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As a small child, I was lucky to be at the launch of Apollo 17, the last manned mission to the Moon, and I've remained enamored with space ever since. And fortunate as a physician to have contributed to NASA life sciences research and to practice aerospace medicine, inspired by the cross-disciplinary teamwork required to tackle audacious challenges and how space is has often brought the world together through the lens of seeing our planet as one without borders. Now, just as the historic Apollo moon landings were transformational inflection points in history, so too is the global health crisis of COVID-19, which, despite its many challenges and tragedies, like the sinister Cold War setting, which launched the space race, can have silver linings. As Regina Dugan, former head of DARPA, wrote, "Sputnik set off the space age, COVID can spark the health age."

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The silver linings include the unprecedented acceleration of innovation, collaboration and discovery, catalyzing a future of health and medicine that can help us reimagine and bring us a healthier, smarter, more equitable post-COVID world. Now, many solutions ride the rails of rapidly, exponentially developing technologies that are rapidly doubling in their speed-price performance, as exemplified by Moore's Law, which has enabled the billionfold improvements in memory and computation, resulting in the ubiquitous supercomputer smartphones most of us carry in our pockets. I still have my now ancient iPhone 2 here. Still works, which felt magical 12 years ago but now feels slow and kludgy. And I'm sure my iPhone 11 will soon seem antique, perhaps as its features dissolve into the rumored to soon arrive augmented reality smartglasses.

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Now exponential technologies packed into our smart devices are becoming increasingly medicalized, with sensors able to detect an ear infection and more. So what used to fit on a desktop computer now fits on our wrist and these are now entering the domain of FDA-approved medical devices. But the future isn't about any one technology, but their convergence as they get faster, cheaper, better. In fact, creating entire new fields at their interfaces, from computational biology, robotic surgery, digiceuticals, telemedicine to AI-enabled radiology. And while many industries have been disrupted and breached the fourth industrial age, health and medicine often feel stuck in the second or third. Critical data is still stuck being shared on fax machines, paper forms. We're stuck in waiting rooms waiting for our visits. I recently had my own echocardiogram only made available to share with me on a CD-ROM. I don't even own a CD-ROM player anymore.

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Tools for managing pandemics in 2020 rely on the same core technologies used in the pandemic of 1918: face masks, social distancing, handwashing. So part of the challenge in advancing global, local health are our models, our mindsets. We don't really practice health care. We practice sick care. Sick care is based on intermittent episodic data, usually only obtained within the four walls of the clinic or hospital bed, and leads to our reactive sick care model, where we wait for the patient to show up in the emergency room with a heart attack, stroke or late-stage cancer or for the pandemic to arrive on our shores.

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I believe the convergence of many of the accelerating technologies and approaches being catalyzed by COVID will bring us from intermittent sick care to an age of continuous, proactive, personalized, crowdsourced health care that can increasingly bring care anytime, anywhere more effectively and lower costs around the planet.

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For example, the convergence of ever smaller interconnected devices now riding 5G is creating not just an Internet of Things but an Internet of Medical Things. Much of this convergence is in the field of digital health, the ability to connect the dots between data sources from personal genomics and medical records with apps and services that match the needs of an individual, patient or caregiver. And as incentives and reimbursements align, COVID has pushed us to an increasingly virtualized care, from the hospital to home to our phone to on and even inside our bodies. The age of hospital to home-spital is upon us.

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Now, the challenge of this hyperconnected age is that we're creating exponential amounts of big data that's too often siloed in formats that can't even talk to each other. So we need to narrow that gap between data, turning that into actual information for the patient, physician, public health worker, and speed its safe and effective use in the community clinic and bedside. The pandemic has instigated an immense amount of international sharing and collaboration amongst clinicians and researchers to narrow that gap. What was learned in managing patients in Wuhan and then in the intensive care units of Italy has helped New York City hospitals and their learnings in turn have spread to centers around the world.

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Let's take a quick dive into some examples of what's happening across the health care paradigm in the age of COVID and the implications for the future. From new forms of data to help prediction of prevention to faster diagnostics, more tailored therapy and increasingly crowdsourced discovery.

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Let's start with prevention. Now, while our genomes impact our health outcomes and our health spans, our social determinants of health, our social, and our day-to-day behaviors drive most of our risk for disease and associated costs. And we now have an explosion of new tools to help measure and improve our healthy behaviors. The first Fitbit only launched in 2009. Wearables are now ubiquitous and can measure almost every element of our physiology, behavior and even mental health. And they're evolving all the way from disposable tattoos that can stream vital signs 24/7 to an integration of big data that can -- Even small data from a simple wearable, tracking the patient discharged home after a hip replacement or a coronavirus infection can determine if the patient is recovering as expected, walking more, doing great or not so great and trigger early intervention.

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We're evolving from a world of quantified self where our digital data remains silent on our devices to one of quantified health where the data can be shared securely with clinical teams and researchers to help optimize prevention, diagnose disease early and with feedback loops, personalize and optimize therapy. From wristband vitals, including blood pressure, now obtainable without a cuff, and soon sensors that will measure our blood oxygenation levels to continuous blood sugar monitoring, to shock'ables, hearables, ring'ables that can replace an entire sleep lab fitting on our finger to inside'ables, chips beneath our skin, to track our physiology and lab values, to even underwear'ables, Internet of Medical Things sensors so cheap today you can get a pack of ten of them, have one on each pair of your underwear, now being used to do what's called remote patient monitoring to help detect signs of respiratory decompensation of patients with bronchitis or COVID. Breath'ables are showing promise. Nanonoses that can detect molecules in our breath correlating to cancer, metabolic disease and even diagnosing infectious disease. In fact, we now don't need to wear anything. Invisibles, ambient sensing from AI-enabled cameras can track her vital signs. To voice as a biomarker to manage and detect mental health challenges, signs of heart disease, now being able to differentiate between a cough from a common cold to that one caused by coronavirus.

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And we'll soon be exuding our digital exhaust 24/7, our digitome. How do we make sense and truly leverage it? One path is through crowdsourcing. The million-participant All of Us trial from the National Institutes of Health is doing just that where data donors, and I'm one, can contribute our medical records, genomes and wearable data to build a much better and diverse data set, crossing racial and socioeconomic groups to help foster better precision medicine for all of us.

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Integrating this information for the individual and public health will lead to predictalitics, our own personal check engine lights that can give us early proactive warning. And recent work is demonstrating that wearables can detect presymptomatically the onset of the flu, or, as recently published by Stanford, in 83 percent of COVID patients smartwatches can detect COVID infections early, often days before onset of symptoms. Self-reporting websites like Covid Near You enable us to locally generate infections maps, and combined with our social graphs and contact tracing apps, may provide us detailed suggestions about who we might want to consider being near or socially distanced from.

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What about advancements in diagnostics and monitoring? What used to require a full clinic or laboratory can now fit into a digital doctor's bag or the pocket of a patient. From COVID quarantine kits enabling tracking of oxygen saturation, temperature and lung sounds, we're starting to integrate these into virtual visits, providing real-time enhancements of a virtual physical exam. And the diagnostic tools are becoming increasingly infused with AI machine learning, including consumer ultrasounds, which can bring diagnostics anywhere at very low cost, including the ability to evaluate the lungs in suspected COVID patients. The laboratory has shrunk to microfluidic platforms that can be attached to our smartphones and enable anyone to take measurements from blood or saliva.

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Many of these diagnostics are leveraging the smartphone and its camera for a medical selfie. For example, instead of taking your urine to the lab to diagnose a potential urinary tract infection, in the privacy of your home simply dip the urine dipstick, take a picture with your smartphone camera and have the results made available immediately to your doctor and pharmacy. Similar phone-based apps and approaches are being used and developed for fast, frequent, cheap and easy COVID testing. Novel approaches to community level diagnostics are also being explored, including next gen sequencing of sewage for early detection of COVID-19, identifying hotspots and predicted outbreaks a week or more early.

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The explosion of data sources, however, is really beyond the capacity of the human mind to effectively integrate. We're now getting help from AI, or as I call it, IA, intelligence augmentation. IA is being leveraged in reading CT scans to diagnose COVID, to enhancing the vision of a gastroenterologist performing a colonoscopy to identify lesions they might have missed. And AI is playing an active role in helping identify and develop new antivirals. And while AI is often perceived as a threat by some clinicians, it can't replace the human touch or empathy. And I don't think doctors or nurses will be replaced by AI, but doctors and health care systems who're collaborating with AI in the future will be replacing those who don't.

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Finally, therapy. The pandemic has dramatically accelerated the use of virtual visits. Telemedicine visits are up on the order of a thousand percent in many settings. And I don't think we'll ever revert to pre-COVID levels as patients and clinicians are discovering the compelling convenience and efficacy. Even before virtual zoom or facetime with the clinician, asynchronous screening and support has been provided by ever-smarter chat bots that can help discern symptoms and triage problems effectively at lower cost. This includes virtualization and virtual augmentation to meet our mental health crisis, exacerbated by the many economic and other stressors which accompany this pandemic. 3D-printing is finding a role in health care, with newfound applications from printing personal masks to critical parts of ventilators and being leveraged by the growing maker movement, which is playing a major role in pandemic response, from making face shields and masks to improvising do-it-yourself ventilators.

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All together, these efforts are enabling the potential for democratization of health and medicine across the planet and access to information and care that was previously inaccessible. Clinical trials are being reshaped, leveraging smart devices, cloud-based analytic platforms and collaborators around the world. That's at this convergence of many rapidly developing and exponential technologies that we have the real potential to reshape and scale health care at our pandemic age. One where we can dramatically expand access to basic health care, increasingly personalized and proactive, leveraging the scale of digital platforms and technologies, enhancing digital connection and empathy, and the ability to blend virtual and in-person care, and leveraging the power of the crowd to share and build better maps that guide our individual health and public health journeys, and to develop validated and scaled solutions.

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So imagine a new generation of volunteers, a global health corps similar to the volunteer paramedics and firemen of today that can be upskilled, use the powerful new tools to respond

early and collectively to enhance contact tracing, isolation and quarantine, and to help identify and address social and other disparities.

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So coming full circle. Twenty four years after I was at the launch of Apollo 17, I found myself as a medical student on a research clerkship at Johnson Space Center. And much to my surprise, one day in the clinic, I ran right into Gene Cernan, the Apollo 17 commander and the last man to walk on the Moon. After enthusiastically sharing my childhood memories of his launch, he shared one of his famous lines: "I walked on the Moon. What can't you do?" Indeed, what can't we do if we work together as one in the face of this pandemic? And just as the near tragedy of Apollo 13 rallied NASA to work creatively and collectively, so too can this in our pandemic age lead to our finest hour, bring on a true health age. I believe this is possible if we all get out of our linear mindsets, take exponential steps and collaboratively go forth collectively, not only to solve the challenges of this pandemic and predict the future of health and medicine, but boldly to go forth together to accelerate a far better one for everyone on Spaceship Earth.

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Thanks.