The Measured Man - Mark Bowden

Larry Smarr, an astrophysicist turned computer scientist, has a new project: charting his every bodily function in minute detail. What he's discovering may be the future of health care.

Like many people who are careful about their weight, Larry Smarr once spent two weeks measuring everything he put in his mouth. He charted each serving of food in grams or teaspoons, and broke it down into these categories: protein, carbohydrates, fat, sodium, sugar, and fiber.

Larry used the data to fine-tune his diet. With input nailed down, he turned to output. He started charting the calories he burns, in workouts on an elliptical trainer and in the steps he takes each day. If the number on his pedometer falls short of his prescribed daily 7,000, he will find an excuse to go for a walk. Picture a tall, slender man with the supple, slightly deflated look of someone who has lost a lot of weight, plodding purposefully in soft shoes along the sunny sidewalks of La Jolla, California.

Of course, where outputs are concerned, calories are only part of the story, and it is here that Larry begins to differ from your typical health nut. Because human beings also produce waste products, foremost among them … well, poop. Larry collects his and has it analyzed. He is deep into the biochemistry of his feces, keeping detailed charts of their microbial contents. Larry has even been known to haul carefully boxed samples out of his kitchen refrigerator to show incautious visitors. He is eloquent on the subject. He could *sell* the stuff.

VIDEO: Larry Smarr shows off his imaging equipment—and the inside of his colon.

"Have you ever figured how information-rich your stool is?," Larry asks me with a wide smile, his gray-green eyes intent behind rimless glasses. "There are about 100 billion bacteria per gram. Each bacterium has DNA whose length is typically one to 10 megabases—call it 1 million bytes of information. This means human stool has a data capacity of 100,000 terabytes of information stored per gram. That's many orders of magnitude more information density than, say, in a chip in your smartphone or your personal computer. So your stool is far more interesting than a computer."

Larry's fascination is less with feces themselves than with the data they yield. He is not a doctor or a biochemist, he's a computer scientist—one of the early architects of the Internet, in fact. Today he directs a world-class research center on two University of California campuses, San Diego and Irvine, called the California Institute for Telecommunications and Information Technology, or "Calit2" (the *2* represents the repeated *I* and *T* initials). The future is arriving faster at Calit2 than it is in most places. Larry says his eyes are focused "10 years ahead," which in computer terms is more like a century or two, given how rapidly the machines are transforming modern life. Intent on that technological horizon, Larry envisions a coming revolution in medicine, and he is bringing his intellect and his institute to bear on it.

At 63, he is engaged in a computer-aided study of the human body—specifically, *his* body. It's the start of a process that he believes will help lead, within 10 years, to the development of "a distributed planetary computer of enormous power," one that is composed of a billion processors and will enable scientists to create, among many other things, a working computational model of your body. Your particular body, mind you, not just some generalized atlas of the human frame, but a working model of your unique corpus, grounded in your own genome, and—using data collected by nanosensors and transmitted by smartphone—refreshed continually with measurements from your body's insides. This information stream will be collated

with similar readings from millions of other similarly monitored bodies all over the planet. Mining this enormous database, software will produce detailed guidance about diet, supplements, exercise, medication, or treatment—guidance based not on the current practice of lumping symptoms together into broad categories of disorders, but on a precise reading of your own body's peculiarities and its status in real time.

"And at that point," says Larry, in a typically bold pronouncement that would startle generations of white-coated researchers, "you now have, for the first time in history, a scientific basis for medicine."

When Socrates exhorted his followers, "Know thyself," he could not have imagined an acolyte so avid, or so literal, as Larry. You've heard of people who check their pulse every few minutes? Amateurs. When Larry works out, an armband records skin temperature, heat flux, galvanic skin response, and acceleration in three dimensions. When he sleeps, a headband monitors the patterns of his sleep every 30 seconds. He has his blood drawn as many as eight times a year, and regularly tracks 100 separate markers. He is on a first-name basis with his ultrasound and MRI technicians, who provide him with 3-D images of his body, head to toe. Regular colonoscopies record the texture and color of his innards. And then there are the stool samples—last year Larry sent specimens to a lab for analysis nine times.

Larry is a mild, gentle soul, someone generally more interested in talking about you than about himself. He does not go out of his way to get your attention, and nothing about him is remotely annoying or evangelical. But if you show an interest in his project and start asking questions—look out. Beneath the calm and the deference, Larry is an intellectual pitchman of the first order. His quest to know burns with the pure intellectual passion of a precocious 10-year-old. He visibly shudders with pleasure at a good, hard question; his shoulders subtly rise and square, and his forehead leans into the task. Because Larry is on a mission. He's out to change the world and, along the way, defeat at least one incurable disease: his own. (More on this in a moment.)

Larry is in the vanguard of what some call the "quantified life," which envisions replacing the guesswork and supposition presently guiding individual health decisions with specific guidance tailored to the particular details of each person's body. Because of his accomplishments and stature in his field, Larry cannot easily be dismissed as a kook. He believes in immersing himself in his work. Years ago, at the University of Illinois, when he was taking part in an experiment to unravel complex environmental systems with supercomputers, Larry installed a coral-reef aquarium in his home, complete with shrimp and 16 other phyla of small marine critters. It was maddeningly fragile. The coral kept peeling off the rocks and dying. He eventually discovered that just five drops of molybdenum, a metallic element, in a 250-gallon tank once a week solved the problem. That such a tiny factor played so decisive a role helped him better grasp the complexity of the situation. And as he fought to sustain the delicate ecosystem in his tank, he developed a personal feel for the larger problem his team was trying to solve.

Today, he is preoccupied with his own ecosystem. The way a computer scientist tends to see it, a genome is a given individual's basic program. Mapping one used to cost billions. Today it can be done for thousands, and soon the price will drop below $1,000. Once people know their genetic codes, and begin thoroughly monitoring their bodily systems, they will theoretically approach the point where computers can "know" a lot more about them than any doctor ever could. In such a world, people will spot disease long before they feel sick—as Larry did. They will regard the doctor as more consultant than oracle.

Not everyone sees this potential revolution as a good one. Do people really want or need to know this much about themselves? Is such a preoccupation with health even *healthy*? What if swimming in oceans of bio-data causes more harm than good?

"Frankly, I'd rather go river rafting," says Dr. H. Gilbert Welch, a professor of medicine at the Dartmouth Institute for Health Policy and Clinical Practice, and the author of *Overdiagnosed: Making People Sick in*

the Pursuit of Health. "Data is not information. Information is not knowledge. And knowledge is certainly not wisdom." Welch believes that individuals who monitor themselves as closely as Larry does are pretty much guaranteed to find something "wrong." Contradictory as it sounds, he says abnormality is *normal*.

"It brings to mind the fad a few years ago with getting full-body CT scans," Welch says. "Something like 80 percent of those who did it found something abnormal about themselves. The essence of life is variability. Constant monitoring is a recipe for all of us to be judged 'sick.' Judging ourselves sick, we seek intervention." And intervention, usually with drugs or surgery, he warns, is never risk-free. Humbler medical practitioners, aware of the sordid history of some medical practices (see: bloodletting, lobotomy, trepanning), weigh the consequences of intervention carefully. Doing no harm often demands doing nothing. The human body is, after all, remarkably sturdy and self-healing. As Welch sees it, "Arming ourselves with more data is guaranteed to unleash a lot of intervention" on people who are basically healthy.

Not to mention creating an epidemic of anxiety. In other words, the "quantified life" might itself belong to the catalog of affliction, filed under *Looking too closely, hazards of*.

In that sense, the story of Larry Smarr might be less a pioneering saga than a cautionary tale.

Larry's journey started with that most American of preoccupations, losing weight. Larry doesn't update the photo each time he renews his California driver's license, preferring to keep, as a reminder, the one taken soon after his arrival at UCSD 12 years ago, with his wife, Janet. It shows a 51-year-old Larry, one with more and longer hair, a wide, round face, and an ample second chin. Call him Jolly Larry. He had just arrived from Illinois, a place he now refers to as "the epicenter of the obesity epidemic," and he had a girth to match his oversize professional reputation. (Deep-fried, sugarcoated pastries were a particular favorite of his back then.) Arriving in La Jolla, Jolly Larry found himself surrounded by jogging, hiking, biking, surfing, organic-vegetable-eating superhumans. It was enough to shame him into action. If he was going to fit in on this sunny new campus, he would have to shape up.

So Jolly Larry started working out, reading diet books, and stepping on the scale every day. At first, his charts were disappointing. Like countless strivers before him, he dropped some weight, but not much, and it kept wanting to come back. Three or four popular books on weight loss left him mostly confused, but they did convey a central truth: losing weight was only 20 percent about exercise. The other 80 percent was about what he put in his mouth. What triggered his breakthrough was the advice of Barry Sears, the biochemist who created the Zone Diet, which pressed Larry's buttons precisely. Sears proposed that to diet more effectively, one needed to *know* more. Larry decided to study up on his body chemistry.

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Few people in history have been better positioned to act on such advice. Larry had begun his professional life as an astrophysicist, trying to unravel the core puzzles of the universe. In 1975, when he was working toward his doctorate at the University of Texas, one of his advisers suggested that he get a top-secret government security clearance: behind the walls of America's nuclear-weapons program were not only some of the nation's premier physicists, but also the world's first supercomputers, hundreds of times faster than anything available on any college campus. Larry got his clearance, and in the following years, while working as a fellow at Princeton and at Harvard, he would disappear during summers behind the classified walls of the Lawrence Livermore National Laboratory, in the San Francisco Bay Area. There he would work 16-hour shifts on some of the most difficult problems in his field—but with a crucial difference. Working with a computer at one of his universities, Larry might set it a task to compute overnight. He would go home, and when he returned the next morning, the task would be nearing completion. Working with the new Cray supercomputer at Livermore, he could get the same result in a minute and a half.

When he'd return to his university posts in the fall, and rejoin his colleagues working at a comparative

snail's pace, he'd tell them, "You know, guys, we could be using supercomputers to solve the laws of physics, instead of trying to do these closed-form static solutions that you do." They would look at him as if he was crazy. "What are you talking about?" they'd ask. "That can't be done." To them, it seemed impossible. The supercomputer enabled not just faster work, but a different style and language of experimentation. But when he tried to explain to his colleagues, who were still working mostly with pencils and paper, they scratched their heads. "It was like I was living in two different worlds," Larry says.

When one of the first Cray computers outside of secret nuclear programs was set up in Munich, Larry started spending his summers there. "And in about '82, we were at a beer garden and it was probably my second glass of beer, and I was being hosted by a German astrophysicist, world-class," Larry recalls. "He asks, 'Tell me something. My father helped build the trains Germany relied on during the war. And here in our occupied country, you guys, you Americans, come over here and mooch off of our supercomputers because you don't have the wit to put them in your universities where people can get access to them. Have I got that right?' And I said, 'Pretty much.' And he asks, 'How did you guys win the war?'"

Larry brought that question home with him to his perch at the University of Illinois. There, in 1983, he helped draft "The Black Proposal," an unusually concise recommendation (in a black cover) for a $55 million National Science Foundation supercomputer center. When it was funded, along with four other NSF centers, Larry and others argued for using the protocols of the military's ARPANET (the precursor to the Internet) to link the centers, so that civilian researchers across the nation could use the fastest computers in America for basic research. The linking proposal was controversial not only because it took on the cult of secrecy surrounding the most-advanced computers in America, but because it specifically recommended that the NSF include only computer networks using TCP/IP, a universal computer protocol designed to facilitate not secrecy, but collaboration. TCP/IP allowed different kinds of computers to exchange data seamlessly. At the time, the large computer companies—DEC, IBM, General Electric, etc.—preferred a market model where manufacturers competed to create large fiefdoms, networks that used only their own machines. By adopting Larry's proposal, the NSF enabled computer networks to plug into the system, a critical step toward today's Internet.

By the time, years later, that Larry heeded Barry Sears's suggestion to learn more about his body's chemistry, Larry had at his disposal at UCSD a supercomputer with a capacity many times greater than that of any he'd worked on at Livermore. His research interests had shifted from astrophysics to the impact computers were having on all kinds of fields, including medicine. Calit2 already had numerous grants to study "digitally enabled genomic medicine," so in 2010 Larry signed himself up as a test subject. As his personal quest to lose weight evolved into an effort to understand human biochemistry, his own body became the equivalent of the coral-reef tank he'd once kept in his living room.

Larry had already radically changed his diet, breaking his intake into subcategories, aiming for a caloric split of 40 percent low-glycemic carbohydrates, 30 percent lean protein, and 30 percent omega-3–enriched fat. His meal portions were about half of ordinary restaurant portions. Following what was essentially Barry Sears's Zone Diet, Larry had lost a pound every 10 weeks, dropping 20 pounds in four years.

Most people would have been happy with that. But his dieting taught Larry something. If he wanted good health, he could not simply trust how he felt and wing it. If he wanted to understand what was happening in his body, he had to examine the data. And despite his weight loss, the data were now telling him something that didn't seem to make sense. By his calculations, the pounds should still have been falling off, but they weren't.

According to his measurements, he had doubled his strength and tripled the number of steps he took each day. His REM periods, the most valuable periods of sleep, accounted for more than half the time he spent in the sack—twice the typical proportion for a man of his age. His weight was steady. But Larry wanted to

know more. He had been getting blood tests once or twice a year as part of his normal health maintenance, but by the end of 2010 he was sending off blood samples more often and graphing dozens of markers, which enabled him to at least better define the mystery. The Zone Diet is designed to reduce inflammation, and because he followed it faithfully, Larry expected his blood-test inflammation score to be low. But the C-reactive protein (CRP), which rises in response to inflammation, was high.

"I had discovered that my body is chronically inflamed—just the opposite of what I expected!" he wrote in an account of his project published last year in a special issue of *Strategic News Service*, a computer/telecommunications newsletter. (The article was prefaced by an enthusiastic note from the publisher, Mark R. Anderson, who said that it "may be the most important Special Letter we have ever published. For many of you reading it, it may also save your lives, or extend them.") Larry wrote:

> Even more intriguing: after I had been tracking my CRP for two years, I noticed that it had suddenly more than doubled in less than a year. Troubled, I showed my graphs to my doctors and suggested that something bad was about to happen.

Here you should try to imagine the average physician's reaction when a patient, outwardly healthy, arrives with detailed graphs of his body chemistry, concerned that something evil is stalking his insides.

"Do you have a symptom?," Larry was asked.

"No," he answered. "I feel fine."

He was assured that charts like his were "academic," and not useful for clinical practice. The doctors told him to come back if and when he found something actually wrong with *him*, as opposed to finding anomalies in his charts.

I ask Larry a question his doctors might have been too polite to ask: "Are you a hypochondriac?"

"A hypochondriac is someone who imagines that they have things that are wrong with them and worries about that," he says. "I am the opposite of a hypochondriac. I don't make any assumptions about what might be right or wrong with me, and I don't imagine it. I measure it."

Larry was beginning to have serious doubts about the way medicine is practiced in this country. "Here's the way I look at it; the average American has something like two 20-minute visits a year with a doctor," he explains. "So you have 40 minutes a year that that doctor is going to help you make good decisions. You have 500,000 minutes a year on your own, and every one of those, you are making decisions. So we're already in a situation where you are in charge of your ship—your body—and you are making a lot of pretty horrible decisions, or else two-thirds of the United States' citizens wouldn't be overweight or obese. You wouldn't have the CDC saying that 42 percent of Americans may be obese by 2030, and a third of all Americans may develop diabetes by 2050. That's the result of a lot of bad decisions that people are individually making on their own."

A few weeks after his doctors dismissed his graphs as "academic," Larry felt a severe pain in the left side of his abdomen. At his doctor's office, he was diagnosed with an acute bout of diverticulitis, an intestinal disease caused by inflammation. He was put on a 10-day antibiotic program to treat the ailment. To Larry, this perfectly illustrated the problem. Doctors were ready, eager, and well-equipped to address a clinical symptom, but unwilling to wade with him into his charts, which, although undeniably abstract, had foretold the problem! It was at this point that Larry decided to take over his own health care.

He asked to see the written report from his last colonoscopy, and underwent another. He began testing his stool, recognizing that all of us are, in fact, "superorganisms," that our gastrointestinal, or GI, tracts are a

collaboration between human digestive cells and the trillions of bacteria that line our intestines. The stool samples provided detailed charts of the workings of these microorganisms, which is what Larry means when he calls his poop "data-rich." He was learning more about the biochemistry of his own body than any patient had ever known, and the numbers continued to add up in an alarming way. They suggested that he was suffering not from diverticulitis, but from some kind of inflamed-bowel disease. He then went looking for an expert to help him interpret the data. He didn't have to look far: Dr. William J. Sandborn had recently left the Mayo Clinic to take over the GI Division of UCSD's School of Medicine.

"I think he felt like he wasn't really being taken seriously," says Sandborn. "So he came over and we looked, and we ended up finding some degree of inflammation that was pointing in the direction of Crohn's disease, but he wasn't really having many symptoms. So the question then became: Is this some kind of early subclinical Crohn's disease? Should we even go as far as treating it, or just wait?"

Larry's impressive quest to fine-tune his body had led him to this: an early diagnosis of Crohn's disease, an incurable condition. It isn't fatal, but it has a long list of uncomfortable and sometimes painful symptoms that tend to flare up from time to time; they center around the GI tract, but may include eye inflammation, swollen joints, fever, fatigue, and others. Apart from that one episode of abdominal pain, Larry was still feeling fine. But the graphs showed, and his new doctor more or less confirmed, that he was sick.

And that part about its being incurable? Let's just say that in Larry, Crohn's disease has encountered a very dedicated adversary.

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If past thinkers leaned heavily on the steam engine as an all-purpose analogy—e.g., contents under pressure will explode (think Marx's ideas on revolution or Freud's about repressed desire)—today we prefer our metaphors to be electronic. We talk about neural "circuitry," about "processing" information, or about how genes "encode" our physical essence. In this worldview, our bodies are computers, and DNA functions as our basic program, our "operating system."

This is certainly how Larry, the computer scientist, talks about the human body. In this context, all of human history can be seen as a progression from a world that was data-poor to one that is data-rich. Starting with those early summers working in secrecy at Livermore, Larry has witnessed firsthand the exponential progress of computing power posited by Moore's Law, which states that the computer-chip transistor count should double roughly every two years. So when Larry talks about the potential for computers to help us understand our bodies, he isn't talking about their showing us more isolated details about an unfathomably complex system; he's talking about knowing *everything*.

"We are going to know—once you know each of your cells' 6 billion genome bases, with all the imaging down to the micron level, and when you know every damn gene and every bacterium—at a certain point, there is no more data to know," he says. "So certainly by 2030, there is not going to be that much more to learn … I mean, you are going to get the wiring diagram, basically." Once they are armed with the wiring diagram, Larry sees no reason why individuals cannot maintain their health the way modern car owners maintain their automobiles.

Larry actually concedes the point made by Dartmouth's Welch—that presented with enough data, pretty much everyone is going to find something wrong with them. He just disputes that this would be a bad thing. "All of us do have something beginning to go wrong, but then, so do our automobiles," Larry says. "In today's world of automobile preventive maintenance, we don't wait for our cars to break down and then go to the 'car doctor.' Every 10,000 or 20,000 miles, we go in and get an exhaustive look at all the key variables since the last check. If they find something wrong with my car—which will be different from what they find about yours—then they take appropriate action and I go back to driving a 'healthy' car.

Occasionally, something is discovered that indicates a bunch of cars need to be called in and get a certain item replaced. I can imagine that occasionally, as a new DNA segment is related to some disease, people with that DNA signature will be called in for 'preventive maintenance.'"

If Larry is right, then our descendants may view early-21st-century medical practices, which we consider a triumph of reason over superstition, in the same way we now view 18th- and 19th-century folk remedies. A particularly likely candidate for scorn in an age of "quantified" health care is our one-pill-fits-all approach to prescription drugs. In his book *The Creative Destruction of Medicine*, the physician-author Eric Topol cites such dosing as an example of medicine that is "population-based," rather than "patient-centered." He notes the widespread use of statins to lower LDL cholesterol, a factor in heart disease. Topol doesn't deny the cholesterol-lowering effect of these drugs, but he argues that double-blind testing also shows that this effect benefits only a tiny fraction of those treated. One of the most effective statins, Crestor, has been found to reduce the incidence of stroke, heart attack, or death from 4 percent of patients in the placebo group to 2 percent of the group taking the statin. And yet these drugs are widely administered to patients considered at risk. Topol writes:

> Instead of identifying the 1 person or 2 people out of every 100 who would benefit, the whole population with the criteria that were tested is deemed treatable … What constitutes evidence-based medicine today is what is good for a large population, not for any particular individual.

Pharmaceutical companies don't mind. And as long as the harmful side effects are within acceptable limits, the Food and Drug Administration doesn't mind, either. Some patients will be helped. All of them will be buying the pills, and all will be subjected to follow-up tests, some of them uncomfortable and most of them unnecessary. What if there were a way, Topol asks, of knowing, before prescribing the drug, which 2 percent would be most likely to benefit from it? In an observation that Larry wholeheartedly endorses, Topol writes:

> Fortunately, our ability to get just that information is rapidly emerging, [and we are] beginning an era characterized by the right drug, the right dose, and the right screen for the right patients, with the right doctor, at the right cost.

Getting there will mean essentially dismantling the health-care industry as we know it. (Thus the *creative destruction* of Topol's title.) Or, as Larry puts it: "A lot of enormously wealthy, established, powerful institutions in our society are going to be destroyed." And why not? Over the past 20 years, computers have been toppling and rebuilding industries one by one, from retail sales (Walmart and Amazon), to banking (ATMs and online services), to finance (high-speed online investing), to entertainment (Web streaming, downloads, YouTube, etc.), to publishing (e-books and news aggregators). We're just babes in this new digital era, and it will eventually upend almost every field of human endeavor.

Larry sees medicine as a stubborn holdout. Current efforts to reform the system—for instance, the Obama administration's initiative to digitize all health records by 2014—are just toes in the water. Medicine has barely begun to take advantage of the million-fold increase in the amount of data available for the diagnosis and treatment of disease. Take the standard annual physical, with its weigh-in, blood-pressure check, and handful of numbers gleaned from select tests performed on a blood sample. To Larry, these data points give your doctor little more than a "cartoon" image of your body. Now imagine peering at the same image drawn from a galaxy of *billions* of data points. The cartoon becomes a high-definition, 3-D picture, with every system and organ in the body measured and mapped in real time.

Indeed, a very early prototype of this kind of high-definition image already exists at Calit2. It is, of course, of Larry.

Inside a "cave" fashioned from large HD screens (each with dual rear projectors) and linked to 18 gaming

PCs to create a graphics supercomputer, Larry and I step *into* a stunning image assembled from an MRI scan of his torso. The room, the size of a walk-in closet, is lined with giant screens, front, sides, and back. More screens angle from these walls toward a floor that is illuminated from above. Two curved, waist-high metal railings offer support, because viewers at the center of this visual world can easily lose their balance. A sensor strapped to your forehead tells the computer where you are looking, so as you turn your head it smoothly blends the images on the screens to create a seamless 360-degree alternative world. (This is clearly the future of video games and cinema.) I had to lean on the metal bars to remind myself I was not someplace else. Once we were in position, Jürgen P. Schulze, a Calit2 research scientist, punched up a display of Larry's own coiled, 63-year-old entrails. I felt as if I could reach out and touch the wrinkled contours of his intestines and arteries.

Larry's inner 10-year-old rejoices. "Look!" he says, lifting and opening his hands. "This is me!"

He points to the source of his health concerns, the precise six-inch stretch of his sigmoid colon that is visibly distorted and inflamed. This is Larry's discovery, and his enemy.

I note that the display breaks new ground in the annals of self-disclosure: Larry is literally turning himself inside-out for a journalist. He does worry a little about making public such intimate details, but this openness is part of how he believes medicine ought to be—and ultimately *will* be—practiced. The current consensus that medical records should be strictly private, subject to the scrutiny of only doctor and patient, will be yet another casualty if Larry's health-care vision comes to pass. "A different way to organize society is to say it is human-focused, human-centered, patient-centered, and that there are no legal or financial repercussions from sharing data," he says. "There is a huge societal benefit from sharing the data, getting it out from the firewalls, letting software look across millions of these things."

The way the system works now, when a technician examines the MRI of a patient's abdomen, in two dimensions, on a single screen, she compares and contrasts it with perhaps thousands or even tens of thousands of other images she has seen. She then writes a report to the physician explaining, on the basis of her memory and experience, what is normal or abnormal in what she sees.

But "software can go in, volumetrically, over, say, a *million* different abdomens," says Larry, gesturing at the image of his own innards, "and come up with exquisite distribution functions of how things are arranged, what is abnormal or normal, on every little thing in there. In my case, what I have found is inflammation. Unaddressed, it may lead to structural damage and maybe eventually surgery, cutting that part out. So I am going to have another MRI in three months, and that will tell me whether the things I am doing have made it better, or if it is the same, or has gotten worse."

It's that sense of control that appeals to Larry as much as anything.

"The way we do things now," he says, "the technician will examine it and write up a report, which goes to my doctor, and then he explains it all to me. So I am *disembodied*. Patients are completely severed from having any relationship with their body. You are helpless."

Shedding that sense of disembodiment and helplessness is, in theory, one of the most attractive features of Larry Smarr's quantified self. Individuals will understand their own bodies and take care of themselves; doctors will merely assist with the maintenance and fine-tuning. With that sense of personal ownership established, Larry believes, the average American won't continue to drink 500 cans of soda a year, or ingest some 60 pounds of high-fructose corn syrup. After all, educational campaigns about cigarettes have helped lower the share of smokers in America to below 20 percent. If we made such inroads into the obesity epidemic, Larry says, "we would have a national celebration."

For his part, Larry is no longer disembodied. He has had key snippets of his DNA sequenced, and will have

the whole thing completely sequenced by the end of this year. In just what he has seen so far, he has discovered telltale markers linked with late-onset Crohn's disease. He has developed his own theory of the disease, based on his reading of the most recent medical literature and his growing perception of himself as a superorganism. In a nutshell, he suspects that some of the essential bacteria that should line the walls of his intestine at the point where it is inflamed have been killed off, probably by some antibiotic regimen he underwent years ago. So he has begun charting, through stool samples, the bewilderingly complex microbial ecology of his intestines.

He showed me a detailed analysis of one such sample on his computer, drawing my attention to the word *firmicute*. "So, what the hell is a *firmicute*?" he asks rhetorically. "And in particular, it is in these two groups, *Clostridium leptum* and *Clostridium coccoides*. So I go back, and I go, 'Clostri-Clostri-Clostri, that rings a bell. I had it in my last stool measurement.'" He pulls up an older chart on his screen. "Here is my stool measurement from January 1, 2012. And here are my bacteria. *Lactobacillus* and *Bifidobacteria*: that is what you get in, like, a yogurt and stuff like that, right? *Clostridiums*: you can have them from zero to four-plus. Four-plus is what they should be. And you can see I am deficient here on a number of them," he says, pointing to low numbers on the chart. "So then I went back over time and got them plotted, and they never were above two, and now they are collapsed down to one. So it looks like I am losing. So what do *Clostridia* do? Because I am missing them—I am missing that service."

You may note the *Alice in Wonderland* quality of all this. Every question Larry seeks to answer raises new questions, every door he opens leads to a level of more-bewildering complexity. One could easily conclude that these levels never bottom out, that the intricacy of the human body, composed of its trillions of cells—each dancing to the tune of a genetic program but also subject to random intersections with outside forces such as radiation, chemicals, and physical accidents—is for all practical purposes infinite, and hence permanently beyond our full comprehension. But Larry, with his astrophysics background, is utterly undaunted by complexity. This is the gift of the computer age: things once considered too numerous to count can now be counted. And Larry believes that questions about how the human body functions are ultimately finite.

In his own case, Larry has zeroed in on what he believes is the specific missing bacterial component behind the immune-system malfunction causing his bowel inflammation. He's begun a regimen of supplements to replace that component. If it doesn't work, he'll devise a new plan. He isn't aiming for immortality—not yet, although, as far as he is concerned, it's not out of the question. As we develop our ability to replace broken-down body parts with bioengineered organs, and as we work toward a complete understanding of human systems and biochemistry … Why not?

Reflecting on Larry's vision of a patient-centric, computer-assisted world of medical care, Dr. Welch allows: "I can conceive of this happening. But is this the model we want for good health? What does it mean to be healthy? Is it something we learn from a machine? Is it the absence of abnormality? Health is a state of mind. I don't think constantly monitoring yourself is the right path to that state of mind. Data alone is not the answer. We went through all of this with the Human Genome Project. You heard it then: if we could just get all of this data, all of our problems would be solved. It turned out that the predictive power of mapping the genome wasn't all that great, because there are other factors at play: the environment, behavior, and chance. Randomness has a lot to do with it."

And these are not the only reasons to be skeptical of Larry's vision. Researchers will certainly continue to map the human body in ever-greater detail, enabling doctors to spot emerging illness earlier and to design drug treatments with far more precision. But in the end, how many people will want to track their bodily functions the way Larry does, even if software greatly simplifies the task? Larry says the amount of time he has spent monitoring and studying himself has grown a lot, but that it still adds up to less time each day than most Americans spend watching television. But even if that time is radically reduced by software, how

many of us, understanding that our decrypted genome may reveal terrible news about our future—Alzheimer's, crippling neuromuscular diseases, schizophrenia, and so on—will even want to know?

When I ask Larry this question, he frowns and says, "I can't understand that." The very idea stumps him. To him, *not wanting to know something*—even bad news—just doesn't compute. His whole life is about finding out. He's a scientist to his core.

"I hear it a lot, but I don't understand it. Because whatever it is, if you suspect that you are going to have, say, Alzheimer's within five years or 10 years, then that should focus your mind on what it is you want to accomplish in the days that you have left." Then, after a moment more thought, he adds, "And if you don't know, those days are going to just slide by, in which you could have done something that you always meant to do."

He knows that the way he lives and works might seem eccentric or even a little crazy to others. "Most of my life, people have thought I was crazy at any given point," he says. "Maybe being crazy simply means you are clear-sighted and you are looking at the fact that you are in a period of rapid change. I see the world as it will be, and of course, that is a different world than the one we live in now."

Larry is in a hurry to get there. He sees himself 10 years down the road as someone healthy and active and strong, instead of someone struggling to manage the increasingly uncomfortable and debilitating effects of Crohn's. As he makes his way down the supplements aisle of his Whole Foods Market, looking for a very specific assortment of probiotics with which to mix his remedial cocktail, he's not just trying to save himself. He's trying to save you.

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Excerpted from *The Measured Man - Mark Bowden - The Atlantic*
http://www.theatlantic.com/magazine/archive/2012/07/the-measured-man/309018/

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