I WOULD NEVER have met Harriett were it not for our mutual friend, Linda. I’m a physician in Northern California; Harriett’s a communications executive in New York City. Linda co-founded an online personal genomics company, to which Harriett and I each sent our genetic information for analysis.

Linda introduced us after she saw that Harriett and I had something in common: a rare type of mitochondrial DNA, which meant we were distantly related. It turns out that we also share that genealogy with a prehistoric celebrity: Ötzi the Iceman, whose 5,300-year-old frozen corpse was discovered in the Alps in 1991. For fun, I even started a Facebook group for people with the same DNA variant as Ötzi and Harriett and me.

I tell this story to make a point. Harriett and I met over a feat of biomedical science—mass-market, low-cost gene analysis—that once was unimaginable and now is commonplace. The convergence of digital
technologies and social platforms made it possible for us to learn our genotypes and share what we found out with the online universe.

Since then, we’ve seen an explosion of tech-driven gains and innovations that have the potential to reshape many aspects of health and medicine. All around us, technologies from artificial intelligence (AI) to personal genomics and robotics are advancing exponentially, giving form to the future of medicine.

The innovations I describe here—many of which are still in early stages—are impressive in their own right. But I also appreciate them for enabling the shift away from our traditional compartmentalized health care toward a model of “connected health.” We have the opportunity now to connect the dots—to move beyond institutions delivering episodic and reactive care, primarily after disease has developed, into an era of continuous and proactive care designed to get ahead of disease. Think of it: ever present, analytics-enabled, real-time, individualized attention to our health and well-being. Not just to treat disease, but increasingly, to prevent it.

IN THE OLD MODEL OF MEDICINE, patients’ health data was collected only intermittently, primarily in clinic visits, and scattered among paper files and siloed electronic medical record systems. Today there’s a far better option: personal technology that can monitor vital signs continuously and record health data comprehensively.

Just a decade after the first Fitbit launched the “wearables” revolution, health tracking devices are ubiquitous. Most are used to measure and document fitness activities. In the future these sensing technologies will be central to disease prevention, diagnosis, and therapy. They’ll measure health objectively, detect changes that may indicate a developing condition, and relay patients’ data to their clinicians.

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INFORMATION

An Explosion of Health Data
Just how fast is the growth of health-related data? A report from the Stanford University School of Medicine put it this way: “The sheer volume of health care data is growing at an astronomical rate: 153 exabytes (one exabyte = one billion gigabytes) were produced in 2013 and an estimated 2,314 exabytes will be produced in 2020, translating to an overall rate of increase [of] at least 48 percent annually.”

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NANOSCIENCE

Useful DNA Origami
Bioengineers have made nanoscale tetrahedrons, bunnies, and more by folding DNA into origami. They enter the desired shape into an algorithm that determines how to bend a long DNA strand, or scaffold, into two- and three-dimensional shapes held together by shorter DNA pieces. Other molecules studded along the scaffold’s surface give it its function, like ferrying medicine or gene editing tools to a particular part of the body. MIT’s Mark Bathe says the “holy grail” of DNA origami would be a structure that can cross the blood-brain barrier that now keeps many drugs from reaching the brain.

—THERESA MACHEMER
Flexible, electronic medical tattoos and stick-on sensors can take an electrocardiogram, measure respiratory rate, check blood sugar, and transmit results seamlessly via Bluetooth. It’s mobile vital sign tracking, but at a level once found only in an intensive care unit.

Hearing aids or earbuds with embedded sensors will not only amplify sound but also track heart rate and movement. Such smart earpieces also could be integrated with a digital coach to cheer on a runner, or a guide to lend assistance to dementia patients.

A monitoring patch on a pregnant woman's belly can detect uterine muscle movement, the better to know when labor is progressing. Later, parents can keep a digital eye on their infant via a baby cam that sends an alert if the baby stops breathing. There’s even high-tech help for developing preemies. For example, a WiFi-like box so it can capture vital signs and sleep patterns of several people in the same residence.

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bacterial or viral infection, and the best drugs to treat it, can mean long waits for blood cultures. But scientists have developed biochips that can do a complete microbial scan in a couple of hours, without culturing—and in the process may identify mutations that make some microbes antibiotic resistant.

The boom in research into the human microbiome—the trillions of bacteria on and in each individual’s body—is encouraging new modes of diagnosis and increasing understanding. Genetic analysis could help unlock the many secrets of the gut microbiome, believed to play a role in the risk and development of obesity, inflammatory bowel disease, cardiovascular disease, and even neurologic conditions.

Thanks to artificial intelligence and machine learning, diagnostic tools can be trained to read tissue samples and radiologic scans. Google researchers fed more than a quarter-million patients’ retinal scans into algorithms that recognize patterns—and the technology “learned” to spot which patterns predict a patient has high blood pressure or is at increased risk for heart attack or stroke. In some comparisons, digital tools produced more accurate analyses than did human pathologists, dermatologists, or radiologists.

IN THE UNITED STATES, the days of doctors routinely making house calls are long gone. Soon to follow: the practice of most medical care occurring in person in a practitioner’s office, a clinic, or a hospital. Increasingly, care will be delivered in a blended, real-world-mixed-with-virtual-world model. The majority of patient-doctor interactions don’t require the “laying on of hands,” or a physical exam. Private (and increasingly reimbursable) Skype-like interactions between patient and physician will take
Many artificial limbs still begin with a plaster cast. Transforming that mold into a socket that comfortably fits the residual limb is an expensive and halting process—if you’re lucky enough to live near a trained prosthetist. Many amputees worldwide don’t have access to prosthetic limbs. Mobile phones and 3D printers may offer a solution, says Albert Yu-Min Lin, a National Geographic explorer who lost part of his leg in 2016. Phone cameras could scan residual limbs, providing measurements to professionals with 3D printers, who would produce matching low-cost sockets to be shipped to amputees all over the world.

See Albert Lin, shown here at Arizona’s Antelope Canyon, on the TV series Explorer. It returns with new episodes on January 7 at 10/9c on National Geographic.

THE PRESCRIPTIONS IN YOUR FUTURE COULD BE DOLED OUT BY AN ATM-LIKE ROBOT, REMOTELY CONTROLLED BY A PROVIDER OR ALGORITHM TO ENSURE THE RIGHT DOSES AT THE RIGHT TIMES.

place through web-based portals. Patients’ vital signs will be obtained and shared with the physician via web-integrated wireless scales, blood pressure cuffs, and monitoring devices. A telemedicine dermatologist can use the selfie you’ve sent to prescreen your suspicious-looking skin spot and tell you either to rest easy or get it checked in person.

The time it usually takes for medical appointments—including travel and waiting room time—will plummet, supplanted by telemedicine visits with a new type of clinician, the “virtualist.” The provider-patient relationship will take a déjà vu turn, with patients in their own homes for appointments.

In the future your prescriptions may include more “digiceuticals.” Already in limited use, they’re meant to enhance well-being or manage a condition with no drugs, no in-person ministrations—just use of prescribed software, or digital exchanges with a practitioner offering information and encouragement.

Though many are still under study, some digiceuticals are demonstrating effectiveness. Examples: At least two firms have developed apps to reduce the relentless noise of tinnitus by retraining the brain to turn down the volume—and some reviewers say it works. To manage heart failure patients, the Mayo Clinic prescribed the use of an app that would track blood pressure, activity, and other factors. The reported result: a 40 percent reduction in hospital readmissions related to cardiac issues.

The conventional prescriptions in your future could be doled out by an ATM-like robot, remotely controlled by a provider or algorithm to ensure the right doses at the right times. Or your clinician could consult your genetics test to determine the most appropriate

Drugs for your specific gene profile.

A few months ago, Harvard and MIT scientists found a way to much more accurately forecast an individual’s risk score for five deadly diseases. They achieved this by looking at DNA changes at 6.6 million locations in the human genome and applying a sophisticated algorithm. But even genetic tests that analyze only parts of the genome—like the one I took—can provide valuable information about predisposition to dementia, Parkinson’s disease, diabetes, and other conditions. Yet again, advances in medical technology may hold benefits for me, and for Harriett. (Sorry, Doc.) If you’re not meeting in person with your practitioner, could a robot serve as well as a human? Soon
they may be answering information and triage calls. A chatbot nurse will try to learn what ails you by asking about your symptoms and tapping into data from your wearable devices and the crowdsourced health records of others like you. Should your complaint be psychological more than physical, you can seek counseling from a virtual therapist programmed to converse as a human would, offer self-help guidance, and lend a sympathetic ear.

Robots may participate in care during face-to-face encounters as well. Consider the robotic phlebotomist, equipped to ultrasonically confirm which vein is the best target, then draw blood or insert an IV. In countries short on human caregivers, caretaker robots may be employed to lift and move patients, as well as interact socially. And robots programmed as physical therapy coaches can help patients stick with their exercise regimes.

IT’S GREAT TO BENEFIT from all this technological progress, but it’s just as important to spread it. In 2016 an estimated 3.6 million people in low- and middle-income countries died because they lacked access to health care. And even more people in those countries—an estimated five million—died because they got poor-quality care. We can change that, starting today, by sharing the wealth of new medical technologies and other health and wellness resources.

Daniel Kraft is a physician-scientist trained at Stanford and Harvard. He serves as faculty chair for medicine at Singularity University and is founder and chair of Exponential Medicine, a program that explores the convergence of accelerating technologies and their implications for the future of health care.

AI ANALYSIS
The Sharp Eyes of AI
Correctly identifying the cancer cells in a lung tissue sample (below left) is key to successful treatment. It’s also an ideal diagnostic use of artificial intelligence. In one study, the same AI that Google uses to identify objects online was trained to recognize forms of cancer. It then found two forms in a tissue sample (below right) as accurately as a human could, in seconds. AI also has been used to model the precise dosage of a cancer drug to shrink tumors but cause minimal toxic side effects. —LC

For the sample at left, AI produced the analysis at right, showing normal lung tissue (gray) and two forms of cancer: adenocarcinoma (red) and squamous cell carcinoma (blue).

REGAINING MOBILITY
Robotic Support
For patients with severe mobility problems such as partial paralysis, scientists are developing robotics that enfold and support like an exoskeleton. The devices are programmed to guide the body through motions—such as helping a stroke victim walk—that can rebuild posture and strength. —NATASHA DALY