vaccine – Moderna's Proposed Timeline

| | |
|---|---|
| **7 Jan 2020** | Virus identified as of the coronavirus family |
| **10 Jan 2020** | Full RNA sequence made public and the National Institute of Allergy and Infectious Diseases (NIAID) works on finalising the vaccine sequence |
| **13 Jan 2020** | Moderna receives the finalised sequence and begins working on optimised version |
| **7 Feb 2020** | First clinical batch completed |
| **24 Feb 2020** | Vials of the potential vaccine are sent to the National Institute of Health (NIH) |
| **16 Mar 2020** | Phase 1 clinical trial begins with 45 young, healthy volunteers |
| **13 Apr 2020** | Follow up dose of vaccine starts being given to Phase 1 participants |
| **Summer 2020** | Phase 2 trial potentially begins |
| **Autumn 2020** | Phase 3 trial potentially begins and it may be possible to make the vaccine available to emergency workers under emergency use |
| **Apr 2021** | Follow up on Phase 1 volunteers ends |
| **Apr – Jun 2021** | Full Food and Drug Administration (FDA) approval sought |

# PART II – A NEW ERA OF HEALTHCARE, DATA-DRIVEN AND ONLINE

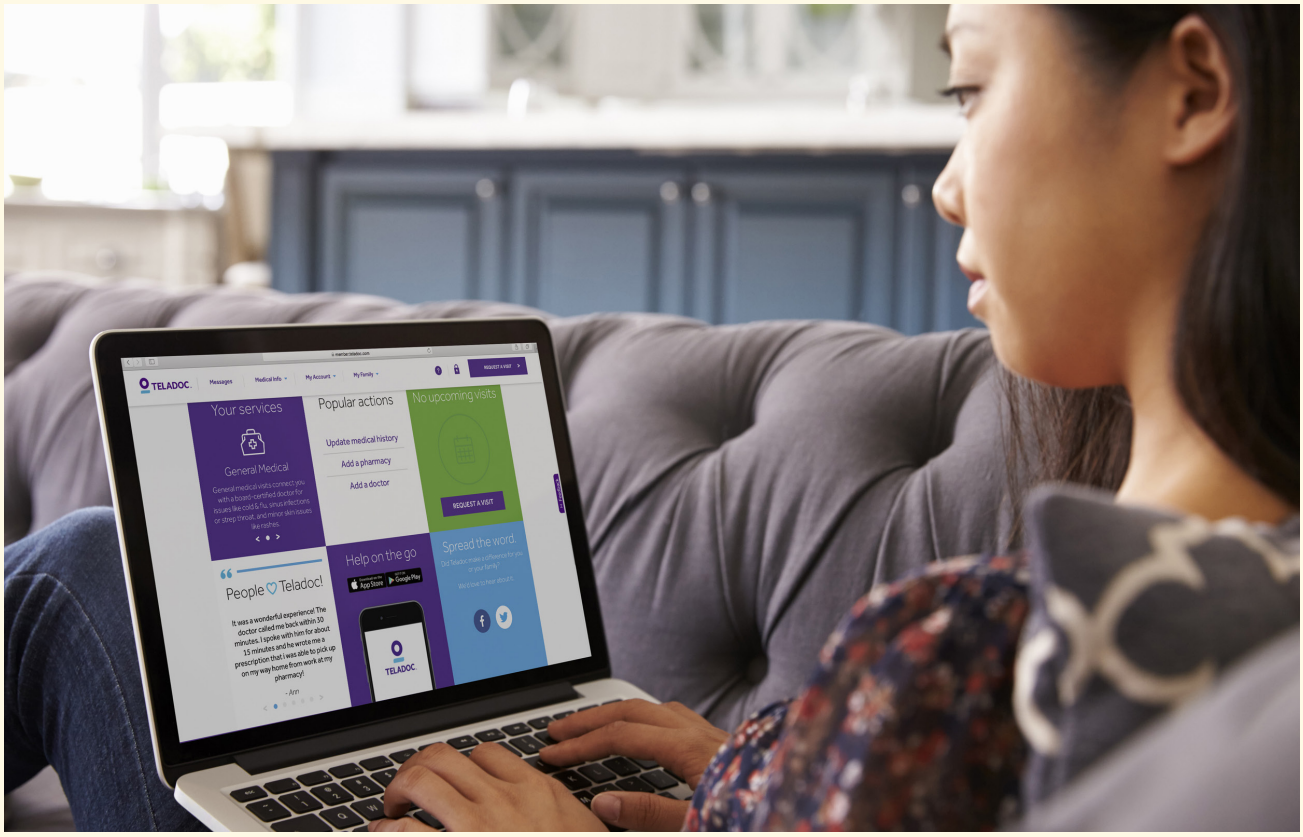
Every healthcare crisis of a pandemic scale throws up new technologies that lead the next cycle. Data-driven solutions and online virtual consultations are both givens for the future direction of healthcare.

## THE SCIENCE OF BIG NUMBERS

Data is playing an increasingly significant role in healthcare. From genetics unlocking the biology of diseases, to the ability to integrate different streams of information from diverse sources to make hospitals function more effectively. It is also helping to develop testing kits and infrastructure that can cope with processing the testing on the scale that a global pandemic entails. Until recently, we simply did not have the computing power and analytical tools to handle such large data sets or to produce meaningful results within the tight timescales necessary to thwart a fast-spreading virus. Increasingly, we do.

One of the myriad ways in which data analytics might help defeat the coronavirus is by tracking the locations and patients who test positive for the virus and using data algorithms to identify unusual patterns of symptoms and highlight clinical tests that may represent illness. As data analytics become an increasingly normalised component of healthcare, it will be even more important that healthcare organisations can integrate data from multiple siloed sources into a single data platform. That is exactly what US healthcare analytics company, Health Catalyst, provides and has been expanding upon. For example, on top of its existing range of data analytical tools, it is offering capacity planning tools free of charge to healthcare providers. These tools enable the hospitals to undertake scenario-planning so that they can forecast where future coronavirus-related demand is likely to occur and thereby manage hospital capacity and resource constraints (personnel and supplies) better.

Times of pandemic, when demand is high and resources may be low, highlight the importance of healthcare systems being able to operate as efficiently as possible. As we come out of this current situation, it is highly likely that more thought will be given to building automation into hospitals' infrastructure. As more monitoring devices are developed, medics will need a single, comprehensive viewing platform on which to monitor patients. Data analytics will be embedded into these platforms in a way that helps doctors to make better informed medical decisions through, for example, automatic risk scores and predictive health warnings. They will also help healthcare providers to deal with crisis more efficiently in the face of overstretched healthcare personnel, as monitoring systems take more of the strain. As well as reducing costs, such systems will also improve the quality of patient care and save lives. This pandemic may be the very catalyst needed to incentivise healthcare providers to install patient monitoring platforms, and data-driven solutions more generally.






## A NEW ERA OF VIRTUAL CARE – DR BOT WILL SEE YOU NOW

Although still a nascent industry, telemedicine is growing rapidly in the face of this global pandemic. Telemedicine allows clinical consultations to take place remotely, often by video conferencing, but they can also be led by artificial intelligence (AI) technology. The ability to diagnose individuals and advise them via an online doctor's appointment means that those who think they may have been exposed to the virus can be given medical advice without having to leave their homes. This prevents further spread of the virus, but also reduces unnecessary exposure for medical staff. Using AI technology, telemedicine can be scaled up much sooner than traditional methods, reducing the burden on the traditional healthcare system, which then has more resources (time and personnel) to deal with the most critical cases.

A press release from Teladoc, a US telehealth company, said that the company conducted 100,000 virtual appointments during the week of 8 March: "The demand for virtual care visits has accelerated as several health plans have waived consumer cost sharing and public health officials at all levels of [the US] government have encouraged the public to take advantage of virtual care services. These actions have driven many people to use telemedicine for the first time, with more than half of all the Teladoc Health visits this month being from first time users."

Likewise, Ping An Good Doctor, the largest Chinese telehealth company, which had 3 million monthly paying users at the end of 2019, reported that the average number of daily new registrations between 22 January and 6 February was 10 times greater than in the first 21 days of January. Its online consultations had also grown nine times on average per day over the same period. Tokyo-based LINE Healthcare Corporation (a joint venture between Japanese companies LINE and M3) saw its online consultations increasing 40 times month-on-month.

Although triggered by the crisis, this sudden shift could lead to a long-lasting change in consumer behaviour as people become less sceptical and realise the advantages of online services.

## IF TECHNOLOGY WINS, SO DO WE

In the face of a large-scale global lockdown, there is no denying the scale of the healthcare challenge ahead. However, companies across the globe are rising to that challenge, thanks to the newly-emerging technologies at their disposal, some of which did not exist five years ago. Not all the technologies we have mentioned in this paper will live up to their initial promise, nor can we be certain which will succeed, but we can be assured that in this troubled time, answers will be found, and much sooner than possible in previous pandemics.

The combination of increased human knowledge and innovative technologies converging – that is, genetics, machine learning, imaging, sensors and cloud computing – means that we are living through a period of accelerated change. Such is the rate at which technologies and solutions are moving forward, this paper will quickly date, and that is a good thing. Whatever shape the solutions come in, the past five years have been an eye opener for what is possible in healthcare. The next five years promise even more. Coronavirus will not just change how healthcare systems around the world deal with this and future pandemics, this time of crisis is forcing them to adapt and adopt technology as never before. The healthcare systems that emerge will ultimately be stronger and better able to keep us healthy and well in the years ahead.

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*Investment Manager*

Julia joined Baillie Gifford in 2008 and is the Portfolio Manager of the Health Innovation Strategy. Prior to Baillie Gifford, Julia worked as a management consultant for McKinsey & Co advising firms in Denmark, Russia and Hungary. Since joining Baillie Gifford Julia has worked on a number of regional and global investment strategies. Julia has a passion for the transformation taking place in healthcare, and it was this passion which led to the establishment of the strategy. She believes that over the next 10 years healthcare systems around the world will experience a monumental change and we will witness a move away from reactive medicine to a world where prevention and cure will become an integral part of healthcare driven by technology. Julia is also a member of the International Growth and Positive Change portfolio construction groups.

Julia obtained a BSc, MSc and PhD in Economics from the University of Aarhus, Denmark and speaks fluent Russian and Danish.

## ROSE NGUYEN
*Investment Manager*

Rose joined Baillie Gifford in 2013 as an investment analyst. Rose worked on various regional and global strategies before joining the Health Innovation team as an Investment Manager. Having observed the innovations in multiple industries, she believes that the great convergence of different technologies and sciences will ultimately transform life science. Biology can move from alchemy and randomness to become a more predictable, deterministic and repeatable science, that will give rise to a plethora of exciting investment opportunities. She joined the Health Innovation team in September 2018 at the inception of the strategy.

Rose graduated BA (Hons) in Economics and MPhil in Finance and Economics from the University of Cambridge in 2012 and 2013 respectively.

## MARINA RECORD
*Investment Manager*

Marina joined Baillie Gifford in 2008 as an investment analyst. She worked in a number of global teams before joining Long Term Global Growth, where she focused on analysing companies with the potential for sustained rapid growth. It was here that Marina developed an interest in healthcare, intrigued by the accelerating pace of progress in the field. She joined the Health Innovation team in January 2018 as an Investment Manager, to fully focus her attention on exploring the potential consequences of such progress and how Baillie Gifford can help.

Marina graduated from the London School of Economics and the Higher School of Economics in Russia with BSc degrees in Banking and Finance and in Economics, having studied on these programmes simultaneously.

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