Aging + TECHNOLOGY

Third in a series of reports on biomedical engineering innovations

MANAGING CARE THROUGH THE AIR

Growing old in a wireless world will mean not just keeping your body healthy but keeping it online

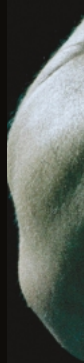
By Philip E. Ross

IT MIGHT NOT BE POLITIC to compare people to cattle, but for the moment bovines are ahead of humans in the use of wireless technology for remote health monitoring. Cows in Britain, and now in the United States, are being equipped with wireless under-the-skin electronic sensor packages, costing about US $100, that monitor heartbeat, temperature, and other signs of impending mad cow disease. Sure, few people would want such an intrusive watch on their vitals, but that just might be what's needed to keep the next generation of older people living longer on their own.

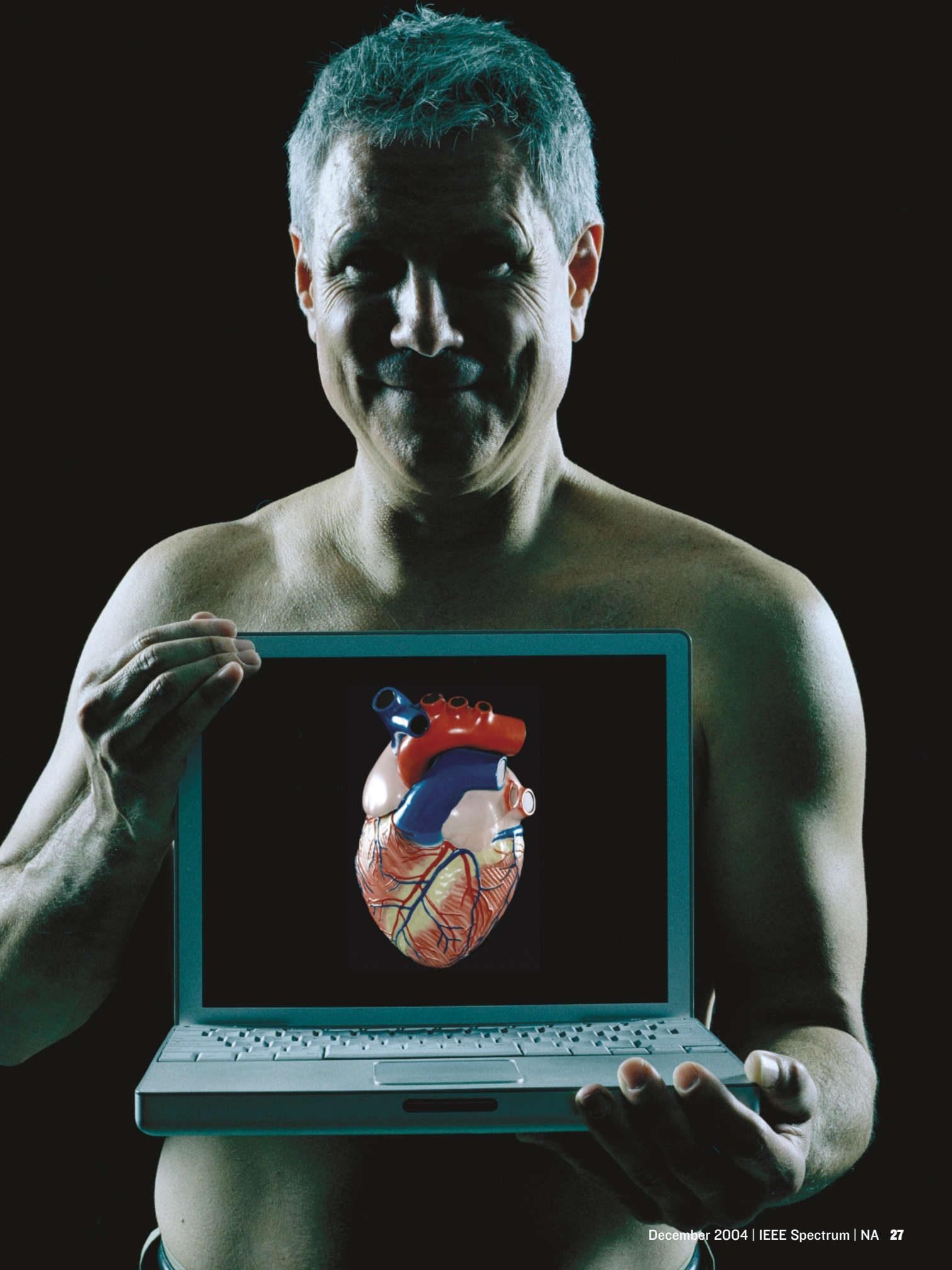
And it will be quite a generation. The worldwide population of those over 65 is predicted to reach 761 million by 2025, more than double what it was in 1990. Assuming current trends continue, this century will see the first time in human history that the old outnumber the young.

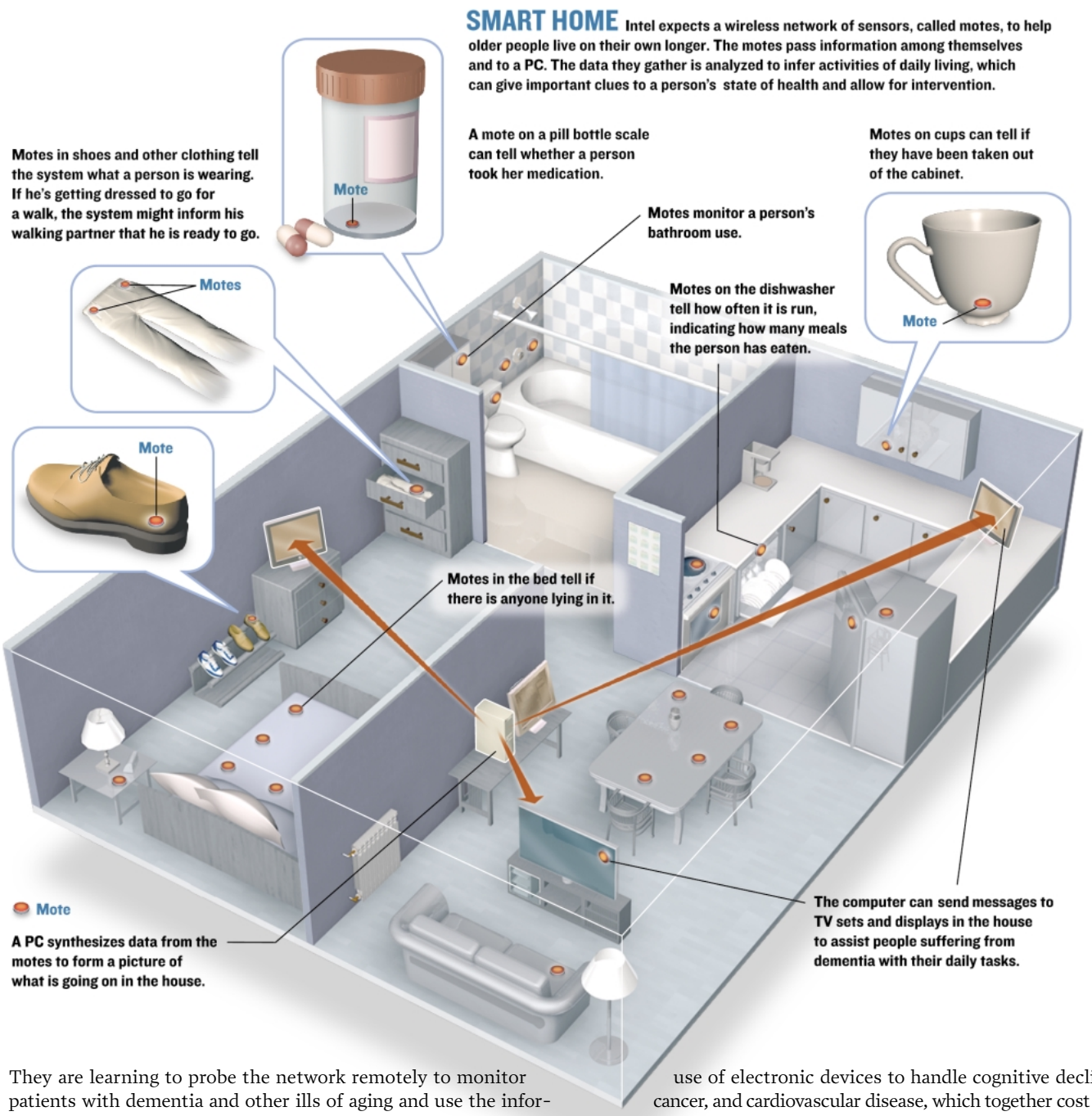
Meeting the needs of those with the chronic diseases of aging—heart disease, Alzheimer's, and so forth—is a labor-intensive chore we increasingly cannot afford. Health care consumes 15 percent of the U.S. gross national product, up from 5 percent in 1960. In Japan and Europe, which manage care more frugally, the share has in most cases already passed the 10 percent mark. And the numbers continue to rise. We will have to find clever ways to economize on labor, the most expensive element in health care. "General practitioners and other front-line health care people are overwhelmed; they haven't got time for patients, and the vast majority would welcome relief from some well-chosen, well-placed technology," says Philippe M. Fauchet, an electrical engineer and director of the Center for Future Health at the University of Rochester, in New York. He and others are betting that information gleaned from our increasingly networked world will be a big part of the solution.

Manufacturers of pacemakers are already beaming out data from the devices in the hope of picking up early trouble signs, so as to keep people out of the hospital. Meanwhile, electronics giants are working to pepper the home with a network of wirelessly linked sensors slapped on nearly everything from coffee cups to bathroom doors.



BRENT HUMPHREYS





They are learning to probe the network remotely to monitor patients with dementia and other ills of aging and use the information to help the patients' families care for them. The next generation of older people may live in a world where every beat of their hearts and every ordinary thing they do is watched, analyzed, and evaluated for signs of trouble. Orwellian as it may seem, such care may actually be less intrusive than the alternative: the loss of independence that follows when people must leave their own homes for nursing homes.

WIRELESS REMOTE MONITORING of older people could be a big market, and a group of high-tech heavyweights is trying to jump-start it. Companies including General Electric, Hewlett-Packard, Honeywell, and Intel have teamed up in the Center for Aging Services Technologies (CAST), in Washington, D.C., established in 2002 to encourage collaborative aging-related technology development and advocate for such technology with the U.S. government. Eric Dishman, chairman of CAST and Intel's director of proactive health research, says that Intel's immediate focus is on the use of electronic devices to handle cognitive decline, cancer, and cardiovascular disease, which together cost the U.S. economy some $600 billion a year, if you include estimates of lost productivity. Intel's idea is to deduce the actions of older people in their homes through a network of wireless sensors and use that information to help patients comply with doctors' orders, enable remote caregiving by family and friends, and detect early signs of disease and prevent its progression.

The key technology, according to Dishman, will be tiny battery-powered sensors called motes. These sensors, being developed at the University of California, Berkeley, and Crossbow Technology Inc., in San Jose, Calif., organize themselves into a wireless network, sharing data with one another and with computers. Currently, each mote is about as big as a matchbox, but engineers are working to make them small enough to be unobtrusively integrated into everything from sneakers to coffee cups [see illustration, "Smart Home"].

Of course, neither the families of older people nor their doctors should have to be glued to their computer screens, watching and evaluating every bit of data coming from the motes in order to care for

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the elderly. "You don't want to get an e-mail every time a cabinet door opens in your mom's kitchen," says Dishman. "But you do want it when she's not drinking enough, after 30 years of having three cups of coffee or tea a day." It would take a large degree of intelligence, but software in a home PC could analyze the information coming from the motes, recording the routine and acting on the alarming.

PREVENTION OF DISEASE comes from unglamorous things like encouraging people to eat properly and to exercise, changes in habit that are famously hard to effect. The single best aid to such behavior modification is a support group, and there is some evidence that such groups can be bound more tightly together with technology. "[Motes] could let your walking buddy know you've got your walking stuff out and maybe suggest opportune times to go walking together," says Dishman.

Using wireless sensors to track the routine activities of daily life—how people dress, what they cook in the morning, how well they drive their cars—might make for a mundane set of data. But such data can greatly help in the diagnosis of neurological disorders such as Parkinson's or Alzheimer's disease. Parkinson's can so far be diagnosed only through behavioral changes, principally changes in gait.

About 22 MILLION PEOPLE worldwide suffer from heart failure

Yet to get a really early diagnosis would require noticing quite subtle distinctions. Experts have studied videos from Michael J. Fox's sitcom "Spin City" to see how the actor behaved in the period before he was diagnosed with Parkinson's. These videos, which constitute a rare treasure trove, appear to show the length of Fox's stride getting shorter over time. Dishman contends that a set of behavioral markers for diagnosing Alzheimer's should emerge from such data as well. "Most people are not diagnosed until they have already had the disease for five or even 10 years before they either acknowledge or realize it," he says. The markers might show the onset of Alzheimer's well before that, in time for drug therapies to have an effect.

Wireless networks can also bring a measure of independence to the lives of people suffering from cognitive decline. Intel set up a prototype network of sensors inspired by the needs of Barbara, a patient with Alzheimer's disease whom Dishman recently met in a field study. The network used off-the-shelf motion sensors to detect Barbara's movements, pressure sensors in chairs to tell whether she was sitting in them, contact and magnetic switches to sense the opening of drawers and cabinets in the kitchen, radio frequency identification tags in her shoes, and antennas to sense the tags when she entered the kitchen.

All this was for a seemingly simple task: to make sure Barbara stayed hydrated, a common problem for those with Alzheimer's. The system, connected to a PC, can tell how long it has been since anyone was in the kitchen. If it's been too long, the unit can prompt Barbara to go get a cup of tea through a text message on the TV in whatever room she may be in. It then follows Barbara's progress as she tries to make tea. If the system notices she is having trouble—say, if she is in the kitchen but is taking an unusually long time to open the cabinet—it prompts a TV in the kitchen to ask her if she needs help. If she says she does, the system can then walk her through whatever problem she is having, monitoring her progress on the way.

A similar system can help patients comply with doctors' orders. It has been estimated that in the United States about 45 percent of people over 75 take multiple drugs. And according to a study at Johns Hopkins University, in Baltimore, as patients take more drugs, they make more errors in taking those drugs.

To improve compliance, each tap in the sink and bottle in the refrigerator could be monitored with a mote to record a person's liquid intake, and each medicine bottle could sit on a mote-connected scale. "We have a prototype with a scale fine-grained enough to tell whether the patient took the pill out of the vial," Dishman says.

A less technologically ambitious, wired version of what Intel plans is commercially available from Living Independently Group Inc., a New York City start-up. The system links infrared motion detectors to a controller that shares the home's telephone line. In the first two weeks of operation, the system builds up a pattern of the monitored person's routine; thereafter, it notes changes that imply health problems.

As with Intel's vision, Living Independently's system gets its information from seemingly commonplace sources. "One consumer uses a set of dishes and silverware every day, which she then washes and puts in the dish rack," says David J. Stern, Living Independently's chief professional officer. "The activity at that dish rack is indicative of meals." If the activity were to drop, then perhaps a social worker might come over to see if anything were amiss, he adds. The system might also note that a bathroom door had opened and then closed and conclude that the patient had gone into the bathroom. It could then set off an alert if the door didn't open again for more than, say, an hour.

ALTHOUGH YOU CAN LEARN a lot about people's health from their habits and appliances, sometimes you have to get even closer, with body-borne sensors. Since August 2002, doctors in parts of the United States have been taking advantage of a system built by CardioNet Inc., in San Diego, to discover the presence and nature of their patients' heart problems.

Some serious heart problems affecting older people are transient and infrequent and can go unnoticed even by the patient. A sudden slowing of the heart rate that leads to a fainting spell, for example, may last less than a minute and occur only once or twice a week. That's often enough to make driving a car dangerous but not frequent enough for a doctor to spot during a checkup or even by using a portable 24-hour electrocardiogram (ECG) recorder, called a Holter monitor. "It's like when the car never makes that noise when you are with the mechanic," explains Lawrence Watts, CardioNet's vice president of marketing. Another problem, the uncoordinated quivering of the small upper chambers of the heart, a leading cause of stroke in people over 70, can be both infrequent and without obvious symptoms. So patient-triggered ECG recorders could miss it.

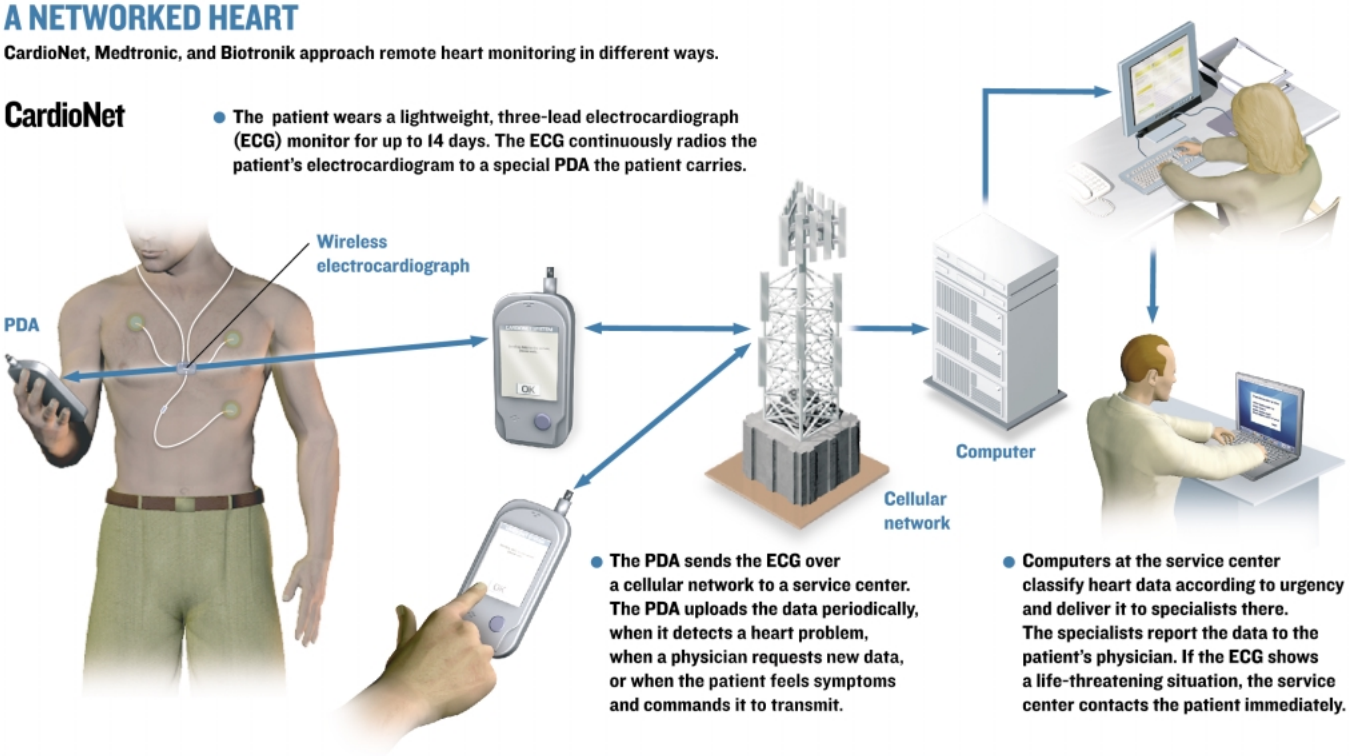
Called mobile cardiac outpatient telemetry, CardioNet's system consists of a small three-lead ECG monitor, worn either as a pendant around the neck or on a belt clip, and a PDA-like device [see illustration, "A Networked Heart"]. The ECG monitor sends its data via a 900-megahertz wireless link to the PDA, which evaluates and stores the waveform. If software in the PDA notices a potentially harmful change, say, a sudden slowing of the heartbeat, it automatically transmits the relevant data over a cellular network to a monitoring center, which is staffed around the clock. Computers there, after making a preliminary judgment of the severity of the problem, determine where to put the event in a queue for the center's clinical staff to review. If the staff decides the event is routine, the data is just included in a daily report to the patient's

A NETWORKED HEART

CardioNet, Medtronic, and Biotronik approach remote heart monitoring in different ways.

CardioNet

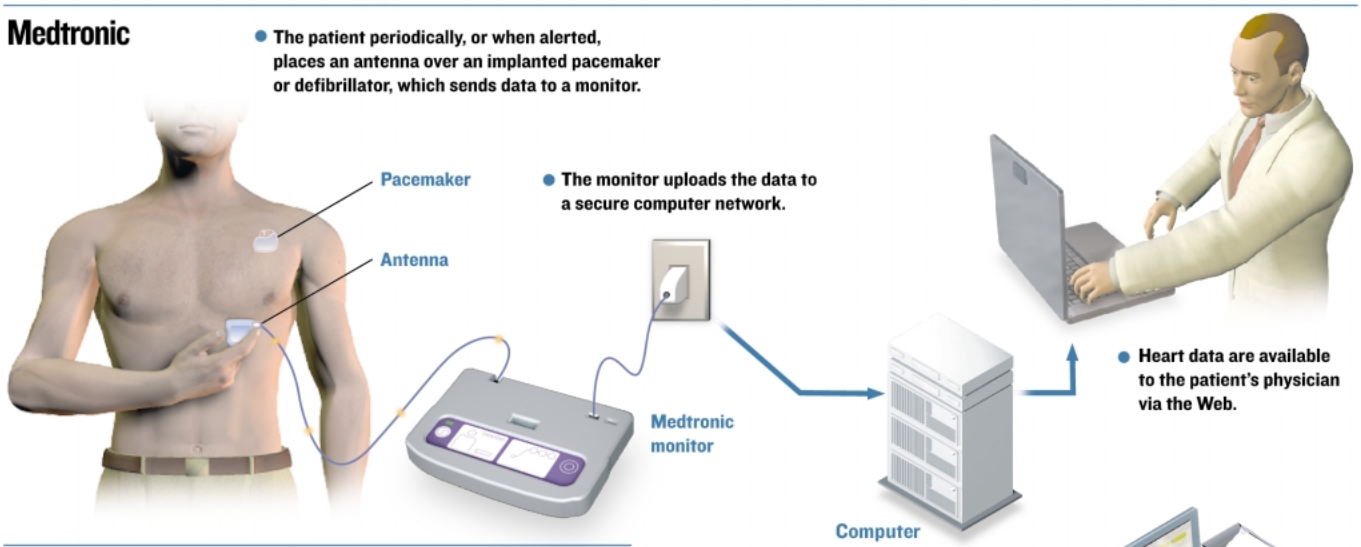
- The patient wears a lightweight, three-lead electrocardiograph (ECG) monitor for up to 14 days. The ECG continuously radios the patient's electrocardiogram to a special PDA the patient carries.



- The PDA sends the ECG over a cellular network to a service center. The PDA uploads the data periodically, when it detects a heart problem, when a physician requests new data, or when the patient feels symptoms and commands it to transmit.
- Computers at the service center classify heart data according to urgency and deliver it to specialists there. The specialists report the data to the patient's physician. If the ECG shows a life-threatening situation, the service center contacts the patient immediately.

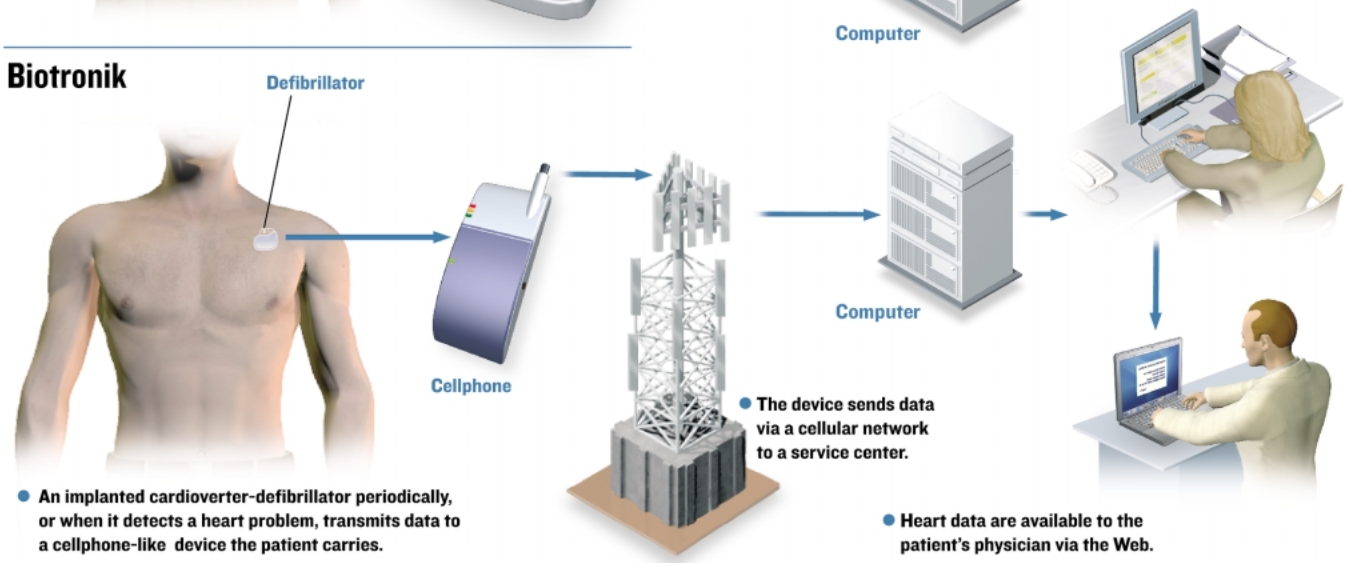
Medtronic

- The patient periodically, or when alerted, places an antenna over an implanted pacemaker or defibrillator, which sends data to a monitor.



- The monitor uploads the data to a secure computer network.
- Heart data are available to the patient's physician via the Web.

Biotronik



- An implanted cardioverter-defibrillator periodically, or when it detects a heart problem, transmits data to a cellphone-like device the patient carries.
- The device sends data via a cellular network to a service center.
- Heart data are available to the patient's physician via the Web.

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physician. If the event is judged serious, the center alerts the physician and calls the patient with instructions to proceed to a hospital.

Patients typically wear the device for no more than 10 to 14 days, after which the physician has enough data to figure out what the real problem is, explains Watts. The alternative can be days of observation in the hospital.

THE BODY ITSELF now plays host to some sensors. By the end of this month, Medtronic Inc., in Minneapolis, expects to gain approval to market in the United States a device designed to alleviate the symptoms of heart failure and warn, through a short-range wireless link to the Internet, of a patient's declining condition. About 22 million people worldwide suffer from heart failure, a condition in which the heart beats so weakly or inefficiently that fluid begins to pool in the lungs. This is the most rapidly growing cardiovascular condition in the world, and about half of all patients die within five years. Heart failure is the single greatest cause of hospitalization in the United States, costing some $10 billion a year in direct expenses.

Pacemakers are typically used to steady a heart that beats too slowly or too quickly. But several years ago, Medtronic and other pacemaker companies developed a therapy for failing hearts, called cardiac resynchronization therapy. It involves using a pacemaker to coordinate the contractions of the heart's chambers. Heart failure occurs when contractions are out of sync, often because of damage from a heart attack. Medtronic found that by measuring the impedance between the pacemaker's electrode and the device's case, implanted under the skin near the collarbone, the pacemaker could deduce how much fluid had pooled in the lungs.

The new heart failure device will be compatible with a two-year-old system Medtronic set up in the United States, called the CareLink Network, that lets doctors keep tabs on patients by taking data from pacemakers and other devices implanted in their chests [again, see "A Networked Heart"]. The patient puts an antenna over his chest to pick up data on fluid buildup, electrocardiogram and other physiological data, and data on the functioning of the pacemaker; the antenna then transmits the information over a phone line to a secure Internet site, accessible only to the patient's doctor. In early studies the device was able to detect the signs of a dangerous fluid buildup 10 or 11 days before the patient noticed any symptoms. The hope is that such warning will allow doctors to treat the patient before things get serious, avoiding hospitalization by, say, adjusting medications.

Heart failure is just the most recent use for pacemakers. The lower chambers of some hearts are subject to sudden life-threatening storms of quivering, called ventricular fibrillation, that set the different chambers contracting in an uncoordinated fashion. Implanted cardioverter-defibrillators, or ICDs, use software algorithms to look for signs of trouble in the heartbeat and deliver an electric jolt to set things right again. A wireless connection to a cardiologist can help here, too.

ICDs made by Biotronik GmbH & Co., in Berlin, use an approach to wireless monitoring that is a bit more hands-off than Medtronic's CareLink [again, see "A Networked Heart"]. Without requiring the patient to place an antenna over her chest, the ICD automatically transmits its data to a special external cellphone, using a 402- to 405-MHz frequency, which passes through skin and tissue with minimal attenuation. The cellphone then e-mails the data directly to a monitoring center and from there to the doctor.

In the uploaded data "we look for signs of arrhythmia, instances in which we applied a shock, and whether things changed as a result of medication or the lack of it," says Biotronik's Robert H. Leong, a product manager for home monitoring. "We also check that the battery, lead, and insulation are okay."

The market for cardiac pacemakers and defibrillators is almost $8 billion per year now and is projected to top $14 billion by 2007, notes Leong. To some extent, that fast rate of adoption represents a shift in spending from labor to technology. "We're not going to double the number of doctors and hospitals in that time," he says.

REMOTE HEALTH CARE MONITORING may seem like the best answer to managing the care of the next generation of older people, but those in the health care field need some convincing. Medical practice is conservative and rightly requires evidence that a new approach to health care will work. And those who pay for health care—insurers and governments—want to know if it will really save money, and how much.

Biotronik's Leong complains that American health care authorities are resistant to change. "More than 10 000 people are walking around with our cellphone-based system in Europe, where it was introduced around 2001, and it's just getting into Japan," he says. The United States lags in part because federal agencies continue to apply standards devised for drugs, which may be inappropriate for electronic devices, he argues.

There are signs of improvement. The U.S. government dedicated a chunk of radio spectrum to medical telemetry, and it has pledged to rule more promptly on applications for new medical devices.

Part of the health care industry's conservatism can be traced to the ancient medical dictum, "First, do no harm." But not all its motives are so laudable. One source for this story, who wished to remain anonymous, said that doctors may fear a system that sends out time-stamped alerts about a patient, because it might produce a record that could be used against them. Accountability obviously has its enemies.

Of course, there's a tradeoff here for the patient's sense of privacy, as well. But it is one that might seem almost a no-brainer to many potential users of the technology. "I've gotten thousands of e-mails from consumers in the past six months, begging for these technologies," says Intel's Dishman. "Overwhelmingly, they say, let me make the decisions on privacy. A lot think they've already lost their privacy by being institutionalized. They say, give me a break, I'm perfectly willing to share information with my daughter or whoever in order to continue to live in my own home."

Soon enough, it seems, we'll be confronting the fundamental problem of reconciling ourselves to a world in which we must account for our behavior to things as much as to people—things that nag us to take our medication, get to the gym, floss after eating. It would be a world in which doctor's orders enforce themselves—unless, of course, we throw the "off" switch. ■

TO PROBE FURTHER

Eric Dishman spelled out Intel's vision for wireless remote monitoring in "Inventing Wellness Systems for Aging in Place," *IEEE Computer*, May 2004, pp. 34–41.

Many universities and companies working on aging-related technologies post their progress at the Center for Aging Services Technologies' Web site, http://www.agingtech.org.

You can find information about Medtronic's cardiac device network at http://www.medtronic.com/carelink/.

ABOUT THE AUTHOR

PHILIP E. ROSS (M) wrote "Beat the Heat" for the May issue of *IEEE Spectrum*. His work has also appeared in *Scientific American*, *Forbes*, and *Red Herring*.