The App-ification of Medicine

A four-faceted information revolution in health

BRET SWANSON > September 2015

Several months ago, I went to an orthopedic surgeon to check out my sore right shoulder. He had asked me to get X-rays of the shoulder at an affiliated medical imaging clinic before my appointment with him. After pushing and pulling on my arms and back for a few minutes, he decided to pull up the X-rays on his expensive computer system. When the pictures of my shoulder popped up on the screen, however, the doctor just shook his head.

"Who took these pictures?" he asked. "They look like film negatives."

My bones were black, and the background was white, the opposite of what he expected. He called for the information technology (IT) staff to see whether the problem was with the digital X-ray files or his computer system. As the IT staffer was searching for a solution, I pulled out my iPhone and opened my photo library.

"Would these photos help?" I asked. "I downloaded the X-rays from the disk the clinic gave me."

"Let me see those," the surgeon replied, taking the phone and zooming in with his fingers. He could see from the X-rays on my smartphone that there was no structural damage. He prescribed two months of physical therapy, which worked like a charm, and my shoulder still feels great.

Who knows what the problem was with those X-ray files. The story, however insignificant on its own, is just one of millions demonstrating both the problems with today's healthcare system and the vast potential of IT to improve, transform, and transcend the entire industry.

Computers and the Internet are on the cusp of making healthcare more personal, consumer oriented, cost effective, innovative, agile, and entrepreneurial. IT will empower both consumers and medical practitioners. We will have better knowledge of our bodies, and so will our doctors. We will communicate with our physicians more easily, and doctors will move down the cutting edge of treatment more quickly. Often the entire process will become automated, and the ubiquitous doctor visit will be saved for rare occasions. Researchers and entrepreneurs will make use of the new information to deliver better treat-

ments and cures, and patients themselves will get in on the act. They already are.

Smartphones and software apps are an important component of this transformation. They are, however, just one facet of a much broader and deeper information revolution in health. This revolution will proceed down multiple paths of technology, medicine, research, and business, and each will build on and feed the others.

The Problem – Too Little Information

These opportunities come not a moment too soon for a health industry in various stages of crisis, as well as for patients desperate for more cost-effective care. The healthcare market is vast and deep, but many of its details are invisible and its scale impenetrable. It floats along, growing in bulk but too rarely in sophistication, even as health insurance rates continue to soar.

Healthcare employment is growing fast as well, but that's part of the problem. Between 1990 and 2010, while the rest of the American economy enjoyed annual productivity gains of around 2%, American healthcare productivity actually declined 0.6% per year. Over 20 years, that's a productivity differential of around 60%. If we could raise the productivity of healthcare, which is about one-sixth of GDP, we could substantially improve the nation's economic health.

Gene therapy, stem cells, organ transplants, robotic surgery, and robotic limbs—these are examples of the best of American technology. They seem almost miraculous in their sci-fi sophistication and healing power. Our highly trained doctors and nurses are the world's best. Yet, the inefficient structure of American healthcare is a heavy burden. We know the central problems: (1) lack of competition and innovation due to regulation and (2) a third-party payment system (Medicare, Medicaid, and nominally private insurance) that obscures price, choice, and value. This system saps our time and weighs on our individual and governmental budgets. According to the Centers for Medicare and Medicaid Services (CMS), today's health expenditures in the United States (around $3 trillion) will grow to more than $5.4 trillion by 2024. Healthcare's portion of the national economy is thus expected to grow to nearly 20% from an already-high 17%. This dead weight isn't just breaking our finances; it threatens to deaden our innovative capacity.

Government attempts to inject IT into the health system from the top down, via electronic health records for example, are well-meaning. The top-down mandates, however, ignore the fundamental reason healthcare had failed to deploy IT as effectively as nearly every other industry: perverse incentives that reward inefficiency and penalize innovation and thrift.[1]

As deliriously frustrating as the paper-based medical record system is, the information revolution in health is, fortunately, far broader and more potent. Electronic medical records are just the beginning, and their deployment is likely to be successful only when bottom-up incentives to deploy in such technologies become a reality.

The Solution — More Information

The proliferation and democratization of computer and communications power will drive the real revolution from the bottom up. Consider that in 1971, Intel's first microprocessor, the 4004, contained 2,300 transistors, the tiny digital switches that are the chief building blocks of the information age. Between 1971 and 1986, Intel sold around one million 4004 chips. Today, an Apple A8 chip, the brains of the iPhone 6 and iPad, contains two billion transistors. In just the last three months of 2014, Apple sold 96 million iPhones and iPads. In all, in the fourth quarter of 2014, Apple alone put around 30 quintillion (30,000,000,000,000,000,000) transistors into the hands of people around the world. Individuals now enjoy more computing power, via smartphones and the Internet cloud, than entire hospitals and insurance companies had just a decade ago.

Much of the rest of the economy is riding this Moore's law wave. Today's bloated healthcare world, however, resembles a 1950s mainframe computer—big, bulky, slow, unconnected, and expensive. Despite terribly misguided policy, information is about to intrude on the healthcare world and break this mainframe into millions of pieces. Although the Affordable Care Act (ACA) pretends to be the main driver of changes to our health system, the real action will in fact occur in entrepreneurial realms, specifically in four areas of innovation:

- **Smartphones and Personal Technology** – Supercomputers in billions of individuals' pockets (and on their wrists and in their brains and intestines) all connected via broadband networks, will enable cheap, anywhere, all-the-time diagnostic tools and communication and data collection capabilities.
- **Big Data, Social Data** – With the collection, coordination, sharing, and analysis of unimaginably large troves of specific data on patients, treatments, physicians, and facilities, researchers and patients themselves will dig deeper and make more connections than ever before.

- **The Code of Life** – The truly radical new understanding of biological information networks, including genomics and proteomics, will yield personalized molecular medicine. Cracking this "code of life" is the most fundamental information technology at the heart of the health information revolution…and it is happening.

- **The App-ification of Healthcare** – A smartphone is a platform that empowers millions of diverse apps, products, and services created by other people and firms, targeting the needs of individual consumers. Healthcare, however, is too often a closed and stagnant system. For all of the new information technologies to truly flourish, the healthcare economic model must change. Instead of a centralized, opaque, top-down system of big hospitals, big insurance, and big government, we need an entrepreneurial model of numerous firms and technologies (healthcare "apps") delivering better care at lower prices to patient-consumers. The potential is enormous, but it will only succeed to the extent better policy allows.

Smartphones and Personal Technology

Several years ago, when my four children were much younger, we spent a lot of time at the doctor's office. We would detect an ear infection coming on, make an appointment with the pediatrician, bundle up, drive to the appointment, and then wait 45 minutes for the doctor to perform a three-minute exam. On perhaps a dozen occasions, the doctor told us the ears were fine—only for us to return, bundled, locked, and loaded two days later with an unhappy child with an obviously full-blown infection.

The healthcare system didn't reward our intuition. Tomorrow's parents and children, however, may not have to endure two days, two visits, and two sleepless nights before getting treatment. They will have help from, among other things, their smartphones. Plug a scope into your phone, peer into your child's ear, and let your phone's camera and an app analyze what it sees and senses. Amoxicillin to the rescue, without leaving the house.

Smartphones, tablets, and an array of wearable computers can catalyze a healthcare productivity revolution. They are connected, personal, and broadband-connected general purpose computers, limited in their capabilities mostly by the reach of our imagination. Today, 2.6 billion people around the world use smartphones, according to Ericsson, the wireless infrastructure provider. By 2020, Ericsson expects 6.1 billion smartphone users. Including other connected devices like tablets, wearables, and machine-to-machine wireless connections, total mobile subscriptions could reach 9.1 billion. In the seven years since Apple's App Store first opened in 2008, consumers have downloaded several hundred billion iOS and Android apps. The diversity of the new software tools is astonishing. It's all powered, moreover, by broadband wireless connectivity and the near-infi-

nite computing and storage capacity of the Internet cloud.

Consider CellScope's smartphone otoscope and dermascope attachments—one looks into ears, the other at skin lesions, taking photos, keeping records, and forwarding pictures to your physician. A firm called Smart Vision Labs invented a small iPhone attachment that can replace a 30-pound, $30,000 piece of optometric equipment for less than $4,000, enabling cheap and mobile eye exams. Mobile electrocardiograms are already in widespread use. Eric Topol, a cardiologist and author of the book *The Patient Will See You Now*, says he has already used his smartphone ECG to diagnose three fellow airplane passengers—one was having a heart attack, another a panic attack, and the third merely a "transient very slow heart rhythm."[2]

"The first time I had an ECG e-mailed to me by a patient with the subject line 'I'm in atrial fib, now what do I do?' I knew the world had changed," Topol writes. "The patient's phone hadn't just recorded the data—it had interpreted it." Topol insists that although he is a cardiologist, these tools will allow anyone, such as flight attendants, to perform the same tests and relay the crucial information.

Dr. Peter Fitzgerald, a cardiologist and engineer at Stanford's Center for Cardiovascular Technology, estimates that one-third of cardiac clinic visits are unnecessary. Remote technology can do more than replace office visits and cut costs, he said. It can empower patients, individualize their care, and ultimately reduce morbidity and mortality.[3]

The wireless chip maker Qualcomm has partnered with the XPRIZE Foundation to challenge inventors and entrepreneurs to make what was once science fiction a true hand-held reality. To win the prize, this real-world Star Trek-inspired "Tricorder" must be able to make "negative assessments" of (or rule out) 13 core conditions, including anemia, lower urinary infection, Type 2 diabetes, atrial fibrillation, stroke, sleep apnea, tuberculosis, chronic obstructive pulmonary disease (COPD), pneumonia, leukocytosis, hepatitis A, and, last but not least, the dreaded otitis (ear infection). The device must also assess three elective conditions, such as hypertension, melanoma, cholesterol, HIV, and osteoporosis. Last, the device must measure the five vital signs: blood pressure, heart rate, temperature, respiratory rate, and oxygen saturation. Seven finalists have emerged, and the winners will be crowned in January 2016.

Other miniaturized medical breakthroughs will make the Tricorder pursuit look quaint. New research suggests a number of conditions can be diagnosed by looking at the inner eye or, separately, through chemical analysis of human breath. It is easy to see, once these technologies are perfected, how they might be integrated into mobile devices. Meanwhile, two researchers at Caltech have found a way to put a terahertz scanner on a chip. Like X-ray machines, these scanners see through objects, but they aren't as powerful and don't damage human tissue. No doubt you've seen big terahertz machines at airport security checkpoints. Now consider putting one of those in your phone and you've got a personal X-ray machine ready to go.

A host of wearable devices, such as FitBit wristbands and Apple Watches, will accompany this smartphone phenomenon. In just a few years, most watches of any kind will have health monitoring capabilities. Implantable and ingestible devices will also proliferate. Ingestible wireless cameras that perform nonintrusive colonoscopies have already been around for a decade, and the number and type of these devices will only multiply. We are already 3D printing replacement body parts, prosthetics, and pills. And someday, we may have billions of nanoparticles floating inside our bodies that wirelessly connect our brains to computers.

Big Data, Social Data

As all these devices collect information on lifestyle habits (such as diet, exercise, and

sleep), biochemistry, and medicines (and our responses to them), we will compile vast troves of medical data that can fuel new research, as well as treatment. Smart devices will thus help bring the power of Big Data to healthcare. We will collate this real-time data with our genomic profiles and family histories. Then our physicians and thousands of researchers and computer programs will compare our data and profiles with millions of others.

Apple's HealthKit and ResearchKit platforms aim to feed exabytes of data into the global health matrix. HealthKit supports consumer apps that work with watches, wristbands, and other devices, while ResearchKit supports physicians and research teams looking for new ways to gather data and perform studies. Imagine, for example, recruiting and signing up study subjects around the world via smartphones rather than running radio ads and asking a local population to fill out paper forms.

Google's new Life Sciences project, organized under its Alphabet umbrella organization, is using data to target diabetes. The condition, which afflicts some 30 million Americans and is surging around the world, is among the most costly diseases, totaling some $245 billion a year in the United States. It requires a lifetime of blood sugar monitoring, insulin injections, and treatments for its many symptoms. Google hopes a new contact lens that measures blood sugar might eliminate the need to lance one's finger five times a day. It thinks huge databases of information on diet, exercise, insulin, and far more granular information on blood sugar and other biochemistry will, with its partners Sanofi, Novartis, and Dexcom, help it develop far more individualized treatment regimens.

IBM thinks Watson, its artificial intelligence engine, will play a major role in the medical cloud. Today, its Medical Sieve project has radiologists training Watson to get even better at analyzing X-rays and MRI scans. Several health systems are using Watson to help make diagnoses across a range of diseases, and IBM thinks Watson can help design targeted treatments for cancer. Dr. Lukas Wartman of the University of Washington in St. Louis tells the story of his own leukemia treatment, which used a novel genetic therapy originally designed for another type of cancer. He thinks, however, that Big Data can help design custom therapies much more quickly.

"Thanks to gene sequencing and analytics," Wartman writes, "we have the potential of doing a better job of treating the causes of the tumors. The problem is that we can't easily comb through masses of genetic data to spot the patterns and correlations that matter. But, with Watson's help, we might be able to cut weeks of analysis down to mere minutes." While large tech firms like Apple, Google, and IBM aim to transform health with IT, so do thousands of smaller firms both inside and outside medicine. A new firm called Helix, a partnership among Illumina, LabCorp of America, the Mayo Clinic, and others, is an effort to build a high-quality repository of genomic information and platform for third-party genomic apps. These platforms, like the smartphone, will be a key to unleashing entrepreneurial ventures focused on both mundane and cheap new service and radical breakthroughs.

The power of information sharing and analysis, however, extends beyond pharmaceutical firms and Silicon Valley. Individuals with no medical background are using the Internet to make significant breakthroughs in their own health and that of others. Most doctors have funny stories about patients who think they know more than they do because they read something on the Internet. And yet the growing stores of knowledge available do allow the truly diligent patient-consumer to become something like experts in a relatively short period. Patients used to be ignorant and helpless. Doctors, moreover, faced with a rare condition, may have little recourse, and there is little chance such a patient would know anyone with the same affliction. Today, a patient with a rare condition (or even symp-

toms of an undiagnosed condition) can find similar people around the world. In some cases, these laypeople have even helped make medical breakthroughs because they made previously unknown connections via Facebook.[4] Thus, the impersonal correlations of Big Data will be supplemented by the genius and persistence of humans using social media.

In either case, if the problem is too little information, the solution is more information.

The Code of Life

If smartphones and Big Data are the IT we can see—the information on the outside—then molecular bioscience is the information inside.

Watson and Crick's discovery of deoxyribonucleic acid (DNA) in 1953 and the sequencing of the genome in 2000 were great scientific achievements. They are the foundation of the modern information age in medicine. Yet, in the first decade after the National Institutes of Health (NIH) and Craig Venter's team at Celera announced the decoded genome, it's fair to say most casual observers were underwhelmed by the apparent practical progress. Today, genomic medicine is in full flight, and the next several decades will be nothing short of astounding.

Vaccines and antibiotics brought us out of the Dark Ages and boosted human longevity. Yet, the information content of those important public health revolutions was relatively slim. Vaccines were based on the very diseases they were fighting, and antibiotics were an accidental discovery. Although early public health experts, researchers, and the Food and Drug Administration (FDA) over the last century used systematic information in crude ways, medicine until recently was mostly a trial-and-error, hit-and-hope world.[5]

Understanding the codes of the genome, proteome, epigenome, and metabolome, however, will unleash molecular medicine. Combining our new understanding of these biological information networks with traditional IT hardware and software will yield stunning breakthroughs. In 2001, the cost to sequence one genome was $100 million, but today the cost is just $5,000 and is rapidly headed toward $1,000.

"The vital core of medicine," writes Peter Huber in *The Cure in the Code*, "is now on the same plummeting-cost trajectory as chips and software."[6]

Just as the macrocosm of vacuum tubes gave way to the microcosm of silicon chips, we are moving from the goopy world of petri dishes to the biocosm of DNA and protein codes, biomarkers and pathways, the information networks of molecular metabolics. The new knowledge and tools will yield therapies customized not merely to symptoms or broad disease categories but to the individual person. Information-based medicine will provide for diagnostic "sniffers"—molecular sleuths meandering through our bodies on the lookout for anomalous cells and intruding microbes. We will *design* therapies to repair some cells and kill others, to open these pathways and block those.

Immuno-oncology (IO), for example, is perhaps the most promising breakthrough in cancer therapy. Traditional therapies burn (radiation), poison (chemotherapy), or excise (surgery) cancer cells, and with only varying degrees of precision and success. IO, on the other hand, uses the body's own immune system to target cancer cells directly and often dynamically: some IO therapies can adapt as the cancer tries to avoid pursuit. IO covers a variety of strategies, but some examples of early therapies are Provenge for prostate cancer and Avastin and Erbitux, which are used against many different cancers.

DNA editing is another new information tool that could change everything. Ever since the discovery that the foundation of biological information is digital, we have wondered whether it was possible to "program" life. The possibility is looking more likely every day. In the last five years, a technology known as

CRISPR/Cas9 has emerged as a powerful tool to "cut and paste" DNA with great precision. It could be used to excise specific genes known to cause disease or merely to replace less favorable genes with better ones. The new technique is thought to be so powerful that some scientists have called for a moratorium on the use of CRISPR on human cells until we know more about its implications for safety and ethics. Nevertheless, DNA editing is an exemplary tool of the new science of bio information, and it is difficult to see how such a genie will be kept in the bottle. The big question will thus be whether and how the scientific and public policy communities can practically steer away from the most destructive possibilities while leaving the door open to beneficial advances.

Molecular medicine will challenge the prevailing model of the FDA. Supervising billion-dollar clinical trials run by big pharmaceutical firms is very different from supervising millions of people who are taking health into their own hands. In a world where individuals know their own genomes, teenagers are discovering causes of rare diseases, and patients and doctors collaborate by surveying all the accumulating data to develop exotic cocktail treatments to suit each individual, the FDA's current model breaks down.[7] Closely monitoring this world of exploding individualized information will be impossible, and if we try to do it, the benefits of the new innovations will be lost.

Designing a new system will not be easy. Just as apps and the Internet demanded (and depended upon) a more flexible regulatory environment than did broadcast TV and radio, so too individualized healthcare in a world of exploding information requires a new and far more flexible model of medical oversight.

The App-ification of Healthcare

The information revolution in health science and technology will unfold, but we do not know at what speed. Policies to encourage scientific discovery and technological experimentation will help. To fully unleash the forces described in the preceding three sections and truly consummate the app-ification of medicine, however, will require a thorough transformation of the *business* of healthcare. Why? Because the business of healthcare is broken.

We spend way too much on lots of things and too little on others. Customers don't know the price of most health products—and neither do many producers. Consumers and producers, moreover, don't talk to each other about the prices they don't know. Market entry into services and therapies is artificially constrained by, for example, insurance and pharmaceutical regulation.

The more we spend on a dysfunctional system, the less we have to invest in future innovation. This opaque and bloated system is the opposite of our market for software apps in which anyone can build an app and individuals choose which apps offer value. Only a dramatic rationalization of the economics of healthcare, from physicians to insurers to consumers, can contain runaway health budgets while at the same time boosting investment in technology and unleashing innovation.

Transforming the business of health might, at first glance, seem easier than genetic engineering or robotic prosthetics. The new medical science often seems miraculous, after all. And yet, because of the obstacles we humans have built, a transformation of the business of health is more speculative and uncertain than the most radical new scientific discoveries.

We must therefore describe an alternative vision to today's health economy, one that is both far more sensitive to the needs and pocketbooks of patient-consumers and promises far more innovation and value from providers. Then policymakers will have to shed the rules that lock in today's frustrations and unleash tomorrow's possibilities.

In today's world, an ever-more diverse population must submit to a shrinking number of

health providers and financial products. The results are high prices and less choice. Both providers and consumers are frustrated, however, because each must deal with a web of administrative bureaucracies that obscure information and suck value out of the system. Robert Graboyes, a researcher at George Mason University's Mercatus Center, calls today's healthcare system the "Fortress" for its immovable inertia and lack of innovation.

On the demand side of the equation, the tax treatment of health insurance and the structure and size of Medicare and Medicaid encourages most of our health dollars to be spent through the insurance channel, rather than directly. This "third-party payer" problem boosts prices and ensures overconsumption of many health services, although it probably leads to under-consumption of services not favored by private or government insurers.

The supply side of the equation is similarly distorted by rules (such as "certificate of need" laws) and payment methods that discourage innovation. Medicare and Medicaid also mold the structure for most of the provider world because they are such a large part of most providers' businesses. A few large payers—Medicare, Medicaid, and large private insurers—will tend to lead to a small number of large providers that can best navigate the payment and regulatory complexity of the administrative apparatus. Unfortunately, the ACA only makes most of these demand and supply side problems worse.[8]

There is a much better way. In the new world of health, a large number of competitive firms would offer a wide range of health and financial products to match the endless variety of consumers, patients, and their individual needs. Consumers would choose which doctors, services, clinics, and insurance products best fit their life circumstances. Graboyes calls this the healthcare "Frontier" for its forward-looking sense of possibility.

As the University of Chicago economist John Cochrane writes:

"We need to permit the Southwest Airlines, Wal-Mart, Amazon, and Apples of the world to bring to healthcare the same dramatic improvements in price, quality, variety, technology and efficiency that they brought to air travel, retail and electronics. We'll know we are there when prices are on hospital websites, cash customers get discounts, and new hospitals and insurers swamp your inbox with attractive offers and great service."

David Goldhill, the author of *Catastrophic Care*, concurs:

"What consumer-driven industries do is give us a massive range of choices to match the complexity of our individual preferences and resources. All a consumer has to do is choose, because in a consumer-driven economy the producers and sellers chase consumers, not the other way around."[9]

Some argue that healthcare cannot be like other industries in which entrepreneurs supply diverse and innovative products and consumers pick and choose which are a good value. A typical objection to a more consumer-driven market is to ask whether grandma really has the time or wherewithal to shop around and pick a heart surgeon on the way to the operating room for an emergency bypass. This fundamentally misunderstands the way most industries work. In almost every product or service, the consumer does not need to deeply understand every intricacy of the technology, business model, and personnel of the service provider. The firms in most industries compete relentlessly to serve consumers, delivering to them the best products at the lowest prices. Markets develop so that consumers can "magically" find what they need on demand.

In a world of growing health information, the vast majority of healthcare will be non-emergency diagnostics, monitoring, and treatment. Health advances in smartphones, Big Data, and molecular medicine are only pushing further in this direction of choice, early diagnosis, and preventive and long-term care. We can both continue to account for emergency

care and major surgeries and shift healthcare toward a consumer model. Let insurance cover truly surprising and serious health events, as insurance should, and move the rest of health supply and demand out of the insurance orbit.

Hospital system executives know this is the direction medicine must take, and they are planning for it. In a 2015 survey of 19 major health system executives, Deloitte found respondents believe that value-based care (VBC) and consumerism "will reshape the future of medicine." While large health systems will make important contributions to consumer-centric health, however, no industry can truly innovate without entrepreneurial firms experimenting with new products and services. Inertia is too powerful, especially in healthcare.

Several ironies and dilemmas prevail. Inpatient services are declining and outpatient services are rising, for example, and yet hospitals, clinics, and physician practices are consolidating into huge health systems and becoming a larger portion of the health landscape. The Deloitte survey found that "the biggest challenge noted by interviewed CEOs when preparing for 2025 is that they believe they must invest in VBC [value based care] capabilities even as much of their existing business is still oriented towards traditional FFS [fee for service] payment models and incentives."

This is the classic innovator's dilemma. How does a firm invest energy and money in speculative, inexpensive products that could end up supplanting today's expensive, best-selling items?

Big is not necessarily bad. Every industry has its economies of scope and scale, and firms should pursue the efficiencies offered by size. Large hospital systems and even insurers will be important parts of the future health landscape. Yet, any industry in which small, independent, competitive upstarts are either prohibited or discouraged will not be an innovative realm. Today's public policies dramatically favor consolidation and obstruct entrepreneurial health ventures. The app-ification of medicine demands a much freer environment in which physicians, researchers, and businesspeople of many backgrounds can approach health solutions in varied ways.

Policy for the Information Age of Health

Greater productivity in healthcare does not mean we need to "cut" healthcare quality or even, necessarily, spending. Healthcare is a superior good—when we have satisfied our other basic needs, it makes sense to spend to feel better, longer. As much as possible, however, individuals should make these decisions.

Productivity comes from matching real technology with real knowledge and real prices to produce real value. This is why medical procedures paid for with cash, such as Lasik eye surgery, have achieved dramatic technical success while driving down costs. The links between patient, doctor, technology, and price are real.

An ideal health system would combine several things:

1. Patients can and should be empowered by technology;

2. Insurance should actually be insurance against unforeseen illness, not a government-guided Rube Goldberg third-party payment infrastructure;

3. Doctors, clinics, technologists, and hospitals should be operating in a more dynamic environment with far more entrepreneurial business models than exist today; and

4. Regulatory bodies, including the FDA, should embrace the new world of personal devices, exploding information, and molecular medicine.

In the end, healthcare decisions should be personal and flexible, like a smartphone. Unfortunately, regulations under the ACA push in just the opposite direction, limiting diversity

and choice in the insurance market, constraining individualized consumer-doctor decisions, and forcing industry consolidation when more health experimentation is needed.

A costly, bloated system will, at some point, degrade our ability to fund high-end research and pay for high-end services. We need technology at the low end of the spectrum—on and inside our bodies, with the patient as consumer of the doctor's services—to foster ever-more technology at the high end: pharmaceuticals, diagnostics, and surgery. With sound public policy, the information revolution in health can cure not only our medical conditions but possibly our economic ills as well. EE

Bret Swanson is president of Entropy Economics and a U.S. Chamber of Commerce Foundation Fellow.

Portions of this report were adapted from the author's previous article "The App-ification of Medicine" in the Winter 2013 edition of the Business Horizon Quarterly.

The views expressed here are those of the author and do not necessarily reflect those of the U.S. Chamber of Commerce Foundation, U.S. Chamber of Commerce, or their affiliates.

[1] A 2013 RAND study, shows that the nearly $50 billion in public and private EHR investments associated with the Affordable Care Ace are, so far at least, not paying off. See, Arthur L. Kellermann and Spencer S. Jones, "What it will take to achieve the as-yet-unfulfilled promises of health information technology," *Health Affairs* 32, no. 1 (2013): 63-68.

[2] Eric Topol, *The Patient Will See You Now* (New York: Basic Books, 2015).

[3] Telemedicine services are growing rapidly in number, sophistication, agility, and cost-effectiveness. Large firms like CVS and smaller firms like Healthcare Magic, Dr. on Demand, ReelDX, and many more are experimenting with a number of business models and technologies. Physician groups, meanwhile, are beginning to develop policy guidelines for this new arena. See, for example, Hilary Daniel and Lois Snyder Sulmasy, "Policy Recommendations to Guide the Use of Telemedicine in Primary Care Settings: An American College of Physicians Position Paper," Annals of Internal Medicine, September 8, 2015.

[4] See Topol, Chapter 1.

[5] Early public health experts did use data about the spread of disease over various populations and geographies to pinpoint the causes of conditions such as cholera. And pharmaceutical firms and regulatory agencies have of course used trials and statistics to evaluate the safety and effectiveness of treatments. The new era, however, is characterized by a deep (although still very incomplete) understanding of the information networks among cells and even molecules. Yes, happy accidents still occur, but to a far greater degree than ever before, the new medicine is based on design.

[6] Peter W. Huber, *The Cure in the Code* (New York: Basic Books, 2013).

[7] See Topol's description of 16-year old Elena Simon, who helped find the genetic cause of her rare liver disease.

[8] See, for example, Scott Gottlieb, "The State of Competition in the Health care Marketplace – The Patient Protection and Affordable Care Act's Impact on Competition," *Testimony*, U.S. House Committee on the Judiciary, Subcommittee on Regulatory Reform, Commercial and Antitrust Law, September 10, 2015.

[9] David Goldhill, *Catastrophic Care* (New York: Vintage Books, 2013).