DO YOU LOOK FAT IN YOUR GENES? p52

Technology Review

MIT's Magazine of Innovation

How BlackBerry Got It Right p36

Intel's Breakthrough

Its new silicon laser could add decades to Moore's Law—and save the digital economy.

By Robert Service p62

The U.S. Government's Plan to Store Everything Forever
By David Talbot p44

Why Placebos Really Work
By Stephan Herrera p79

The Economics behind Digital Media
By Stacy Lawrence p31

Intel's experimental optoelectronic chip

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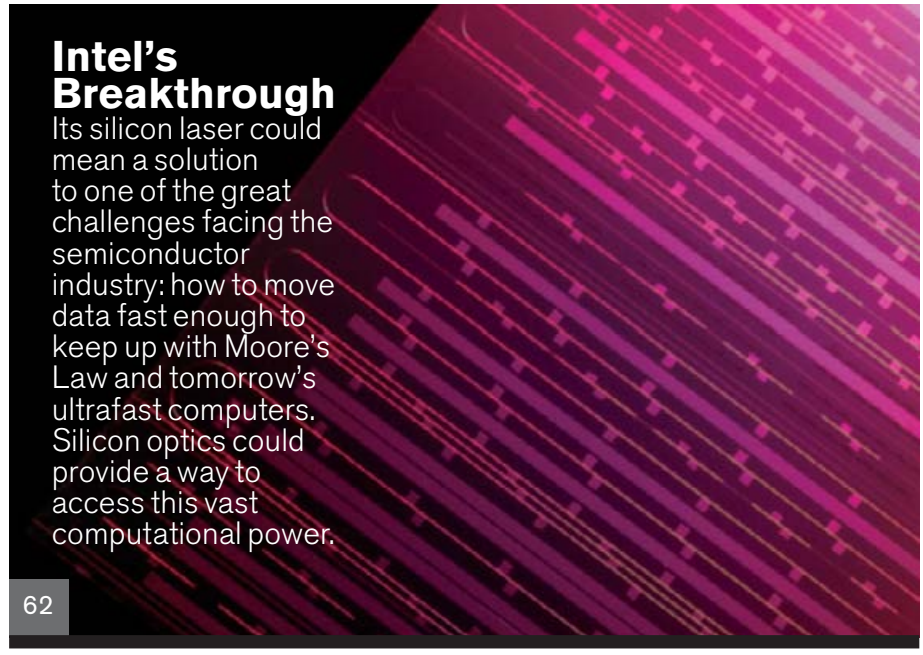
Contents

Volume 108, Number 7



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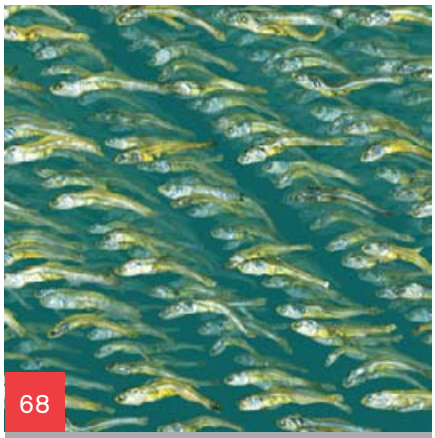
Contents

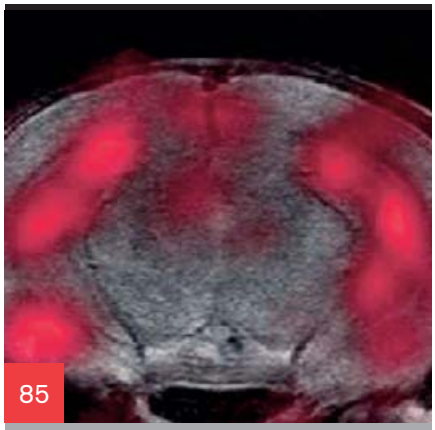


68

DEMO
Computer, design
The work of techno-artist John Maeda.

75

MEGASCOPE
The Amish and technology
Their ways have something to teach us all.



85

FROM THE LAB: BIOTECHNOLOGY
Imaging brain plaques
New methods from two research groups could help the study of Alzheimer's disease.

What's new at technologyreview.com

Technology Review is experimenting with participatory journalism at a new satellite blog on the theme of "continuous computing" (www.continuousblog.net). Authored by senior editor Wade Roush, the blog is both a preview of and a companion to an upcoming feature article in *Technology Review* on the social impact of mobile computing, ubiquitous wireless broadband access, and new Web-based tools for publishing and collaboration.

The blog offers news items, links, and commentary related to these trends. Most importantly, Roush has published an early draft of the article at the blog and is asking visitors to leave comments, suggestions, insertions, and corrections. Comments are folded back into the online draft and are helping Roush to shape the final article.

TechnologyReview.com will also host a regular blog for Roush (wade.trblogs.com), giving him the opportunity to discuss future articles, interesting happenings, and whatever else catches his eye.

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Commonplace Thoughts

W. G. SEBALD, a writer who died in 2001 at the early age of 57, wrote strange books that resist categorization: they combine fiction, criticism, biography, and scrapbook.

"Max" Sebald wrote in German in a style that was (at least in Michael Hulse's English translations) both precise and completely mysterious. In books like *Austerlitz* and *The Emigrants*, paragraphs begin with numbing specificity and then continue for pages, drifting in and out of various characters' points of view. His great theme was (I think) the displacement of individuals from their pasts. This has something to do with Sebald's personal history: the Germany where he grew up was committed to a kind of collective amnesia about the Second World War. As he grew older, Sebald said, the memory of his dead made him anxious—and when he was in his middle 40s, he began constructing his weird, elusive books.

To any reader new to Sebald, his books' oddest property is their use of photography and quotation. Nearly every page includes one or two unexplained, dark and fuzzy, black-and-white photographs—of people (all of them, one fears, long dead) and of buildings, animals, or scraps of newspaper. Long swaths of his texts purport to be selections from the unpublished diaries of family and friends or are presented as recorded speech. Sebald gleaned from the past in a peculiarly evocative way—one he derived, I suspect, from the "commonplace books" popular in the 18th and 19th centuries.

In "Scissorizing and Scrapbooks: Nineteenth-Century Reading, Remaking, and Recirculating," included in *New Media 1740–1915*, a collection of essays from MIT Press, Ellen Gruber Garvey describes the fad. The first commonplace books appeared during the Renaissance and contained hand-copied excerpts from manuscripts—and, eventually, from printed books—along with personal annotations. As Garvey describes, these were succeeded by something closer to what we think of as scrapbooks. In them, people of a literary bent would paste photographs or cuttings from magazines and newspapers. Between the keepsakes, they would scribble appropriate scraps of prose or poetry, or associated thoughts that might profit from later revision.

According to Garvey, such collections were "vernacular" responses to the anxiety many people felt about throwing away the printed materials that proliferated in the 18th and 19th centuries: "They constituted a new subcategory of media—the cheap, disposable, and yet somehow tantalizingly valuable, if only their value could be separated from their ephemerality." Perhaps the most famous commonplace book is that of Thomas Jefferson, where the Founder wrote notes to himself about cuttings and quotations he found interesting. (An edition of Jefferson's commonplace book was published in 1926 and can be bought through online book dealers for less than $200: well worth the price.)

I recently began writing a Web log, or blog (under protest: starting a blog at this late stage feels a little like developing an interest in disco music in 1980), and I have been struck by the parallels between blogging and the commonplace book. Indeed, my blog is called the New Commonplace.

Although Chris Anderson, *Wired*'s editor in chief, wrote on his blog the Long Tail (www.thelongtail.com) that "the first rule of the blogosphere is not to generalize about the blogosphere," the medium's technological properties—pasting, linking, tagging, and so on—have very quickly encouraged a common style of publishing that very few bloggers resist. Anderson is surely right to suggest that blogs are as various as humanity—because posts can be intelligent or silly, rigorously reported or carefree, essayistic or written in a kind of telegraphese—but blogs do seem to have a secondary, critical relationship to primary forms of media and to other blogs. Garvey calls this process "gleaning," an idea she adopted from the critical theorist Michel de Certeau, who spoke of "reading as poaching" to describe the cutting and recompiling of published texts. Gleaners were indigent peasants who collected the spare corn or fruit farmers left behind in their fields. Gleaning seems a useful metaphor for how bloggers select, comment upon, and then redistribute media—and it's a useful metaphor for Sebald's art, too.

Gleaners were indigent peasants who collected the spare corn or fruit that farmers left. Gleaning seems a useful metaphor for how bloggers select, comment upon, and then redistribute media.

In the narrow sense of gleaning, this editor's letter was also a kind of blog. I tried out its themes at www.jasonpontin.com and am indebted to Matt Locke's blog Test (www.test.org.uk) for introducing me to *New Media 1740–1915*. Write to me at jason.pontin@technologyreview.com ■


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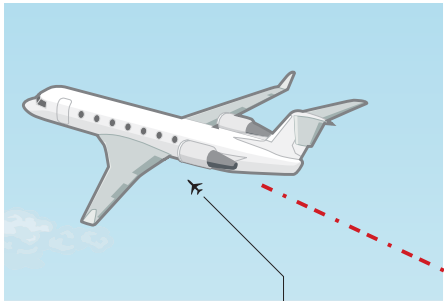

Ten minus Two?

Your piece on how airborne networks might evolve in the future ("10 Emerging Technologies," May 2005) is a bit behind the times. The ability of aircraft to communicate their identities and positions to other nearby aircraft, and to take evasive action if necessary, has been flying for many years. It's called the Traffic Alert and Collision Avoidance System, or TCAS. It equips planes with receivers that listen to the replies transmitted by other aircraft to interrogations from ground radars. A newer technology, called ADS-B, allows aircraft to broadcast their identities and positions.

None of this, however, has much to do with your article's speculation that these technologies will allow "vastly greater numbers of small planes [to] zip in and out of thousands of small airfields." Those small airplanes fly today with virtually no dependence on air traffic control by the Federal Aviation Administration. These planes have no problem now with crowding of the skies. The problems of crowded skies apply only to the planes that fly under control of the ATC system. The best in new automation won't fix those problems until there are more runways on the ground. It doesn't matter how efficiently we are able to get planes from here to there if there's no concrete to land on.

Chuck Kengla
Potomac, MD

I was dismayed to see *TR* list mobile-phone viruses as an emerging technology. The threat of cell-phone viruses is vastly overblown. The wide variety of mobile operating systems limits a virus's impact, and the Symbian viruses noted in the article require the user to click through several installation messages before the software is installed. Mobile-phone designers have learned from the lessons of PC viruses and have implemented a number of systems to protect users from viruses and malicious programs.

Carl Shimer
Oak Park, IL

Environmental Heresies

Stewart Brand should look more carefully at the economics of nuclear power ("Environmental Heresies," May 2005). The underlying proposition of his pronuclear position is that in 30 years, using economies of scale learned from building thousands of nuclear plants, we can drive down the capital costs so that reactors produce energy at a price competitive with today's dirty coal. However, given 30 years of R&D and economies of scale, battery-backed photovoltaic power will cost less than electricity produced from coal or nuclear. Out in the desert, solar-generated hydrogen will still cost less than nuclear hydrogen. The other developments that Brand highlights will reduce or alter energy consumption in ways that will make breeder nuclear reactors unnecessary: negawatts to use energy more efficiently; displacing natural-gas consumption with geothermal heat pumps or solar thermal panels; falling populations that require less energy; and genetic engineering to design bacteria optimized for generating methane.

Chuck Simmons
Redwood City, CA

Who Needs an Energy Policy?

The "Readme" editorial about the lack of a strong federal energy policy ("Fossilized Policy," May 2005) raises two questions. First, why should there be a national policy? Second, why does a viable technology on the verge of commercialization need state support? There are several countries—from France and Germany to Russia and Japan—with national policies on every subject. They have been clearly outperformed by the United States over the last century. The reasons are simple: the greater U.S. protection of individual rights to life, liberty, and property permits a competitive discovery process for the best use of resources.

Kartik B. Ariyur
Minnetonka, MN

Warming to the Topic

In his review of Michael Crichton's latest novel, *State of Fear*, Joseph Romm expresses dismay that Crichton dares to question the validity of carbon dioxide–caused global warming ("Greenhouse Gas," May 2005). Perhaps Romm should read the article in *Regulation* magazine by MIT meteorology professor Richard S. Lindzen, in which Lindzen states that "as a scientist I can find no substantive basis for the warming scenarios being popularly described." He reminds us that better than 98 percent of the greenhouse effect is due to water vapor in the atmosphere, and that carbon dioxide, methane, and chlorofluorocarbons are relatively minor greenhouse gases. If there is any "technological hubris" regarding this issue, it is the arrogant dismissal of those raising legitimate questions regarding carbon dioxide warming theories.

Anthony Stathoplos
West Hartford, CT

Renaissance Redux

Regarding Michael Hawley's plea to "save the diversity of the individual" ("Whither the Renaissance Man?" May 2005): a recent trend in higher education is encouraging. Not long ago, I visited four universities with my high school–aged son. All four stressed a multidisciplinary approach and flexibility in their curricula and requirements to allow work in multiple subject areas. Thus, while the specialization trend we have seen over the last 100 years is likely to continue, in some areas it appears that our institutes of higher learning are responding to students' interest in becoming—and industrial interest in hiring—more well-rounded people with multidisciplinary capabilities. Hawley should take heart: all is not lost.

Scott Simpson
Woodstock, CT

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Each readme presents our take on a social, economic, or political issue raised by an article in the magazine.

STORAGE

Memo to Washington: Save the Data

If you wander along the National Mall in Washington, DC, you can pop into the marble rotunda of the National Archives for a glimpse of the original Declaration of Independence, Constitution, and Bill of Rights. These calfskin parchments are preserved under glass, bathed in argon gas. But no such care is extended to digital federal records. The government is presumed to have used (or received) data in every format ever crafted by the computer industry—some 16,000 formats at last count—and has stored this data on every kind of hardware. But the fast-changing computer industry never stopped to think about long-term preservation, which means records of contemporary history are fast becoming obsolete—and there's no existing system to permanently and reliably archive them.

That's beginning to change, as our story "The Fading Memory of the State," on page 44, reports. The U.S. National Archives and Records Administration (NARA) is in the early stages of developing an Electronic Records Archives that will harmonize and preserve all these digital records and make them available online, so saving the nation's contemporary history from destruction. Solving the problem will in some ways test the limits of computer-science research: NARA must not only preserve every data format ever dreamt up but contend with a volume of material that far exceeds that of even the largest private enterprise. What's more, it has a responsibility to save all this data for the uniquely long (if ill-defined) time period NARA calls "the life of the Republic."

Like any other federal agency, NARA is saddled with a cumbersome procurement process. It has hired two major contractors—Lockheed Martin and Harris Corporation—to generate competing preliminary designs, which are scheduled to be unveiled next month. Common sense suggests that the project will need close and continuing scrutiny from the U.S. Congress—and from the National Academies panel of industry and academic experts that has been advising NARA. The goal: to ensure that the resulting digital archive is not a rigid, custom-built system doomed to obsolescence but rather a flexible system grounded as much as possible in commercial offerings and able to evolve with the IT industry. As a good start, NARA could model its digital archive after early versions of digital archives already built by some nations and academic institutions, including MIT.

Clearly, the general problem of digital-record decay needs more attention than it's currently getting in Washington. Yes, $136 million has been budgeted to date for NARA's digital-

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archive project, but not enough has been done to actually force federal departments to harmonize how they store digital records. And some shortsighted cuts can be found in the administration's proposed 2006 budget—specifically, eliminating $10 million in funding to the National Historical Publications and Records Commission (NHPRC), a grant agency within NARA that supports research in digital archiving and curation. That cut would effectively kill the NHPRC. Yet this is just the kind of small, nimble program that can help find ways to stanch the bleeding of the contemporary historical record. Congress should take the problem more seriously. ■

36

WIRELESS

Push(y) E-Mail

Businesses should beware the danger of incoming distractions.

It has been two and a half years since Research in Motion (RIM) began licensing its BlackBerry software to handset makers like Nokia. The company's decision—which we describe in this month's "Briefcase" section *(see "The Willing Partner," p. 36)*—has paid off handsomely for the company, whose stock price has risen more than 800 percent in that time. While our story credits RIM's success to its smart approach to licensing, there is another reason the company is doing so well: the business world has fundamentally changed the way it thinks about e-mail. This may not be all to the good.

When it first entered the workplace, e-mail was thought to be an "asynchronous" mode of communication. That, in fact, was part of what made it so appealing: unlike the telephone (or the person dropping by your office), an e-mail could be safely ignored until you wanted to reply to it. But before long, workers were expected to monitor incoming e-mail, much of which was time sensitive. The arrival of the BlackBerry amplified e-mail's urgency: suddenly, it wasn't just something you paid attention to in the office. E-mail was hitting you at home, in your car—everywhere, in fact.

Is this bad? In April, Hewlett-Packard reported results of research it commissioned on the effect of e-mail, instant messaging, and the telephone. Glenn Wilson, a psychologist at the University of London, conducted tests involving 80 British workers and claims that technological distractions make workers temporarily dumber by 10 IQ points—that is, more than two times dumber than if they were smoking marijuana.

HP's press release was quickly picked up by major newspapers; it was fun to report that e-mail was making us stupider than pot. But pot isn't the most obvious drug analogy for wireless e-mail. BlackBerry's fondest fans have given their device a nickname: they call it "CrackBerry." Yes, wireless e-mail is often extremely helpful—and many who have it couldn't do without the technology. But its sheer pushiness should give us pause. Companies that dole out wireless e-mail devices should set clear expectations about how these gadgets can be best used to improve efficiency—without inducing stupidity. ■

52

GENETICS

End Fattism

We need to treat obesity as a real disease, not as a "bad habit."

One of the last socially acceptable prejudices is that against the obese. Fed by a steady stream of diet books, TV shows, and even documentaries, the stereotypes are constantly reinforced; overweight people are heavy simply because they eat too many Big Macs and french fries; they're desperately lonely and gorge themselves out of despair; they're couch potatoes who just refuse to exercise. These are, of course, caricatures of a complex problem that affects millions of people.

As Rockefeller University molecular geneticist and obesity researcher Jeffrey Friedman argues in "Wired to Eat," on page 52, obesity is a disorder that is largely caused by genetic factors. For more than a decade, Friedman has visited the remote Micronesian island of Kosrae in an attempt to pinpoint the specific genetic and molecular reasons why the population, descended from a mix of Micronesian and European ancestors, exhibits such a high rate of obesity. He and his colleagues at Rockefeller collected medical information on the entire adult population of some 2,500 islanders and now have begun detailed analysis of the DNA to identify specific genetic variations that are associated with obesity. If Friedman succeeds in finding genetic causes for the island's obesity and health problem, it will have immense implications for how we view overweight people. "We have to realize that obesity is a disease, like cancer, that people have less control over than most of us think," maintains Friedman.

"Obesity is a disease, like cancer, that people have less control over than most of us think."

Writer David Ewing Duncan, who traveled to Kosrae earlier this year to report the story, notes that Friedman's position is controversial among those who treat obesity. Indeed, even health workers on Kosrae are confident they can decrease the island's obesity rate by working with communities to improve their eating and exercise habits. And the people of Kosrae, still stinging from being tagged "Macronesians," appear to be responding. The controversy won't be easily settled—after all, in many ways it is the familiar debate about nature and nurture. Obesity is likely caused by a complex mixture of genetic, environmental, and lifestyle factors. But Friedman deserves credit for attempting to elevate obesity from a "bad habit" caused by slothful behavior to a treatable disease. ■

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Forward

Voices

"We have to realize that obesity is a disease, like cancer, that people have less control over than most of us think."
Jeffrey Friedman, Rockefeller University obesity researcher, p. 54

An adversary with no known return address might calculate it could escape retaliation.
Graham Allison, director of Harvard's Belfer Center for Science and International Affairs, p. 43

"Copper, our traditional interconnect technology, is running out of speed."
Pat Gelsinger, Intel vice president, p. 64

"History as we've known it is dying, and with it the public accountability of government and rational public administration."
Eduard Mark, U.S. Air Force historian, p. 46

"The coal is going to be mined. The only question is how it's going to be burned."
Antonia Herzog, senior scientist with the Natural Resources Defense Council, p. 40

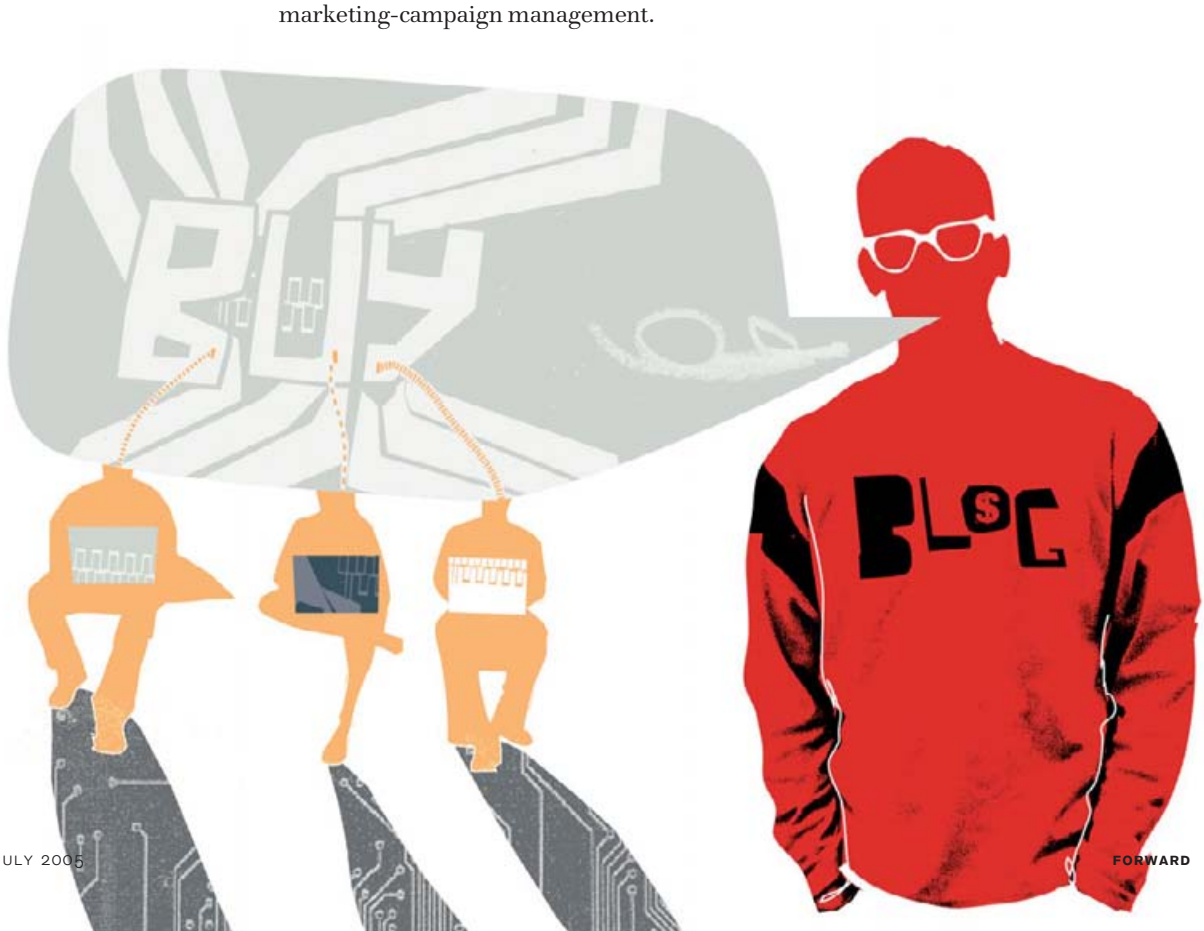
INTERNET

Your Ad Here

Digerati debate the wisdom of product placement in blogs

AUDIENCES ARE NO LONGER disillusioned by product placement in movies (Reese's Pieces in *E.T.*), TV shows (Doritos on *Survivor*), sporting events (Michael Johnson's golden Nikes), or even novels (Fay Weldon's *The Bulgari Connection*). But some in the Web-logging community worry that their attitude toward Web logs, or blogs, may change, now that some bloggers are being paid to mention specific products.

Of course, bloggers have been debating the role of blogs since the medium was born. But the latest controversy flared up in December, when a Portland, OR, company called Marqui announced that it would pay select bloggers $800 a month to publish at least four entries per month about its software, a Web-based system for automating marketing-campaign management.



ANDY POTTS

The company recruited 20 writers whose blogs are widely read in the information technology sector. "We needed a 'geek-to-geek' marketing strategy," explains Marqui CEO Stephen J. King. "We wanted to influence the influencers, and in this world, the geeks are the new high priests." King says the company encouraged the bloggers to write whatever they wanted about the software—positive or negative—and to tell readers about their agreements with Marqui.

But if bloggers belong to a priesthood, it's only because they've taken an implicit vow of sincerity, argued critics of Marqui's program in their own blogs. One of these was Jason Calacanis, founder of Weblogs, a network of technology-focused blogs. "To take money to blog about something—and disclose it or not—works against the public's expectation that blogs are, first and foremost, up-front and honest," Calacanis wrote.

The hullabaloo has brought Marqui exposure, if nothing else. (A Google search for "Marqui" turns up far more items about the blogging program than about the company's software.) King says he shares critics' general distaste for product placement, but he believes Marqui's paid-blogging program is different. "When a shot in a movie zooms in on a Coke can, I think that's manipulative to the extreme," King says. "But the line between product placement and what we believe we're doing on the blogs is disclosure."

"To take money to blog about something... works against the public's expectation that blogs are, first and foremost, up-front and honest."

Most of Marqui's initial bloggers say they consider the work an interesting experiment. Not all of them, however, have re-upped for the program. "I could not tolerate the feeling of having to post to my blog based on a contractual obligation," says Molly Holzschlag, a Web developer who blogs at www.molly.com. "I realized my blog is something I want to be more spontaneous with; it's the only way I can write to it properly. I also had no passion for the product itself—but I must add that I have great respect for the people at Marqui, as well as their courageous move to try something new."

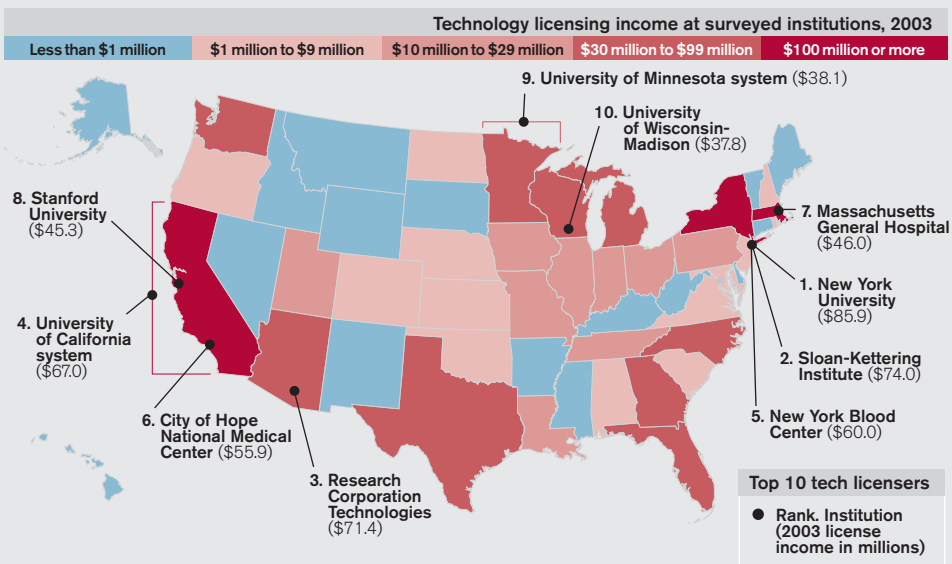
Other companies are trying similar tactics. Finnish cell-phone maker Nokia, for example, recently gave away Nokia 7710 wide-screen smart phones to more than 1,000 "VIPs" around the world, including many bloggers. It's only to be expected that companies will try to exploit blogs as a marketing channel, and that bloggers will face an increasing amount of temptation. Because they're answerable only to their readers—not to editors and publishers, as journalists are—that temptation will be all the greater. The bottom line: readers themselves will have to decide how much commercialism they're willing to swallow as they surf the blogosphere.

Wade Roush

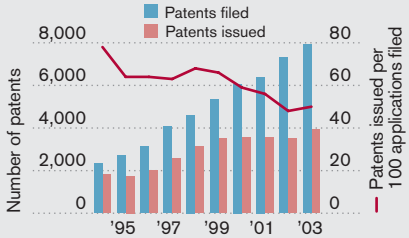
TECH TRANSFER

A Mixed Bag for U.S. Institutions

U.S. academic and nonprofit institutions and technology investment firms that responded to two recent surveys saw their technology licensing revenue grow 7.8 percent between 2002 and 2003, according to the Association of University Technology Managers. The number of patents issued to these institutions also increased, by about 10 percent, but the number of startups they formed dropped from 398 in 2002 to 364 in 2003. Data on all survey respondents for the past 11 years—including irregular participants—show that the number of U.S. patents issued each year, as a proportion of applications filed, is also declining. New York institutions receive the most licensing income, while those in California lead the field in R&D spending, patenting, and startup formation.



Patenting trends among survey respondents



2003's top tech-transfer states

	Respondents' licensing income, in millions	R&D expenditures, in billions	U.S. patents issued	Startups formed
New York	$270	$2.3	220	25
California	$202	$4.4	729	50
Massachusetts	$149	$3.7	440	32
Arizona	$74	$0.5	36	3
Florida	$61	$1.2	117	13

SOURCE: ASSOCIATION OF UNIVERSITY TECHNOLOGY MANAGERS

LANCE CLAYTON (BEAN); COURTESY OF PAUL LINDSLEY/ST. THOMAS HOSPITAL (HEART)

SOFTWARE

Spies like Us

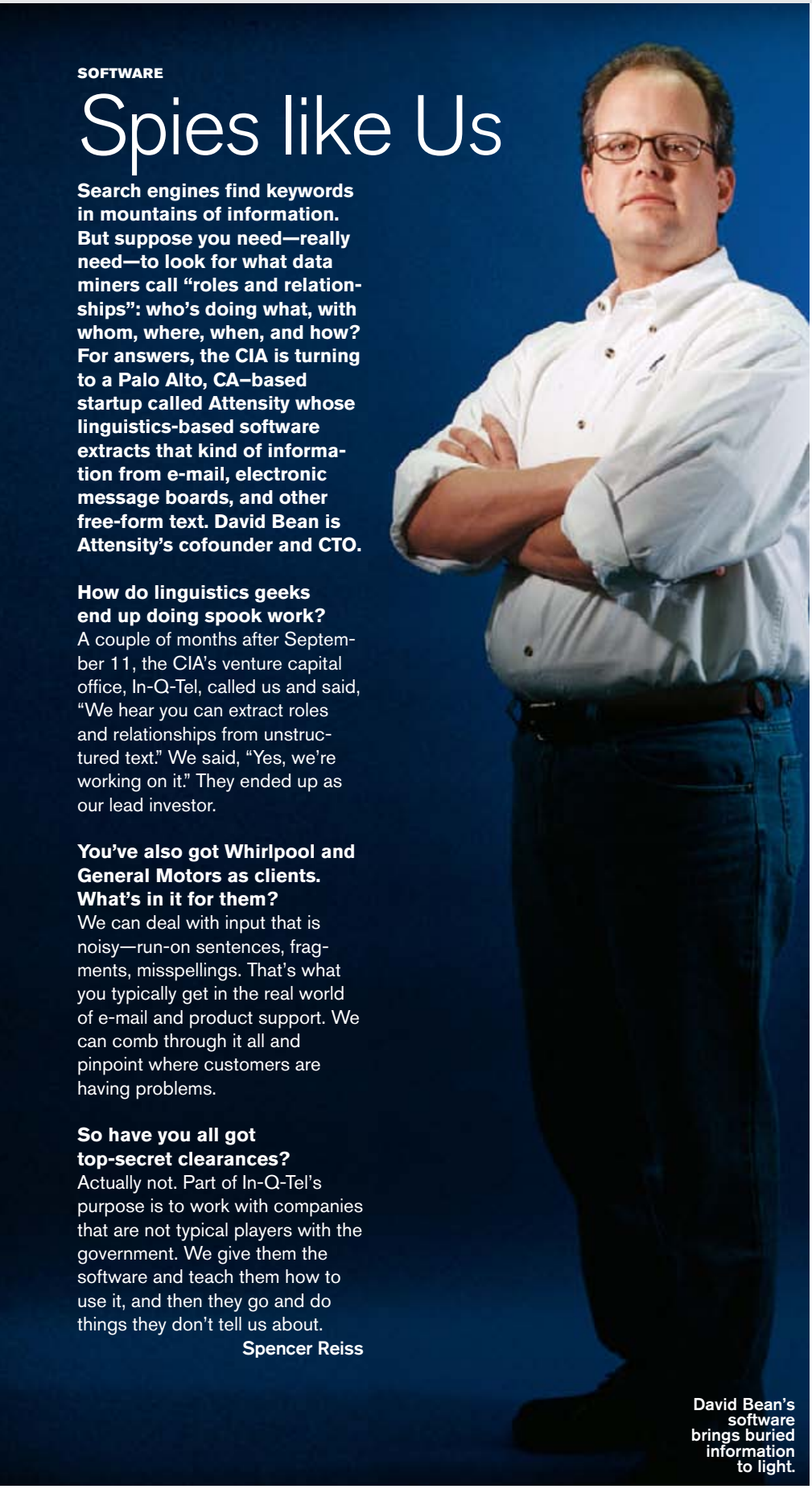
Search engines find keywords in mountains of information. But suppose you need—really need—to look for what data miners call "roles and relationships": who's doing what, with whom, where, when, and how? For answers, the CIA is turning to a Palo Alto, CA–based startup called Attensity whose linguistics-based software extracts that kind of information from e-mail, electronic message boards, and other free-form text. David Bean is Attensity's cofounder and CTO.

How do linguistics geeks end up doing spook work?
A couple of months after September 11, the CIA's venture capital office, In-Q-Tel, called us and said, "We hear you can extract roles and relationships from unstructured text." We said, "Yes, we're working on it." They ended up as our lead investor.

You've also got Whirlpool and General Motors as clients. What's in it for them?
We can deal with input that is noisy—run-on sentences, fragments, misspellings. That's what you typically get in the real world of e-mail and product support. We can comb through it all and pinpoint where customers are having problems.

So have you all got top-secret clearances?
Actually not. Part of In-Q-Tel's purpose is to work with companies that are not typical players with the government. We give them the software and teach them how to use it, and then they go and do things they don't tell us about.

Spencer Reiss



David Bean's software brings buried information to light.

Prototype

Heart Check

A new type of cardiac implant that measures blood pressure from inside the heart could help doctors better manage patients with heart failure, reducing the risk of hospitalization and even helping to prevent the condition from worsening. Developed by Minneapolis-based Medtronic, the device (above) is implanted under the patient's skin. From there, sensors on the ends of conducting leads are fed into the heart's right ventricle, where they continuously track diastolic and systolic pressure, heart rate, body temperature, and level of patient activity. At least once a week, the patient downloads these data to an Internet-connected device that sends them on to his or her doctors. The information helps cardiologists pick the best therapies for each patient and adjust them as necessary—something that is often a hit-or-miss affair otherwise, says cardiologist Mark Aaron of Saint Thomas Heart Institute in Nashville, TN, one of the 28 medical centers that took part in a recent trial of the device. The results of the trial are due to be published later this summer and show that hospitalization could be reduced by up to 41 percent for patients with moderate heart failure.

Pong Redux

Cell-phone games usually rely on keystrokes to control the action, but Finnish researchers have developed a program called SymBall that could turn the whole phone into the controller. The software analyzes in real time images captured by a camera phone; from that information, it works out how

continued on p. 25

STARTUP

Quantum Calculation

D-Wave Systems figures now's the time to commercialize quantum computing

COMPANY: D-Wave Systems

HEADQUARTERS: Vancouver, British Columbia

AMOUNT INVESTED: $22 million Canadian (about $17.5 million U.S.)

LEAD INVESTOR: Draper Fisher Jurvetson

KEY FOUNDERS: Geordie Rose, Alexandre Zagoskin, Bob Wiens, Haig Farris

TECHNOLOGY: Quantum computers

COMPUTERS HAVE INFILTRATED nearly every field of business and science, and they keep getting faster. Nonetheless, researchers routinely encounter problems impossible for even the most powerful supercomputers to solve. The remedy could be quantum computers, which would use the fantastic properties of quantum mechanics to crack such problems in seconds rather than centuries. Since the 1980s, physicists in academic labs and at firms such as IBM, Hewlett-Packard, and NEC have pursued a variety of quantum computing approaches, but none seems likely to deliver a working machine in less than 10 years.

Vancouver startup D-Wave Systems, however, aims to build a quantum computer within three years. It won't be a fully functional quantum computer of the sort long envisioned; but D-Wave is on track to produce a special-purpose, "noisy" piece of quantum hardware that could solve many of the physical-simulation problems that stump today's computers, says David Meyer, a mathematician working on quantum algorithms at the University of California, San Diego.

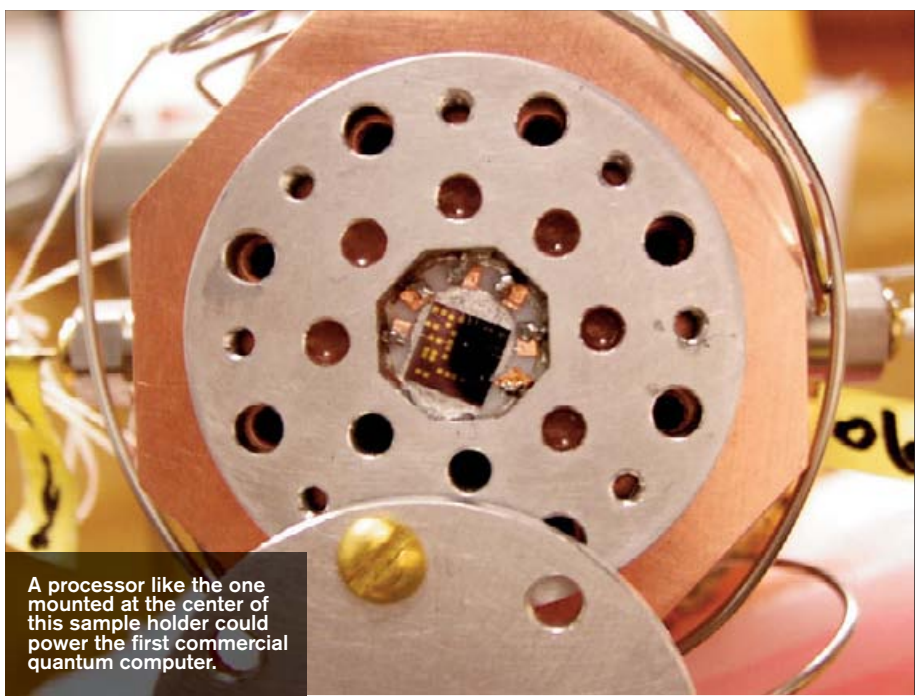
The difference between D-Wave's system and other quantum computer designs is the particular properties of quantum mechanics that they exploit. Other systems rely on a property called entanglement, which says that any two particles that have interacted in the past, even if now spatially separated, may still influence each other's states. But that interdependence is easily disrupted by the particles' interactions with their environment. In contrast, D-Wave's design takes advantage of the far more robust property of quantum physics known as quantum tunneling, which allows particles to "magically" hop from one location to another.

Incorporated in April 1999, D-Wave originated as a series of conversations among students and lecturers at the University of British Columbia. Over the years, it has amassed intellectual property and narrowed its focus, while attracting almost $18 million in funding, initially from angel investors and more recently from the Canadian and German governments, and from venture capital firms. The company plans to complete a prototype device by the end of 2006; a version capable of solving commercial problems could be ready by 2008, says president and CEO Geordie Rose.

The aggressiveness of D-Wave's timetable is made possible by the simplicity of its device's design: an analog chip made of low-temperature superconductors. The chip must be cooled to –269 °C with liquid helium, but it doesn't require the delicate state-of-the-art lasers, vacuum pumps, and other exotic machinery that other quantum computers need.

The design is also amenable to the lithography techniques used to make standard computer chips, further simplifying fabrication. D-Wave patterns an array of loops of low-temperature superconductors such as aluminum and niobium onto a chip. When electricity flows through them, the loops act like tiny magnets. Two refrigerator magnets will naturally flip so that they stick together, minimizing the energy between them. The loops in D-Wave's chip behave similarly, "flipping" the direction of current flow from clockwise to counterclockwise to minimize the magnetic flux between them. Depending on the problem it's meant to tackle, the chip is programmed so that current flows through each loop in a particular direction. The loops then spontaneously flip until they reach a stable energy state, which represents the solution to the problem.

D-Wave's first computer won't be able to accomplish the most widely touted payoff of quantum computing: factoring the extremely large numbers at the heart of modern cryptographic systems exponentially faster than any known computer. It will, however, be ideally suited to solving problems like the infamous traveling-



A processor like the one mounted at the center of this sample holder could power the first commercial quantum computer.

COURTESY OF GEORDIE ROSE/D-WAVE SYSTEMS

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salesman problem, in which a salesman searches for the optimal route among cities. As their complexity grows, such problems quickly become intractable for traditional computers because they require investigating every possible answer. In searching for its own optimal energy state, D-Wave's chip performs exactly this type of calculation automatically, in seconds. Applications—some worth billions of dollars—include optimizing such varied items as truck routes, financial portfolios, and even the layouts of traditional computer chips. D-Wave collaborator Oliver Downs says D-Wave's chip should also excel at modeling other quantum systems, such as the molecular interactions that characterize nanomaterials or drugs.

Although more robust than typical quantum computers, D-Wave's systems will still be delicate. So the firm intends to sell solutions rather than computers, says Rose. A customer will run a program to solve a given problem on its own computers. When the program encounters the "unsolvable" part of the problem, it will remotely call D-Wave's computer to run a subroutine. "For many specialized applications, such dedicated hardware has the potential to be superior to even the most clever software running on a general-purpose computer," says UCSD's Meyer.

And while many approaches to quantum computing have hit a wall, butting up against the limits of lasers and other equipment, Downs believes that D-Wave's early experimental results indicate that its chip is right on schedule. Although Meyer says he can't assess whether the company will meet its self-imposed deadlines, he believes it will succeed in building a machine that can solve exactly the sorts of problems it envisions. "They've employed both very good experimentalists and some pretty serious theory people," he says. "That's certainly the way to approach this kind of problem to make it happen in non-academic amounts of time." **Erika Jonietz**

The aggressiveness of D-Wave's commercialization timetable is made possible by the simplicity of its device's design.

TELECOM

Spectrum Scavenging

A new wireless standard could bring broadband Internet access to rural homes.

MUCH OF THE rural United States is a telecommunications wasteland: residents can tune in only a few broadcast TV channels, and broadband Internet access is prohibitively expensive or nonexistent. But new wireless networking technology—based on the 802.22 standard now being developed by the Institute of Electrical and Electronics Engineers (IEEE)—will enable wireless base stations deployed in rural areas to detect unused TV frequencies and transmit broadband data signals over them directly to modems in homes 40 kilometers or more away.

The base stations and modems will regularly scan the airwaves for vacant TV channels. The system will automatically switch its transmission frequency if, for example, it notices that a new TV station has set up shop. "Our prime directive is to not cause harmful interference to the TV broadcasters," says Carl Stevenson, the chair of the IEEE group putting together the standard.

IEEE created its 802.22 working group shortly after the Federal Communications Commission proposed giving non-TV broadcasters access to unused frequencies to encourage more efficient use of the radio spectrum. Its goal is to publish the standard by January 2008; compliant products will likely be available soon thereafter. One company, WiFi Wireless of Aliso Viejo, CA, has already announced that later this year it will demonstrate products that operate on TV bands. Such products will have to contend, however, with another emerging wireless networking technology called WiMax, which can beam broadband signals over distances of up to eight kilometers and will reach the market early next year. **Corie Lok**

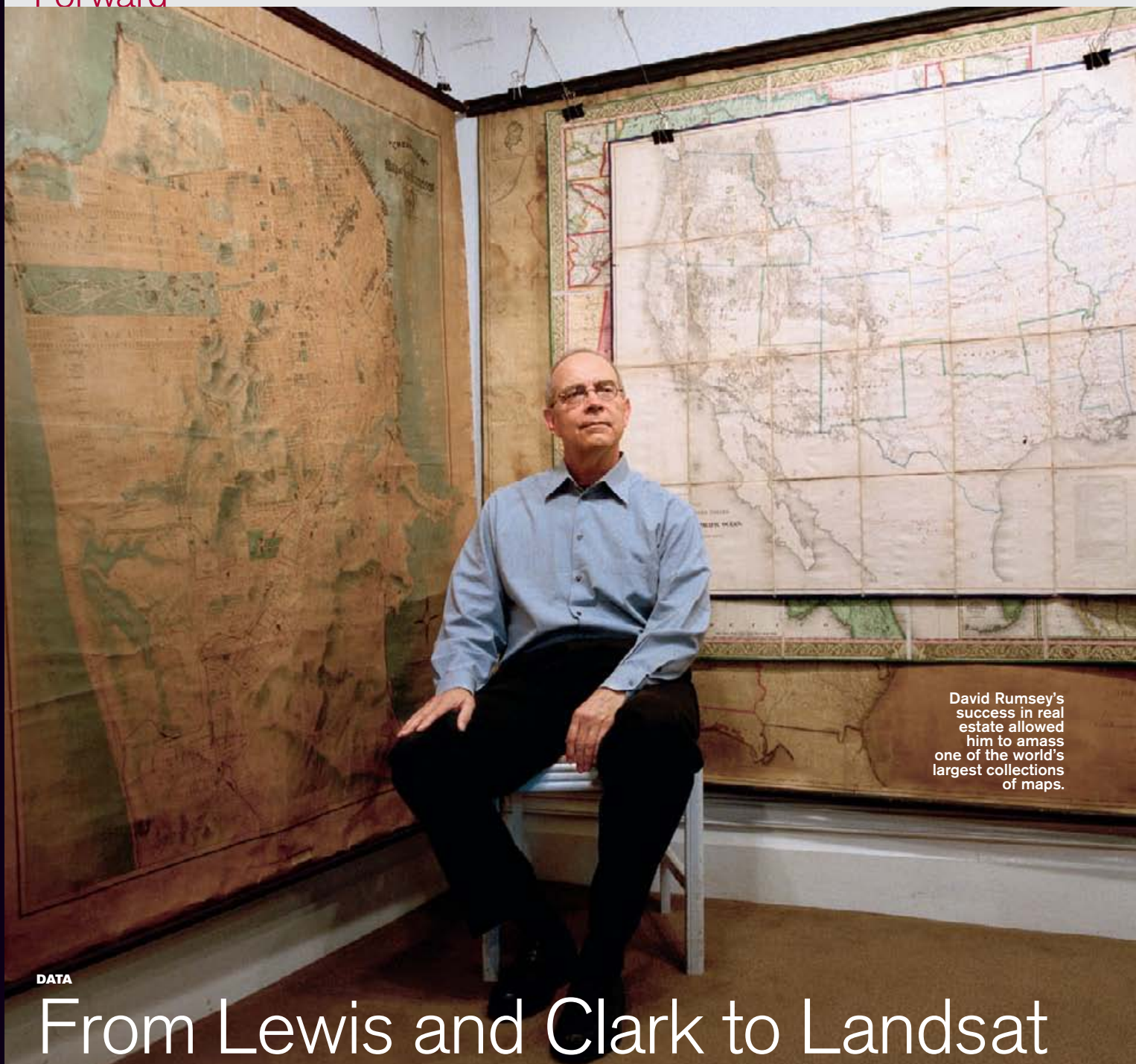
Prototype continued from p. 23

the phone is being moved and the game responds accordingly. The demonstration application, which works on phones running the Symbian 60 operating system, is virtual Ping-Pong. The player wields the phone like a paddle to hit a virtual ball displayed on the phone's screen. Two users can play each other if their phones are connected wirelessly via Bluetooth, to the amusement of onlookers who can't see the ball, table, paddles, or net. Charles Woodward heads the multimedia team at VTT, Finland's national technology research center, that developed the technology. Woodward says the patented interaction method has attracted the interest of a game firm, and a more accurate version is in development.

Seeing-Aisle Cart

Guide dogs may be great at navigating sidewalks, but they're not very good at grocery shopping, so Utah State University computer scientist Vladimir Kulyukin is developing a robotic-guide grocery cart for the visually impaired. Enter a product name into the handle's keypad, and the motorized robot navigates to the corresponding item by reading a series of radio frequency identification tags distributed throughout the store. A laser scans for roadblocks along the way to the appropriate section, where voice instructions indicate which shelf to reach for. The current prototype seeks out only a few items listed on a paper Braille menu posted next to the keypad. However, Kulyukin says future versions of the cart will have dynamic Braille interfaces and scanners to identify brand items by bar code. He's in negotiations to begin testing the technology in a large chain store.

REED SAXON/AP PHOTO; COURTESY OF CHARLES WOODWARD/VTT FINLAND (PONG)



David Rumsey's success in real estate allowed him to amass one of the world's largest collections of maps.

DATA

From Lewis and Clark to Landsat

David Rumsey's digital maps marry past and present

FOR $140, you can buy a handheld Global Positioning System receiver that will gauge your latitude and longitude to within a couple of meters. But in 1804, when Meriwether Lewis and William Clark ventured across the Louisiana Territory, a state-of-the-art positioning system consisted of an octant, a pocket chronometer, and a surveyor's compass.

But somehow, Clark—the cartographer in the group—made do. When San Francisco map collector David Rumsey took his copy of Lewis and Clark's published map of their journey, scanned it into a computer, and matched landmarks such as river junctions against corresponding features on today's maps, he found that it took only a slight amount of digital stretching and twisting to make Clark's map conform to modern coördinates. In fact, Rumsey was able to combine Clark's depiction of his party's route to the Pacific with pages from government atlases from the 1870s and 1970s and photos from NASA Landsat satellites, creating a digital composite that documents not only a historic adventure but the history of mapmaking itself.

To Rumsey, maps are far more than two-dimensional portrayals of landscape;

they have the power to send users on intellectual journeys to distant places and long-ago times. Rumsey believes that by using the latest digital technology, we can learn remarkable things about politics, culture, and science, as seen through the eyes of mapmakers. As the Lewis and Clark composite shows, for example, the Indian tribes whose location, size, and economies Clark described with keen anthropological interest would, within half a century, be cast as enemies and herded onto reservations. Putting one map next to another makes such contrasts leap out at the viewer, says Rumsey. "What excites me is context," he says—meaning the ability, using onscreen tools and the Internet, to juxtapose maps from different periods, or even to examine letters and paintings related to the maps.

Today, visitors to www.davidrumsey.com can create juxtapositions using the thousands of map images Rumsey has digitized and a toolbox of sophisticated map-browsing programs that he developed in collaboration with Luna Imaging, a digital-archiving firm in Los Angeles. The site, which is in its fifth year and attracts two million visitors annually, exists because Rumsey is one of those rare collectors whose interest in sharing their collections eventually surpassed their interest in adding to them.

Rumsey, 61, is a New York City native who earned several fine-arts degrees at Yale University in the late 1960s, then made what he calls an "accidental" fortune developing real estate in San Francisco. His success allowed him, in the early 1980s, to start looking at real estate in a different way—through historical maps. Rumsey spent years combing the world for 18th- and 19th-century maps of North and South America. At the time, the maps were not in great demand and therefore cheap; he would often buy 30 or 40 in a day.

The resulting collection is one of the world's largest: more than 150,000 maps in a variety of formats, from wall maps to atlases to globes to wooden map puzzles, plus related material such as manuscripts, books, and lithographs, all arranged on neatly indexed shelves on the ground floor of Rumsey's elegant four-story Victorian, a few blocks from Golden Gate Park. From the beginning, Rumsey wanted to open the collection to scholars and map mavens. But he couldn't exactly invite thousands of people into his home every year—and the materials themselves are too fragile to withstand regular use.

So around 1998, Rumsey says, he "stopped adding to the collection and turned to the digitizing effort." Making and publishing high-resolution digital facsimiles of maps and other historical documents was—and is—a slow, painstaking process. But several technological advances converged in the late 1990s to make the job more manageable, including high-resolution digital cameras and scanners; wavelet compression, which let Rumsey reduce 300-megabyte files to three megabytes with no significant drop in image quality; viewing software, developed with Luna, that lets users call up just one area of a map at a time, then pan or zoom without having to download an entire map; and, of course, the advent of broadband Internet access.

Rumsey is one of those rare collectors whose interest in sharing their collections eventually surpassed their interest in adding to them.

Rumsey's website now holds some 11,000 items, including gems like an 1894 illustrated directory of downtown San Francisco, the only complete visual record of the area, which was mostly destroyed by earthquake and fire in 1906. An interactive section of the site provides software based on geographical information systems (GIS) standards that lets users fly through 3-D maps of San Francisco, Yosemite Valley, and other locales, or compare up to four historical maps of a given location on one screen.

Anyone is free to copy and reuse the maps for noncommercial purposes under a Creative Commons license. Rumsey himself looks forward to a near future in which location-aware devices such as cell phones and digital cameras will allow people to create their own geo-referenced content, which they can then mix with maps from his collection or others'. "What these location-based technologies are going to allow all of us to do is to become like explorers—to make our own maps," says Rumsey. "And I think people are going to use that to build a whole new interpretation of our culture." **Wade Roush**

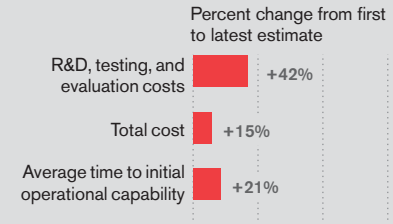
TIMOTHY ARCHIBALD

DEFENSE

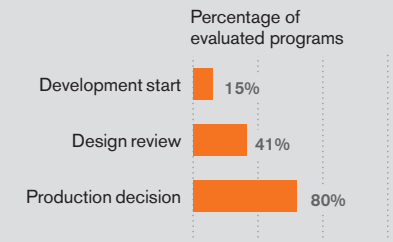
R Deficit = D Inflation

The cost of developing new weapons systems is on the rise, and the U.S. Government Accountability Office (GAO) blames a too early emphasis on product development. The GAO evaluated 54 defense projects and found that just 15 percent had a sufficient scientific basis when they were initiated. The GAO's estimates of the R&D costs of 26 projects (those that had enough financial data available to analyze) were 42 percent higher than initial estimates—an increase from 21 percent to 26 percent of total costs.

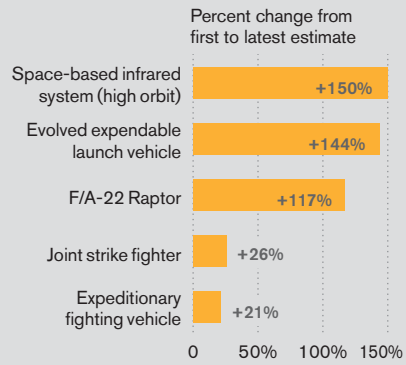
Overall weapons-program development time and costs



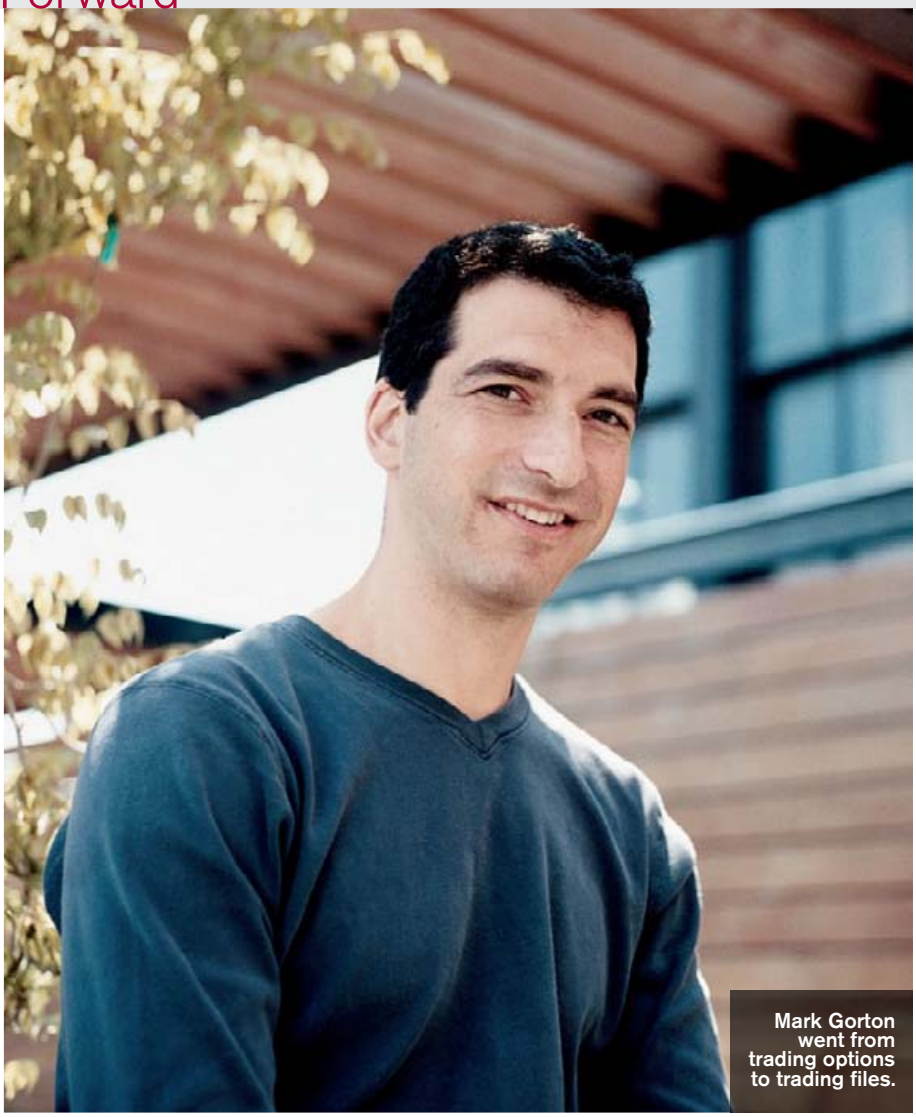
Weapons programs with mature technology, by development stage



Unit cost of selected projects



SOURCE: U.S. GOVERNMENT ACCOUNTABILITY OFFICE



Mark Gorton went from trading options to trading files.

INTERNET

LimeWire's Live Wire

To Mark Gorton, file sharing is all good

One of the most closely watched U.S. Supreme Court cases this spring was *MGM v. Grokster*. In it, the Court heard arguments on whether Grokster and other makers of software used to share music and video files over the Internet should be shut down because of users' illegal copying of copyrighted material. Aerospace engineer turned Wall Street options trader Mark Gorton runs Lime Wire, maker of the popular file-sharing program LimeWire. He spoke to *TR* late this spring about the pending ruling.

Downloads of LimeWire software are running well over a million copies a week. The legal threat isn't hurting the file-sharing business?
I doubt most of our users even think about it.

The music industry certainly does.
They need to get over it. Look at the history: every time there's a technological innovation, someone says the sky is falling. But it never does. The way the music business makes money today is different from what it will be 10 years from now, but that's not unhealthy.

But don't they say that 90 percent of file-sharing traffic is pirated?
I don't see copyright infringement as a discrete issue. File sharing is a net good for society. It lowers the cost of distributing music. The fact that practically everything that's ever been recorded is now available at everyone's fingertips is amazing. When I tell people I run an options-trading company, their eyes glaze over. When I tell them I do LimeWire, they get excited.

Even if the record companies lose this battle, won't they still go after individual downloaders?
They have the right to file 10 million lawsuits. Whether they have the societal backing to do that is another question. If 20 kids on every campus in America are being sued, will there still be public support for more-stringent copyright law? But it's not just political calculation: these are their customers.

Do you see file sharing extending beyond digital media?
Absolutely. It's perfect for something like job seeking: people can post their own résumés. And it wouldn't surprise me to see an open alternative to eBay.

Couldn't the courts outlaw all this?
Sure, they could put all the current domestic file-sharing software makers out of business. But the software will still be out there. LimeWire is open source. And the user networks will survive.

Under a U.S. Supreme Court ban, presumably things would shift offshore. We've already got sites like allofmp3.com operating from Russia.
Then maybe they'll sue the ISPs that connect up to Russia. But if you start making everyone responsible for everything that goes over the network, it's a very different Internet from the one we have today.

Big media companies don't seem to see it that way.
Right, and they don't have much to lose, so they're giving it a shot. It distracts them from reality, which is that they shut down Napster four years ago, they shut down Aimster, and file sharing is more popular than ever.

You're pretty cocky, given that your business is at risk of being outlawed.
I'm pretty confident the Court will do the right thing. And I have other businesses. As much as I enjoy doing LimeWire, it's not like my life depends on it. **Spencer Reiss**

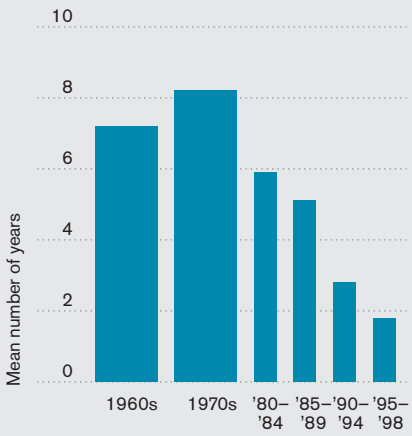
JOSHUA PAUL (GORTON); COURTESY OF RICK FERGUSON/AIRDAT (PLANE)

DRUG DEVELOPMENT

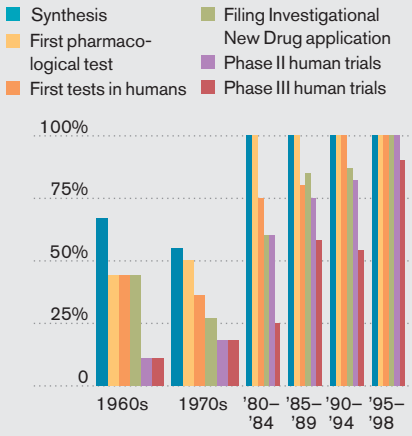
First-in-Class Ain't What It Used to Be

In the pharmaceutical sector, the amount of time in which a new product has a market all to itself has diminished considerably over the past several decades. By the late 1990s, it wasn't uncommon for a first-in-class drug (the first drug to use a particular molecular mechanism to treat a condition) to have several competitors in various stages of clinical development—even before it was approved. A few decades ago, a new drug would have a corner on the market for about eight years. Now, that figure is closer to two years.

Time from first-in-class drug's approval to first competitor's approval



Percentage of newly approved first-in-class drugs with at least one competitor in an earlier stage of development



SOURCE: *PHARMACOECONOMICS*, TUFTS CENTER FOR THE STUDY OF DRUG DEVELOPMENT

WEATHER

Proclaiming Rain Falls Mainly to a Plane


Commuter planes like this one could help improve weather forecasts.

SINCE JANUARY, newly developed sensors affixed to 64 commuter planes owned by Eagan, MN–based Mesaba Airlines (a Northwest Airlink affiliate) have been sending real-time data on humidity, temperature, wind speed, turbulence, atmospheric pressure, and location to a central station on the ground. In early findings, data from the planes is allowing forecasters to predict with far greater precision the arrival time of precipitation or freezing temperatures and the likelihood of severe thunderstorms or fog.

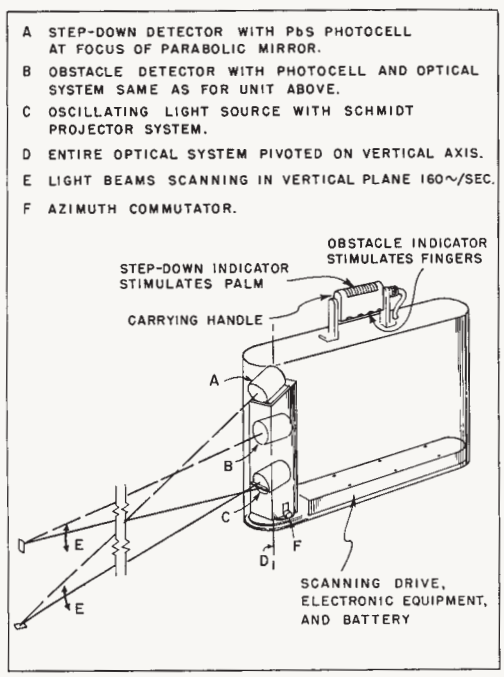
Readings from the sensors fill a huge gap in the data meteorologists collect. The lower ranges of the atmosphere, below 6,000 meters, are where weather forms. But currently, in the entire United States, 69 weather balloons take just two daily "soundings" in the lower atmosphere. In the new project, each commuter plane takes measurements every time it takes off and lands—which adds up to 600 to 800 total soundings daily. The planes also send regular dispatches from cruising altitudes.

"The amount of data we're getting is just incredible," says Jeff Last, a Green Bay, WI, meteorologist with the National Weather Service, one of the agencies involved in the project. In one test this winter, a forecast using data from the sensors accurately predicted a snowstorm's arrival, while a traditional forecast was off by three hours.

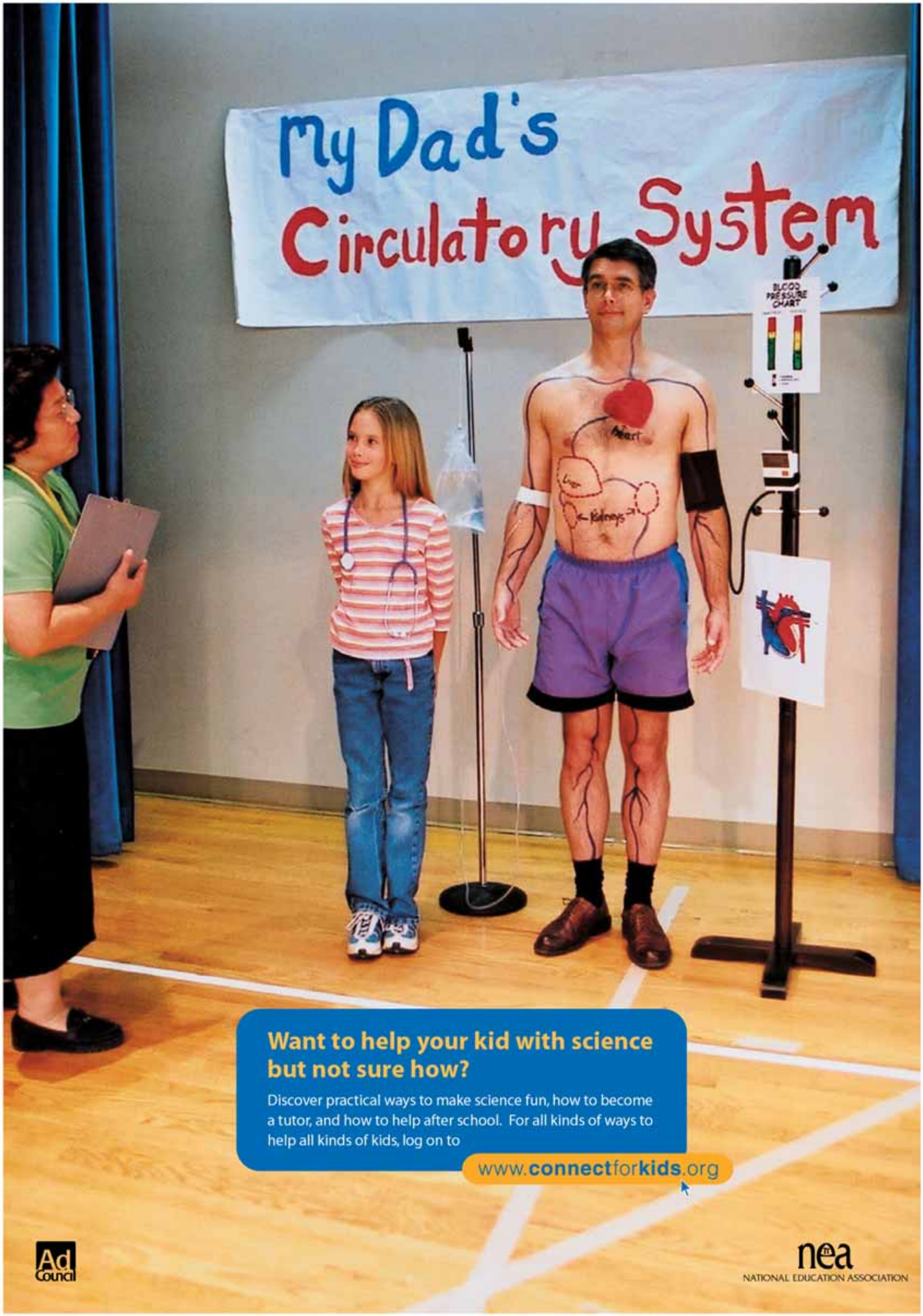
In addition to the National Weather Service, the project involves other government agencies, including NASA, and several universities and private companies. AirDat of Morrisville, NC, the company that processes the sensor data, hopes to eventually sell climate information to airlines, agricultural businesses, and others interested in a sharper weather picture. **David Talbot**

50 years ago in *Technology Review*

From "Visual Aids" (July 1955, p. 468)



Functional diagram showing the operating elements of electro-mechanical device for assuring safe mobility of foot travel for the blind.


My Dad's Circulatory System
BLOOD PRESSURE CHART
Heart
Kidneys
Want to help your kid with science but not sure how?
Discover practical ways to make science fun, how to become a tutor, and how to help after school. For all kinds of ways to help all kinds of kids, log on to
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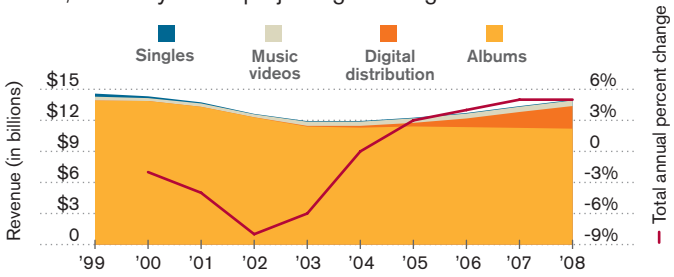
Data Mine

Digital Media Make Their Mark

THREE DIGITAL-MEDIA technologies crossed a threshold last year; more than half of U.S. households now have a DVD player, a wireless phone, and Internet access. Still, only about one-quarter of homes have broadband; this limitation is impeding the proliferation of digital media. One technology that has been a pariah for music-industry types may soon be a darling: digital audio, long blamed for eroded revenues, is expected to substantially contribute to music labels' top lines this year in the form of paid downloads. This could help create the first growth in revenue for the sector in five years. One business sees nothing but blue skies: video-game revenue is expected to continue its outrageous climb, bolstered over the next few years by the release of next-generation consoles that will likely have enhanced online capabilities. But what will make the biggest mark on the industry in the coming years? Digital video recorders, predict media executives. **Stacy Lawrence**

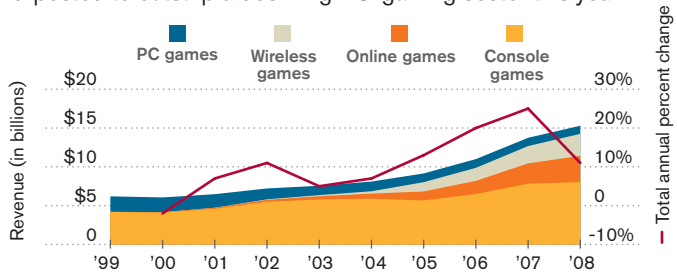
U.S. recorded-music market by format

Music revenues have been slashed by almost one-fifth since 1999, but analysts are projecting overall growth in 2005.



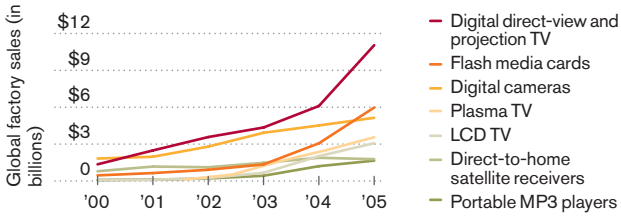
U.S. video-game revenue by type

Wireless-game revenue, previously almost nonexistent, is expected to outstrip a declining PC-gaming sector this year.



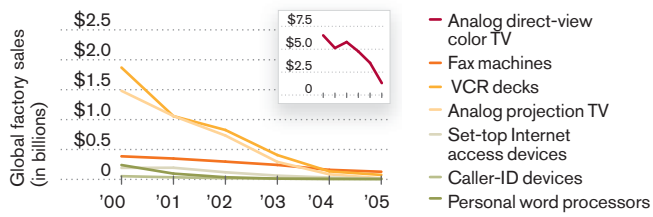
Consumer electronics with the most rapidly increasing sales

TVs with next-generation screens, digital cameras, MP3 players, and satellite receivers are quickly becoming popular.



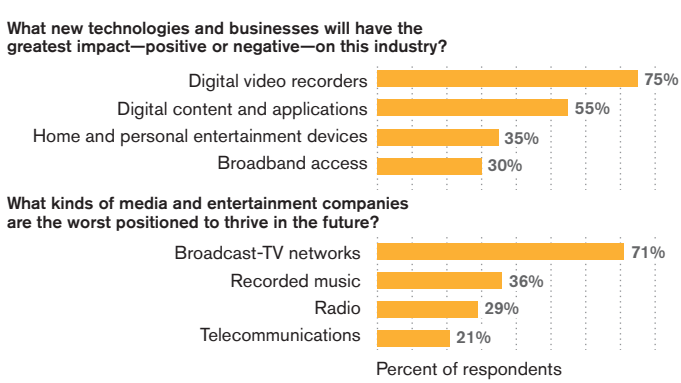
Consumer electronics with the most rapidly declining sales

Sales of set-top Internet access devices for TVs; VCR players; and analog TV have all sharply declined in the last five years.



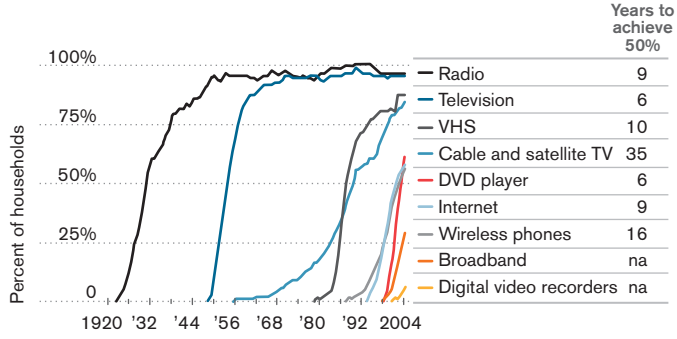
Media-executive survey on breakthrough and stumbling technologies*

Most entertainment execs say that DVRs and digital content will shake up their industry, while almost three-quarters see tough times ahead for broadcast TV.



U.S. adoption rate of select media technologies

In the last five years, three recent digital-media technologies reached more than half of Americans for the first time.



*BASED ON A SURVEY OF 23 MEDIA AND ENTERTAINMENT INDUSTRY CEOS, CFOS, AND FINANCIAL STAKEHOLDERS.
SOURCES: PRICEWATERHOUSECOOPERS, CONSUMER ELECTRONICS ASSOCIATION, ERNST & YOUNG

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Funding of Innovative Startups

Company	Founded	CEO	Recent funding	Key investors	Technology	Prospects
Savi Networks	2005 (Sunnyvale, CA)	Not yet appointed	$50 million	Joint venture between Savi Technology and Hutchison Port Holdings	Radio frequency ID–based information network to track and manage ocean cargo containers	**The threat of terrorism has created an obvious demand to monitor cargo containers.**
T-RAM Semiconductor	2000 (San Jose, CA)	Kenneth Young	$40 million	Bear Stearns Health Innoventures, Genentech, and Lehman Brothers Healthcare Fund	High-density, high-speed SRAM (static random-access memory) chips based on technology from Stanford University	**There are high-end applications that could use high-density SRAM; network servers are one lucrative target.**
InPhase Technologies	2000 (Longmont, CO)	Nelson Diaz	$5 million	Bayer MaterialScience	Holographic data-storage technology that produces a disc with 50 times the capacity of a common DVD	**The technology is risky, but the recent partnership with Bayer is a strong endorsement.**
Axial Biotech	2002 (Salt Lake City, UT)	John Climaco	$4.1 million	VSpring Capital, Medtronic Sofamor Danek, and Ohio Biotech Group	Improved diagnostic and prognostic tests for diseases of the spine	**Earlier detection of spinal conditions could improve outcomes.**
NanoString Technologies	2000 (Seattle, WA)	H. Perry Fell	$3.8 million	OVP Venture Partners and Draper Fisher Jurvetson	A high-speed, ultrasensitive bar-coding system for identifying individual molecules	**It's early, but if NanoString's technology works, it could be a useful new biotech tool.**
Ikaria	2005 (Seattle, WA)	Not yet appointed	Not disclosed	Arch Venture Partners, Venrock Associates, 5AM Ventures, Aravis Ventures, and Washington Research Foundation	A way to induce reversible hibernation in mice developed at the Fred Hutchinson Cancer Research Center	**The killer app is to apply "hibernation" to humans, allowing for more time to treat trauma, stroke, or cardiac arrest.**

Will take time to reach market **Strong competitive position** **High-benefit, high-risk technology**

Company Spotlight

InPhase Technologies In the storage sector, InPhase Technologies, which was founded in December 2000 as a spinout of research done at Bell Labs, expects to become one of the first companies to bring holographic data storage to market. The company introduced a prototype of a holographic storage drive earlier this year.

In the deal recently announced, Bayer MaterialScience has agreed to a joint development deal with InPhase. Bayer MaterialScience, which is part of German chemical and pharmaceutical giant Bayer, will invest $5 million in the startup. The two companies say that by 2006 they will introduce both a recording and reading device and a holographic data-storage medium, based on polymers made by Bayer MaterialScience, with a capacity of 300 gigabytes. Bayer MaterialScience is one of the world's largest producers of polymers, including materials used in CDs and DVDs.

Conventional optical storage devices, such as DVDs or CDs, record one bit of data at a time. But holographic drives can read or write a million bits at once, encoded as the interference pattern of two intersecting laser beams. InPhase promises two gigabytes of data on a chip the size of a postage stamp, or 20 gigabytes on one the size of a credit card. A 300-gigabyte disc will offer 50 times the storage capacity of a common DVD and 460 times that of a CD.

InPhase and Bayer MaterialScience say they are also coöperating to research new types of specialty polymers that will make possible discs with a capacity of up to 1.6 terabytes—equivalent to the content of about four million books or about 1.6 million high-resolution photographs. Such discs could be available by 2009.

NanoString Venture capitalists salivate over enormous market opportunities even when they're accompanied by enormous challenges. So it's no wonder that they've recently invested in NanoString's molecule-tagging technology. According to NanoString CEO H. Perry Fell, the company's first market will be gene expression analysis, a billion-dollar business.

NanoString recently announced new funding of $3.8 million; an earlier round of financing, raising $4.3 million, was completed last August.

"We're tagging, identifying, and counting individual molecules," says Fell of his company's technology, which places a kind of bar code on molecules. Eventually, the technology could be used in a wide variety of biological assays, and in applications such as clinical diagnostics, forensics, and agriculture.

NanoString's chief scientist, Krassen Dimitrov, invented the company's core technology in 2000 while at the Institute for Systems Biology in Seattle. There he worked with Leroy Hood, a biotech pioneer and inventor of the automated DNA sequencer, among other biomedical tools. Hood now heads NanoString's scientific-advisory board.

NanoString has an exclusive license from the Institute for Systems Biology for Dimitrov's technology. The company says the technology is faster, cheaper, and 100,000 times more sensitive than existing DNA microarrays, which use DNA probes to test for the presence of particular biomolecules in solution.

But don't expect anything from NanoString too soon. The company won't even have a working prototype ready until the summer of 2006. **Andrew Madden**

Investors Tire of Energy, Think Chips Are Fab

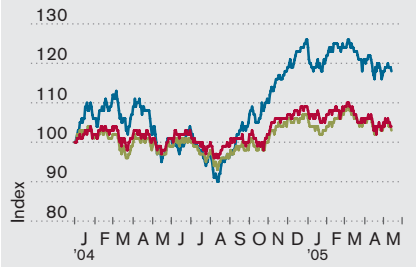
Shell Trading and Transport down; upstart Ibiden up

Ask anyone who drives a car: gasoline prices are out of control. But that's no shocker. The price of gas is a function of the price of oil, which, while having retreated from an April high of almost $60 a barrel, is still at a healthy $48. The good news: if the market lives up to its reputation as a dependable portent of the future, there may be more relief in sight, as energy stocks were some of the poorest performers in our indices in the month ending May 13. Every single energy stock in the *TR* Large-Cap 100 fell during the month, led by a 4.9 percent drop in Shell Transport and Trading (the minority partner in Shell Oil). The same did not hold true in the *TR* Small-Cap 50, but last month's focus stock, First Calgary Petroleums, continued its journey downward, falling 14.2 percent.

The *TR* Large-Cap 100 and Small-Cap 50 indices live online, where they are updated daily. Visit www.technologyreview.com/trindex.

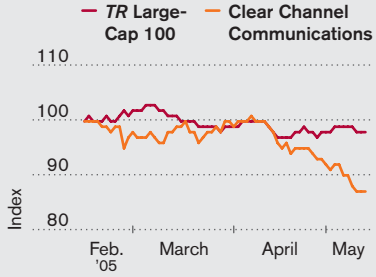
Semiconductor stocks, on the other hand, are enjoying a deserved reprieve. The top gainers in both indices were chip stocks—Texas Instruments and Japanese upstart Ibiden—but they were joined on the way up by most of their industry brethren. The cause, interestingly, was less a preponderance of good news than a lack of bad news. Chip stocks famously move ahead of fundamental results, and with first-quarter reporting season having passed with no real blowups, many investors are clearly trying to get a leg up on those who wait till the writing's on the wall. **Duff McDonald**

TR stock index comparison



	% change 4/15–5/13	One-year % change
TR Large-Cap 100	0.7%	5.9%
TR Small-Cap 50	1.4%	19.9%
S&P 500	1.0%	5.3%

In depth: Clear Channel Communications



In April, Clear Channel Communications announced plans to spin off its entertainment and venue-management business and sell a stake in its billboard-advertising division through an initial public offering. Investors were not pleased. Through May 13, the stock was down 25.5 percent from its 52-week high and was the biggest loser in the *TR* Large-Cap 100 for the month.

TR Large-Cap 100

	% change 4/15–5/13	Total market cap (millions)
Semiconductors and equipment	8.5%	$386,945
Computers	6.2%	$702,968
Consumer	4.1%	$178,305
Software and services	3.8%	$474,156
Aerospace and defense	3.0%	$231,271
Health care	0.7%	$206,603
Biotechnology and pharmaceuticals	0.1%	$1,205,500
Media	-1.5%	$458,532
Telecommunication services	-1.7%	$745,830
Energy	-3.4%	$1,173,538

TR Small-Cap 50

	% change 4/15–5/13	Total market cap (millions)
Semiconductors and equipment	7.2%	$8,098
Biotechnology and pharmaceuticals	6.6%	$11,753
Software and services	4.2%	$15,822
Computers	1.9%	$15,864
Aerospace and defense	1.0%	$5,897
Health care	0.3%	$9,631
Telecommunication services	0.1%	$3,406
Media	-3.3%	$11,640
Energy	-4.0%	$9,433
Consumer	-7.5%	$2,595

TR Large-Cap 100, top gainers

	% change 4/15–5/13	One-year % change
EMC (NYSE: EMC)	20.1%	32.5%
Texas Instruments (NYSE: TXN)	16.4%	3.1%
Nokia (NYSE: NOK)	15.5%	26.3%

TR Small-Cap 50, top gainers

	% change 4/15–5/13	One-year % change
Ibiden (Tokyo: 4062)	21.0%	74.6%
Macromedia (Nasdaq: MACR)	15.8%	66.0%
CACI International (NYSE: CAI)	14.4%	52.9%

TR Large-Cap 100, top losers

	% change 4/15–5/13	One-year % change
Clear Channel Communications (NYSE: CCU)	-9.6%	-25.5%
Telecom Italia (NYSE: TI)	-9.1%	9.5%
Deutsche Telekom (NYSE: DT)	-6.8%	18.9%

TR Small-Cap 50, top losers

	% change 4/15–5/13	One-year % change
Brocade (Nasdaq: BRCD)	-22.1%	-20.9%
The Cooper Companies (NYSE: COO)	-14.3%	8.4%
First Calgary Petroleums (Toronto: FCP)	-14.2%	37.1%

SOURCES: STANDARD AND POOR'S CUSTOM INDEX SERVICES, *TECHNOLOGY REVIEW*, YAHOO FINANCE

The Willing Partner

THE CASE: Corporate customers have loved Research in Motion's BlackBerry since its 1999 launch. But as the popularity of the device increased, so did the number of the company's critics, many of whom believed Research in Motion was too small to maintain its dominance. When the company began to license its software in 2002, many saw this move as a drastic change in course. Instead, it was an object lesson in smart partnering.

In November 2002, Research in Motion (RIM) and Nokia announced a licensing arrangement allowing Nokia to offer its customers the ability to receive e-mail using RIM's BlackBerry software. The news perplexed industry watchers. For the three years before the deal, only RIM's devices could connect with the company's enterprise server, so that RIM owned both parts of the market for wireless e-mail: the devices and their software. RIM, in fact, seemed to own the very *notion* of that market.

The BlackBerry was the hardware equivalent of a *killer app*, the now overused term popularized in the 1980s to describe a piece of software so attractive to users that they feel they cannot be without it. Every new technology needs a killer app to establish its acceptance; for wireless e-mail, the BlackBerry filled that need. As businesses started to deploy the device to an increasingly mobile—and pressed—workforce, BlackBerry emerged as a critical tool for businesspeople.

Why, then, would RIM make its proprietary software available to others? Why would the company partner with a massive competitive threat such as Nokia? To many observers outside RIM, these decisions signaled a major shift in the company's business model. But to those inside RIM, they stemmed from a strategy the company had always followed.

RIM's case highlights a business problem that countless technology companies have had to deal with: when a company creates a revolutionary product whose software becomes critical to the establishment of a market, it has to figure out whether to keep its software all to itself or license it in an effort to make its technology the industry standard.

RIM is not left to its own devices.

COURTESY OF RESEARCH IN MOTION

Research in Motion

FY 2005 revenues: $1.35 billion
Employees: 3,000
Number of e-mails sent across North America that go through RIM's data center each day: 100 million

Building the Platform

RIM has, throughout its history, followed two imperatives: make the best possible proprietary device for wireless e-mail and follow whatever course will increase the size of that market. Started in 1984 as a firm that built electronic devices for other companies, RIM signed its first deal with General Motors, to deliver a networked display system that scrolled words across LED signs in GM factories. The idea behind what eventually became the BlackBerry system dates to 1989, when RIM worked on an outsourced project for Ericsson. As RIM focused more on wireless data, it started manufacturing its own devices. Pager companies like Motorola had tried to combine e-mail with pagers, but none of the devices achieved much success. By the early 1990s, even PC-based e-mail had yet to take off, and many in the telecommunications industry saw wireless e-mail as a product that people did not really want or need.

RIM proved the viability of this market in stages. First, it received an order in 1997 from BellSouth for $50 million worth of wireless e-mail devices. BellSouth was offering a pioneering service intended to allow data transmission in applications like inventory tracking for rail transport. Its so-called Mobitex network used Ericsson technology, but it still needed a supplier to build a hardware component for consumer use. The opportunity gave Research in Motion a critical test network for its device.

The opportunity also convinced RIM that it ought to seek out a larger market for its new device, known within the company as PocketLink. In 1998, RIM began working with a California-based branding agency called Lexicon. One Lexicon strategist thought the gadget's keyboard resembled the seeds of a berry; the BlackBerry launched in January 1999. Instead of employing a stylus and handwriting recognition software, the device used a small, thumb-operated qwerty keyboard. But as impressive as its physical design was, the truly remarkable thing about the BlackBerry was that RIM provided everything needed to make it work: the device itself, the software that made it run, the servers that routed e-mail from the wired network, and the airtime that RIM leased from mobile-phone carriers. "As first mover in the market, we had an opportunity to build a brand around a new category," said Dave Werezak, vice president of RIM's Enterprise Business Unit.

By mid-1999, months after the BlackBerry launch, RIM also began selling BlackBerry Enterprise Servers, mostly to corporate clients. These servers were installed in customers' IT departments and allowed BlackBerry users to send and receive e-mail from almost anywhere. Furthermore, the servers, which worked with RIM's integrated e-mail management system, allowed for the coördination of wired and unwired e-mail, so that customers could use their BlackBerries to access the e-mail accounts they used at the office.

RIM licenses its BlackBerry software to handset makers like Nokia.

Businesspeople were soon addicted to "push e-mail" (so called because new messages are sent directly to the device, rather than requiring a user to request them from a server), and RIM decided to alter the way it sold BlackBerry, in an effort to increase the size of the market. For the first year and a half that the BlackBerry was on the market, RIM leased airtime from carriers for the transmission of data. But in June 2000, it decided to switch course and instead let carriers sell the BlackBerry service directly to customers. In the new arrangement, RIM received up to 20 percent of carriers' fees. With thousands of the carriers' salespeople pushing RIM products, the service quickly spread globally: in 2002, RIM sold 360,000 devices; in 2004, it sold 2.3 million.

Just as RIM was sewing up the market for wireless e-mail, events outside its walls were helping to make that market vastly richer. By 2002, a new nonvoice international wireless standard, the General Packet Radio Service (GPRS), had emerged. Up until then, BlackBerry data traveled largely on the data-only Mobitex network, which didn't offer as much coverage as the new network. GPRS uses existing GSM (Global System for Mobile Communications) radio base stations and converts wireless data into standard Internet packets, enabling interoperability between the Internet and the GSM network at up to 10 times the speed of prior systems. The increased speed of data transmission and the convergence of voice and text data were attractive to both carriers and handset makers (who could offer data and voice in a single device). By the time RIM announced its agreement with Nokia, a new age had dawned: e-mail could now be sent and received on cell phones. With the hardening of the GPRS network, handset manufacturers could offer data-transmission software supplied by RIM.

The Logic of Partnership

From November 2002, when RIM began licensing its technology to cell-phone makers like Nokia, to May 2005, the company's stock rose more than 800 percent. But even as the company grows, critics continue to warn of looming "BlackBerry killers." RIM is sometimes depicted as the strong first mover that will later get crushed by a large player. As early as 2000, analysts predicted that PDA manufacturers and cell-phone makers would soon provide push e-mail functions that would make BlackBerry technology obsolete, and in April 2005, the *Wall Street Journal* listed a number of wealthy companies—both those making e-mail devices and those making network software—that were all nipping at RIM's heels. "Awakened by RIM's achievement, tech giants and hungry upstarts are responding with an arsenal of gear aimed at cracking the BlackBerry's stronghold," the *Journal* wrote. One month before, the *Economist* cited a pessimistic analyst who said, "Business-model transitions are always fraught with challenges."

RIM chairman and co-CEO Jim Balsillie says when Nokia approached RIM, "Our attitude was, 'Great, beautiful, love it.'" After the Nokia deal, others fell in line, including deals with Siemens, Motorola, and HTC.

It is that notion—that RIM has abandoned its strategy by loosening its proprietary grip on wireless e-mail—that most frustrates executives at the company, who contend that from the beginning, RIM's goal was to build a middleware platform for mobile e-mail that was compatible with multiple devices, applications, networks, and protocols and that spanned the globe. "We've always wanted to go there," says chairman and co-CEO Jim Balsillie, "but the question was, Would anyone go with us?" Balsillie, who has run RIM with Mike Lazaridis in a rare joint arrangement since 1992, says that the answer, at first, was no. "[There] was really a lack of interest, in the rest of the market, to work with us until we became a standard." As Balsillie sees it, RIM's licensing effort signals that it is the market, not RIM, that has changed. "There was no interest in partnering with us until we became successful," he says.

Of course, RIM did become successful, and as it did, it made overtures to handset makers, proposing partnerships. By the middle of 2002, Nokia and others finally became receptive when they saw that the new GPRS network would be strong enough to support cell phones that could send and receive e-mail. When Nokia approached RIM, says Balsillie, "Our attitude was, 'Great, beautiful, love it.'" By March 2003, RIM was calling its new licensing model BlackBerry Connect. After the Nokia deal, others fell in line, including deals with Siemens, Motorola, and HTC.

Welcome to the DMZ

RIM partnered with handset makers largely because it believed partnerships work well for companies with industry positions like its own. Balsillie compares that position to a demilitarized zone, one he says facilitates convergence between traditionally separate parts of the telecommunications and hardware industries. But like the strip of land between North Korea and South Korea, RIM's DMZ is also a buffer between two sides: the handset makers and the wireless carriers. "We are a middleware. And that's a really useful place to be. A lot of people seem to be agreeing with us by buying our products and partnering with us," says Balsillie.

RIM believes its status as first mover has allowed it to pioneer functions necessary in this middle ground, such as wireless data transmission and security. "If

COURTESY OF NOKIA

someone wants to be the middleware platform DMZ [like RIM], then I would think you would have to replicate the whole equation. You can't just pick and choose parts," Balsillie says. The DMZ role, he argues, requires you to please a number of parties: individual customers, corporate IT departments, handset manufacturers, operating-system makers such as Palm, and carriers all over the world. By the end of 2005, RIM will have signed on some 200 carriers—some profitable, others not—so that its services will be available everywhere in the world that its customers plan to be.

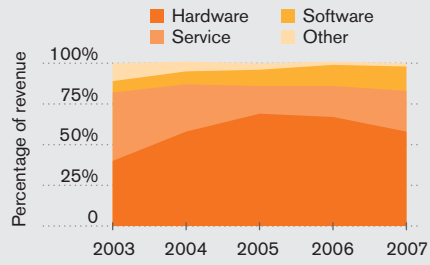
RIM's neutrality, of course, does not protect it against other companies that would like to run the DMZ. Two of the most cited potential BlackBerry killers are Microsoft and Good Technology, the upstart privately held software vendor that has more than 5,000 organizations paying for its rival GoodLink system. For its part, Microsoft is introducing new versions of its mail server and PocketPC software that include support for push e-mail, BlackBerry style. Some say that Microsoft has a lock on so many corporate servers that with these additions, it will easily be able to move customers to a free Microsoft-run wireless platform next year. The DMZ is also flooded with other well-armed competitors, among them Seven, Intellisync, and Visto.

Part of what saves RIM from despair is that while its position in the market may be neutral, its customers' feelings about its product are not. As RIM corporate-marketing vice president Mark Guibert explains, "Our customers became such raving, evangelical fans of the technology that the brand grew very virally and became very strong."

That kind of loyalty and enthusiasm has worked not only at the level of the individual user, but also at the level of the corporation. "We should never underestimate the brand of RIM. *Fortune* 500 companies have a definite preference for RIM," says Albert Chu of PalmSource. The software company worked with RIM to develop BlackBerry Connect for Palm OS, which allows PDAs equipped with Palm's operating system to access BlackBerry wireless services. "We clearly want to enable any solution that our customers want; if our customers want wireless push e-mail, we want to make sure we have that enabled for our platform. If RIM is the best brand out there, then we want to make sure that there's a RIM/BlackBerry solution on the Palm OS."

All This—and More?

RIM is beating analysts' predictions of software's contribution to its revenues. In its latest quarter, software accounted for 14 percent of revenue.



SOURCE: CREDIT SUISSE FIRST BOSTON

Another way RIM protects itself is by partnering with the kinds of companies that could pose major threats. RIM denies that its partnership arrangements have anything to do with self-protection: "We are not partnering with companies *because* they are competitors," says Guibert, but "because that is what we do really well." Motive, however, is unimportant. The result of these arrangements is that RIM has given big companies a reason to want BlackBerry to stick around.

RIM's small size has helped its dealings with prospective partners. According to Balsillie, when Nokia came calling in 2002, it didn't see RIM as a competitor. (RIM has a market valuation of $12.4 billion; Nokia has more than $15 billion in cash. Nokia sells more than 100 million cell phones a year; RIM has fewer than three million subscribers.) "Nokia's got a lot of worries; RIM's not one of them. I am sure of that," Balsillie says.

Growing in a Growing Market

Today, more than 42,000 BlackBerry Enterprise Servers have been installed worldwide, and almost three million people subscribe to the BlackBerry service in some form. That's up from a million in January 2004, thanks largely to RIM's recent success in Europe. By this summer, Nokia, HTC, T-Mobile, and Sony Ericsson will all have products featuring BlackBerry Connect. Siemens is offering a device with BlackBerry Built-In, an additional form of licensing that uses RIM's Java-based applications as well as the push-based wireless services of BlackBerry Connect. This spring, RIM settled a patent dispute with NTP, an intellectual-property holding company, for $450 million; in doing so, it successfully resolved concerns about its future expansion in the United States. According to Ken Dulaney, an analyst for IT research company Gartner, RIM shipped more than 700,000 PDAs globally in the first quarter of 2005, a 75 percent increase from a year earlier.

Still, RIM has its skeptics. When the company announced in April that during the fourth quarter of fiscal 2005, it received 66 percent of its revenue from handhelds and 14 percent from software, some contended that it did not have its heart in licensing deals. But that 14 percent represented $57 million—a nice bump up from the $5 million that software licensing contributed in the fourth quarter of 2003. Dulaney predicts that RIM's hardware business will not survive long term against competition from Asian manufacturers. But he also points out that RIM's revenues are boosted by individual user fees of about $10 per month, and he projects that the company will have five million users by year's end. "Today, RIM is measured by its BlackBerry devices," he says. "To survive, RIM has to be measured by seats installed." Balsillie, for his part, says it is not clear—or important—whether future revenues will come mostly from licensing or from sales of handheld devices.

Of course, Balsillie's actions indicate that he *does* care where future revenues come from: RIM, through its partnerships, is tying its fate to that of the wireless e-mail industry as a whole, an industry that has grown and is projected to keep growing exponentially. Between 2002 and 2005, the number of users more than doubled—from 14.6 million to 30.8 million. Most of this growth has been in the corporate sector, but future growth is projected to include consumer markets as well. "It's a rapidly, dramatically expanding market, so I am hardly fretting," says Balsillie. "If the market is going to 3X, and our market shrinks somewhat, who cares? It's all about enabling the market and driving it forward. It's all about that. Oh yeah, for sure. Without a doubt." **Alex Frankel**

THE DAY A HAIRSTYLE REQUIRES 100,000 LBS. OF THRUST, WE'LL MAKE ONE KIND OF SOFTWARE SOLUTION.

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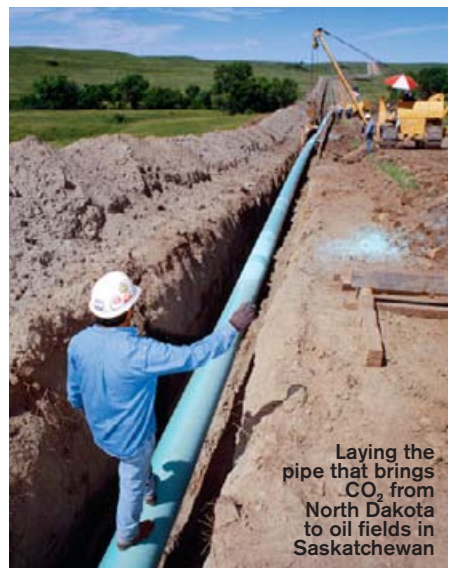
Carbon Dioxide for Sale

THE CASE: In 1988, the Basin Electric Power Coöperative of Bismarck, ND, bought a troubled chemical plant that converted coal into synthetic natural gas. The gamble paid off, and the story of Basin's success is altering the business of power and the politics of pollution.

On September 14, 2000, the Dakota Gasification Company moved beyond survival. The company's one-of-a-kind chemical plant in Beulah, ND—an industrial beast that converts 18,000 tons of lignite coal into 170 million cubic feet of synthetic natural gas per day (enough to heat 2,500 homes for a year)—had been written off 15 years earlier as a government-financed boondoggle, a misbegotten product of crisis-driven U.S. energy policies. But the determined subsidiary of a rural utility defied its critics. That September day, the company took a dirty by-product—carbon dioxide—and made it a financial asset by turning on a new CO_2 pipeline. Not only would the move secure the plant's viability, but it would also help clean up the environmental reputation of coal power.

Dakota Gasification operates a 300-kilometer pipeline full of carbon dioxide. This river of pollution heads north from Beulah to the aging oil fields of southeastern Saskatchewan. There the CO_2 plunges a kilometer and a half below the earth's surface into thick, stubborn oil deposits. The CO_2 cuts the oil's viscosity by a factor of four and eases its flow to the surface. Beulah's CO_2 is expected to help extract 130 million extra barrels of oil from the Saskatchewan oil fields, for which Dakota is well compensated. Once in the ground, the carbon dioxide takes the petroleum's place, becoming trapped beneath an impermeable stack of limestone, sandstone, and shale. The process safely buries more CO_2 in a year than a hundred thousand cars release in their operational lifetime.

Policymakers are increasingly looking to Dakota's technology as the potential key to clean domestic power in the future. The Bush administration has advanced coal gasification and underground storage of greenhouse gases as a long-term solution to a long-term problem. The U.S. Department of Energy is championing a 10-year R&D program, dubbed FutureGen, that is aimed at perfecting a task that Dakota is currently accomplishing with technology that dates from the 1970s. "FutureGen is promoting technology that hasn't even been demonstrated at small pilot plants," says Dale Simbeck, vice president of technology for SFA Pacific, an energy consultancy based in Mountain View, CA. "But here's a large-scale operation that's technically successful and that's doing all these things that are being talked about."



Laying the pipe that brings CO_2 from North Dakota to oil fields in Saskatchewan

STEVE CRANE

Dakota Gasification Company

FY 2005 revenues: $234.5 million
Employees: 700
CO_2 stored underground: Six million tons

Al Lukes, Dakota's chief operating officer, says he's used to the surprised reactions of international visitors who come to see what's happening in the northern plains: "People look at us and say, 'My God, you can do that?'"

As Dakota's story spreads, policymakers face an increasingly stark choice. The International Energy Agency projects that enough coal plants to produce 1,400 gigawatts of electricity will have been installed between 2003 and 2030. These plants will generate about 118 billion tons of carbon dioxide over their operating lifetimes. That's more than all carbon emissions from coal over the past 250 years combined. Even some pragmatic environmentalists agree that gasification technology may be the biggest single lever available for limiting greenhouse gases over the near term. "The coal is going to be mined. The only question is how it's going to be burned," says Antonia Herzog, a senior scientist with the Natural Resources Defense Council, an environmental advocacy group based in Washington, DC. "If new coal plants are going to be built, they should be gasification plants."

Dakota by Default

Dakota Gasification was conceived during the energy shortages of the 1970s. While OPEC squeezed oil supplies, price controls in the United States choked production of natural gas. Natural-gas-pipeline firms, alarmed by tight supplies, began exploring alternative sources; by 1978, a consortium of gas pipeline companies, Great Plains Gasification Associates, had coalesced to build the world's first synthetic natural-gas plant. Construction commenced in 1981 after President Reagan agreed to backstop the technologically ambitious project with federal loan guarantees, and in 1984 it was complete. Barely a year later, the gas pipeline companies bailed out, defaulting on $1.5 billion in loans.

The problem wasn't Great Plains' technology. Its process, adapted from the chemistry that enabled Nazi Germany to produce synthetic motor fuels, worked as designed: Coal and steam reacted together at 1,000 °C to yield a gaseous mixture of

hydrogen, carbon monoxide, and CO_2 (plus contaminants such as sulfur, mercury, and xenon gas). Pure CO_2 and contaminant streams were bled off, and the remaining carbon monoxide and hydrogen—a mixture known as synthesis gas or "syngas"—was fed to a catalyst to form hydrocarbons. The Nazis' catalysts turned out fuel for tanks, planes, and submarines; Great Plains' catalyst turned out high-quality methane.

Lukes, a chemical engineer who returned to his native North Dakota to work for Great Plains, says what upended the company was directional drilling and the deregulation of natural gas, which took place over several years, beginning in 1978. Deregulation unleashed a frenzied search for new gas deposits, and directional drilling multiplied each well's output. Great Plains expected to fetch $9 to $10 per thousand cubic feet for its synthetic gas, but by the mid-1980s, a gas glut had driven prices as low as $1 per thousand cubic feet. "No way could we make gas for that price," says Lukes.

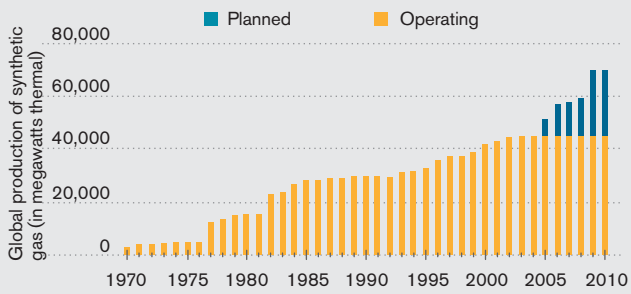
The plant *was* earning revenue, but at its owners' expense: thanks to pricing formulas written into their 25-year gas purchase agreement, the pipelines paid Great Plains upward of 50 percent more than the market price for natural gas.

The Department of Energy took possession of Great Plains when the pipeline companies walked away. Under pressure to protect 822 jobs in economically depressed North Dakota and to recoup some of the government's losses, the agency allowed the plant to keep operating. But it immediately began looking for a buyer. In 1988 it found the Basin Electric Power Coöperative of Bismarck, the local utility that powered the plant. Basin Electric stood to lose $37 million a year—about 8 percent of its annual revenues—if the plant closed. That $37 million "was a big number for Basin back then," says Lukes. Basin acquired the plant for $85 million in cash (and a promise to share future profits with the Department of Energy) and created a subsidiary, Dakota Gasification, to run it.

It was a risky move for Basin. In the years after the purchase, political support for alternative energy wavered. Gas prices slid. And the gas pipelines litigated their gas purchase agreements, forcing a settlement that would strip Dakota's protective price premium by the late 1990s.

Worldwide Gasification-Capacity Forecast

New-plant construction continues to expand the global capacity for producing synthetic gas, a mixture of hydrogen and carbon monoxide used to make, among other things, fuel, plastics, and synthetic natural gas.



SOURCE: UTILIS ENERGY AND THE U.S. DEPARTMENT OF ENERGY

One Company's Trash

Dakota survived by becoming a recycler: the by-products of its waste streams bring in more than $150,000 a day. And its most lucrative by-product—the one that finally secured its future—is carbon dioxide.

Scrubbing oil out with CO_2 isn't as lucrative as striking a major new field. "The big-name oil companies don't go after these. These are like bunts, and they're looking for home runs," says SFA Pacific's Simbeck. But the bunts are worth making for the second-tier oil companies that now dominate U.S. and Canadian oil production. Put the CO_2 in the ground, and you're likely to get more oil—that is, if you *have* CO_2. Most carbon dioxide used in oil fields comes from natural deposits of either CO_2 on its own or CO_2 entrained with natural gas. Oil-field operators north of Beulah had neither.

By the mid-1990s, Dakota looked like a survivor, and Calgary, Alberta–based PanCanadian Petroleum, the operator of one of Canada's largest oil fields, was ready to negotiate. Production at PanCanadian's field in Weyburn, Saskatchewan, peaked in the 1960s, but company geologists believed that CO_2 would rev it back up. Under a 1997 deal, Dakota built gas compressors and a pipeline to deliver the CO_2 to Weyburn, and PanCanadian agreed to pay Dakota for financing costs on the equipment, plus pay a demand charge. In February, Dakota signed up a second Saskatchewan oil producer, Apache Canada, which will begin taking CO_2 next year.

Judy Fairburn, a vice president of operations for EnCana (PanCanadian's new name after merging with Calgary-based Alberta Energy), says that buying Dakota's CO_2 increased production costs at Weyburn, and that PanCanadian predicated its investment on receiving $16 to $18 a barrel. That was a good bet: oil now fetches about $50 a barrel, and Weyburn is delivering 26,000 barrels per day—its highest level since the 1970s. "This oil field is definitely into its second wind," says Fairburn.

With natural gas selling at $7 per thousand cubic feet, Dakota is looking good, too. Asked if Dakota might be out-earning its oil-field customers, Fairburn nervously laughs. "I'll have to calculate that," she says. "They're certainly well positioned."

They are—and not just because of what they are helping to take *out* of the ground. As the oil rises in the Great Plains, Dakota Gasification's industrial CO_2 is pooling underground, creating an environmental benefit that could be worth millions of dollars more in years ahead, if the United States ever decides to adopt a cap-and-trade emissions policy. A $34 million research study sponsored by the International Energy Agency has been tracking the CO_2 underground. Its final report, released last fall, confirmed what everyone expected: the same strata that sealed in Weyburn's oil for 50 million years should hold its CO_2 for thousands of years, if not longer.

Gasification is again in the spotlight, and not just because of its ability to store away greenhouse gases. Today's record-high natural-gas prices show no signs of slipping, despite record levels of gas exploration in North America. And the technology is improving. Dozens of gasification plants have been built since 1984—most of which turn coal-derived syngas into ammonia fertilizers—and their cutting-edge power equipment costs less to build and operate than Dakota's. Major suppliers of the equipment, like General Electric, are taking orders for more. Dakota was not only lucky in its decades-long struggle to prove the viability of coal gasification, it was also right.

Peter Fairley

Home-Brewed E-Commerce

THE DECISION: Though Pura Vida, a coffee company cofounded six years ago by a former Microsoft product manager, started as a tiny operation, it opted to build its own e-commerce system instead of buying off the shelf.

Seattle's Pura Vida is a blend of business and philanthropy, a for-profit firm that gives donations to poor farm families in coffee-growing regions. It operates at breakeven and has funneled $1.2 million to the charities it supports since it began operation in 1999. But despite its benevolent mission, the company competes fiercely with Starbucks, Green Mountain, and other premium-coffee sellers. One weapon that cofounder and CEO John Sage has relied on is a good e-commerce system, which has helped increase sales from $100,000 in 1999 to the nearly $4 million projected for 2005.

From the beginning, Sage and James Ring-Howell, the company's acting chief technology officer, wanted software that could enter information from a customer's online order into Pura Vida's billing, accounting, and distribution systems and into its customer-records database. The two men sketched a system that would use Windows 2000, SQL Server 7.0, Microsoft Commerce Server, Access 2000, and QuickBooks and would require 600 to 700 hours of programmer time to create. Those close to the company questioned Sage about the wisdom of the move; the system was, arguably, too expensive for the nascent company, even considering that much of the programming would be done by volunteers. Ring-Howell estimates the system cost between $25,000 and $50,000 to create (and would have cost between $100,000 and $200,000 were it not for the volunteers), whereas the best off-the-shelf package would have cost between $5,000 and $8,000.

But Sage, a former Microsoft product manager, believed that a custom-built e-commerce system was worth the cost, both for its added efficiency and for the message it would send to prospective customers. Sage wanted the site to have a *Fortune* 500 look and feel. Bells and whistles, like a "constant cup" coffee subscription that customers could tailor, signaled that while Pura Vida was earnest, it was not amateurish. This kind of touch would have been impossible to add with an off-the-shelf product, according to Ring-Howell. The system also needed to be scalable so Sage could go out and market his products without the fear that success would overrun the software.

The result is an e-commerce system that integrates separate systems within the company. Orders for specialty products made with outside groups, like Bishop's Blend (sponsored by the Episcopal Relief and Development agency), can be accounted for accurately because they are fed directly into the correct general-ledger accounts. They don't need to be reëntered separately for inventory management and shipping purposes. Every day, customer-service agents receive lists of customers to check in with about their ordering needs.

Pura Vida director and cofounder Chris Dearnley (right) with Efrain Sanchez, a farmer in Costa Rica

COURTESY SCOTT JAMES/PURA VIDA COFFEE

Pura Vida Coffee

2004 revenues: $2.3 million
Employees: 18
Pounds of coffee sold daily online: 2,000

Integration even reaches across the country to Pura Vida production sites. When coffee orders come in, they influence the amount of coffee that the company roasts on the East and West Coasts, which is determined by the orders' destinations. Roasting coffee closer to where it will be sent optimizes freshness, improves delivery time, and reduces shipping costs.

Pura Vida's system does have drawbacks. There is no support line to call when things go awry. There are no user groups or Internet forums that can help solve problems. The company had to create its own training manuals and documentation. And Ring-Howell estimates that a custom e-commerce system can take three to ten times as long to build and implement as an off-the-shelf product does, "so you better really need it," he says.

Pura Vida felt it had no choice but build its own system six years ago, but a company facing a similar decision today has options. Off-the-shelf e-commerce packages have come a long way in the past five years, says Sage. Products like Microsoft's Great Plains and Oracle's hosted NetSuite now offer capabilities like sales-order processing, accounting, and inventory control and features like customer-relations databases. "Today, the off-the-shelf packages offer almost everything we've developed in house over the years," Sage notes.

Sage is glad the company didn't wait. "I don't regret our decision," he says. "Sometimes you just need to invest ahead of the technology curve. We couldn't have grown our sales 40-fold over the last six years if we hadn't taken the plunge." Of course, Sage had a resource most companies don't have: free labor. Still, it's common for startup companies to face similar decisions about how to give themselves the technology they need. Pura Vida's experience suggests that when the choice is between buying poor off-the-shelf technology and building your own, you should, if you can afford it, build your own.

Julie Bick

By Invitation Graham Allison

Nuclear Accountability

Forensic technology may deter states from giving terrorists nukes.

Graham Allison, director of Harvard University's Belfer Center for Science and International Affairs, is the author of *Nuclear Terrorism: The Ultimate Preventable Catastrophe*.

Scenario one: If North Korea fired a nuclear-armed missile that devastated an American city, how would the U.S. government respond? The state-sponsored attack would fit within the Cold War paradigm; therefore, the certain American response would be an overwhelming retaliation aimed at destroying Pyongyang, Kim Jong Il's nuclear and missile programs, and North Korea's million-man army. Such a response would result in enormous collateral damage, killing millions of North Koreans. Despite reservations about the morality of such a response, those who established the Cold War nuclear doctrine recognized—and accepted—the unintended deaths of millions of innocents. Whoever occupied the White House during such a nuclear attack would understand this also.

Scenario two: If North Korea were discovered to have sold a nuclear bomb to al-Qaeda, which smuggled the weapon into the United States and used it to destroy a city, how would the U.S. government respond? As things stand today, it would, again, launch an overwhelming retaliation against North Korea.

Scenario three: Now imagine a nightmare in which an unknown terrorist group smuggles a nuclear bomb into the United States and detonates it in Manhattan or Los Angeles, killing hundreds of thousands of Americans—but the U.S. government is uncertain where the bomb came from and who delivered it.

The logic of deterrence requires a deterrer and an identified deterree. In Henry Kissinger's formula, "Deterrence requires a combination of power, the will to use it, and the assessment of these by the potential aggressor. Moreover, deterrence is the product of those factors and not the sum. If any one of them is zero, deterrence fails." An adversary with no known return address might calculate that it could escape retaliation. In scenario three, as an American city lies smoldering, how would the U.S. respond if Osama bin Laden announced that he had ordered the action? If the U.S. government knew where bin Laden was, it would already be there.

The terrorist nuclear weapon that destroyed an American city, or the material from which it was made, would almost certainly have originated in a state. Fortunately, producing highly enriched uranium or plutonium—the key ingredients of a nuclear bomb—is a multibillion-dollar, multiyear undertaking, something beyond the capability of nonstate terrorists. After a nuclear September 11, the U.S. government would be eager to exact swift vengeance. But against whom? It must first determine who was responsible for the attack.

Did a state make and deliver the bomb or willingly sell it to terrorists? Or was the weapon stolen from a state that had no intention of losing it? (Indeed, the material could even have come from American stockpiles.) In the first case, identification would provide a bull's-eye for retaliation. In the second, the certainty that the weapon was stolen from, say, a Russian or Pakistani arsenal would generate a demand for the immediate global lockdown of all nuclear weapons and materials.

Today, the technological prerequisite for rethinking the unthinkable is nuclear forensics: the ability to identify a bomb's source from radioactive debris left after it explodes. Building on Cold War techniques, the Pentagon has developed new methods for collecting samples from ground zero, measuring data such as isotopic ratios and the efficiency of the fuel burn in the detonation, and comparing that information to known nuclear data to determine the origin of the materials.

Much about foreign nuclear materials is already known, collected from Cold War military tests, commercial transactions, scientific exchanges, and covert means. But the recent debate about the uranium hexafluoride that Libya turned over after renouncing its nuclear-weapons program illustrates gaps in our knowledge. The U.S. intelligence community believes that North Korea was the source; however, according to informed press reports, it reached that determination by the process of elimination—not by identifying the uranium directly, but rather by ruling out other known sources.

The goal of a robust nuclear forensics program must be to identify nuclear material definitively and quickly. The 2002 study by the National Research Council *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism* concluded that "The technology for developing [postexplosion nuclear attribution] exists but needs to be assembled, an effort that is expected to take several years." Establishing this capability should be a top priority, since effective deterrence requires convincing potential perps that the United States will be able to identify the culprit. ■

STEPHANE MANEL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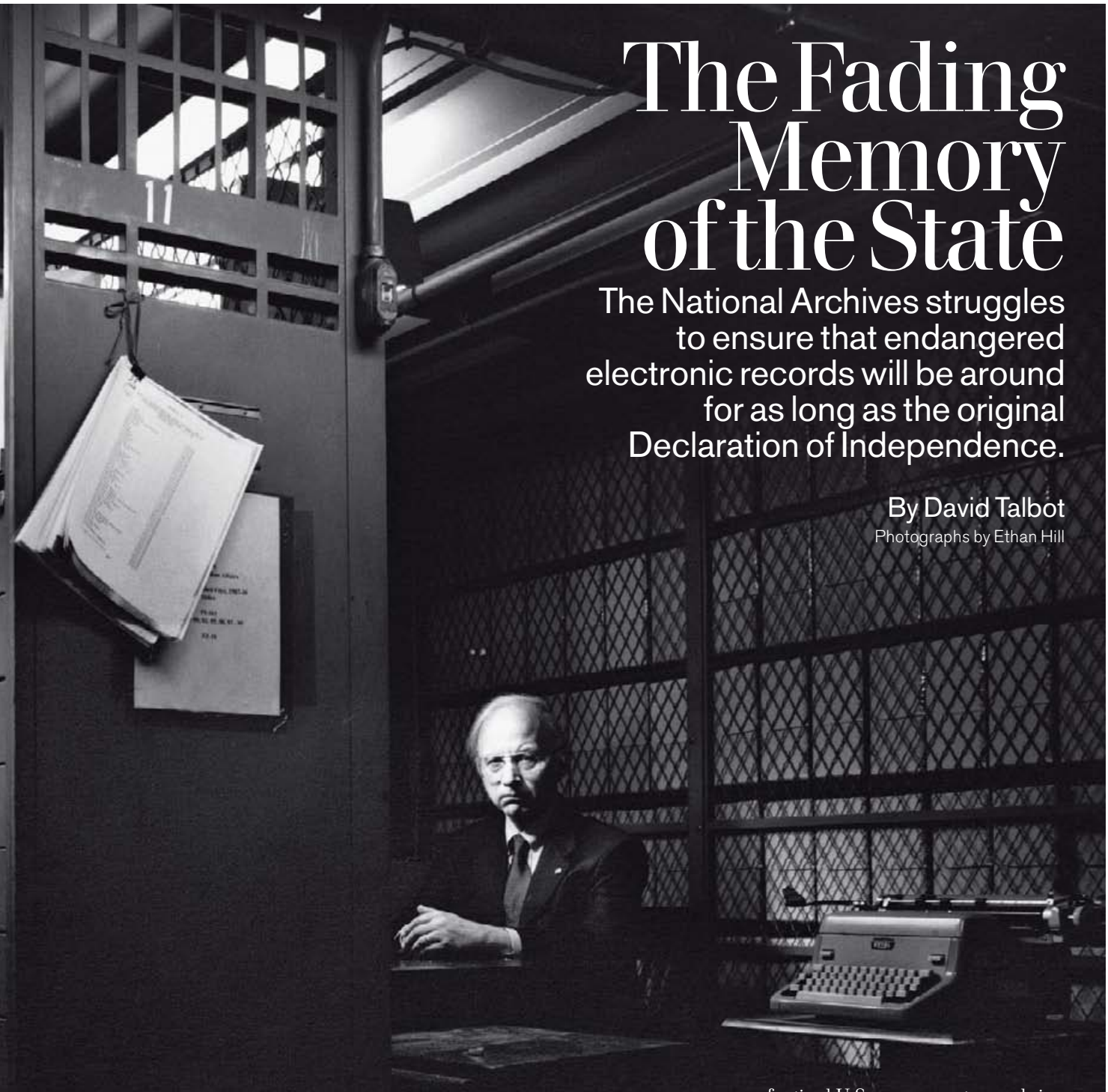
The Fading Memory of the State

The National Archives struggles to ensure that endangered electronic records will be around for as long as the original Declaration of Independence.

By David Talbot

Photographs by Ethan Hill



Allen Weinstein, the Archivist of the United States

THE OFFICIAL REPOSITORY of retired U.S. government records is a boxy white building tucked into the woods of suburban College Park, MD. The National Archives and Records Administration (NARA) is a subdued place, with researchers quietly thumbing through boxes of old census, diplomatic, or military records, and occasionally requesting a copy of one of the computer tapes that fill racks on the climate-controlled upper floors. Researchers generally don't come here to look for contemporary records, though. Those are increasingly digital, and still repose largely at the agencies that created them, or in temporary holding centers. It will take years, or decades, for them to reach NARA, which is charged with saving the retired records of the federal government (NARA preserves all White House records and around 2 percent of all other federal records; it also man-

ages the libraries of 12 recent presidents). Unfortunately, NARA doesn't have decades to come up with ways to preserve this data. Electronic records rot much faster than paper ones, and NARA must either figure out how to save them permanently, or allow the nation to lose its grip on history.

One clear morning earlier this year, I walked into a fourth-floor office overlooking the woods. I was there to ask Allen Weinstein—sworn in as the new Archivist of the United States in February—how NARA will deal with what some have called the pending "tsunami" of digital records. Weinstein is a former professor of history at Smith College and Georgetown University and the author of *Perjury: The Hiss-Chambers Case* (1978) and coauthor of *The Story of America* (2002). He is 67, and freely admits to limited technical knowledge. But a personal experience he related illustrates quite well the challenges he faces. In 1972, Weinstein was a young historian suing for the release of old FBI files. FBI director J. Edgar Hoover—who oversaw a vast machine of domestic espionage—saw a Washington *Post* story about his efforts, wrote a memo to an aide, attached the *Post* article and penned into the newspaper's margin: "What do we know about Weinstein?" It was a telling note about the mind-set of the FBI director and of the federal bureaucracy of that era. And it was saved—Weinstein later found the clipping in his own FBI file.

But it's doubtful such a record would be preserved today, because it would likely be "born digital" and follow a convoluted electronic path. A modern-day J. Edgar Hoover might first use a Web browser to read an online version of the *Washington Post*. He'd follow a link to the Weinstein story. Then he'd send an e-mail containing the link to a subordinate, with a text note: "What do we know about Weinstein?" The subordinate might do a Google search and other electronic searches of Weinstein's life, then write and revise a memo in Microsoft Word 2003, and even create a multimedia PowerPoint presentation about his findings before sending both as attachments back to his boss.

What steps in this process can be easily documented and reliably preserved over decades with today's technology? The short answer: none. "They're all hard problems," says Robert Chadduck, a research director and computer engineer at NARA. And they are symbolic of the challenge facing any organization that needs to retain electronic records for historical or business purposes.

Imagine losing all your tax records, your high school and college yearbooks, and your child's baby pictures and videos. Now multiply such a loss across every federal agency storing terabytes of information, much of which must be preserved by law. That's the disaster NARA is racing to prevent. It is confronting thousands of incompatible data formats cooked up by the computer industry over the past several decades, not to mention the limited lifespan of electronic storage media themselves. The most famous documents in NARA's possession—the Declaration of Independence, the Constitution, and the Bill of Rights—were written on durable calfskin parchment and can safely recline for decades behind glass in a bath of argon gas. It will take a technological miracle to make digital data last that long.

But NARA has hired two contractors—Harris Corporation and Lockheed Martin—to attempt that miracle. The companies are scheduled to submit competing preliminary designs next month for a permanent Electronic Records Archives (ERA). According to NARA's specifications, the system must ultimately be able to absorb any of the 16,000 other software formats believed to be in use throughout the federal bureaucracy—and, at the same time, cope with any future changes in file-reading software and storage hardware. It must ensure that stored records are authentic, available online, and impervious to hacker or terrorist attack. While Congress has authorized $100 million and President Bush's 2006 budget proposes another $36 million, the total price tag is unknown. NARA hopes to roll out the system in stages between 2007 and 2011. If all goes well, Weinstein says, the agency "will have achieved the start of a technological breakthrough equivalent in our field to major 'crash programs' of an earlier era—our Manhattan Project, if you will, or our moon shot."

Data Indigestion

NARA's crash data-preservation project is coming none too soon; today's history is born digital and dies young. Many observers have noted this, but perhaps none more eloquently than a U.S. Air Force historian named Eduard Mark. In a 2003 posting to a Michigan State University discussion group frequented by fellow historians, he wrote: "It will be impossible to write the history of recent diplomatic and military history as we have written about World War II and the early Cold War. Too many records are gone. Think of Villon's haunting refrain, 'Ou sont les neiges d'antan?' and weep....History as we have known it is dying, and with it the public accountability of government and rational public administration." Take the 1989 U.S. invasion of Panama, in which U.S. forces removed Manuel Noriega and 23 troops lost their lives, along with at least 200 Panamanian fighters and 300 civilians. Mark wrote (and recently stood by his comments) that he could not secure many basic records of the invasion, because a number were electronic and had not been kept. "The federal system for maintaining records has in many agencies—indeed in every agency with which I am familiar—collapsed utterly," Mark wrote.

Of course, managing growing data collections is already a crisis for many institutions, from hospitals to banks to universities. Tom Hawk, general manager for enterprise storage at IBM, says that in the next three years, humanity will generate more data—from websites to digital photos and video—than it generated in the previous 1,000 years. "It's a whole new set of challenges to IT organizations that have not been dealing with that level of data and complexity," Hawk says. In 1996, companies spent 11 percent of their IT budgets on storage, but that figure will likely double to 22 percent in 2007, according to International Technology Group of Los Altos, CA.

Megabyte
1,024 kilobytes. The length of a short novel or the storage available on an average floppy disk.

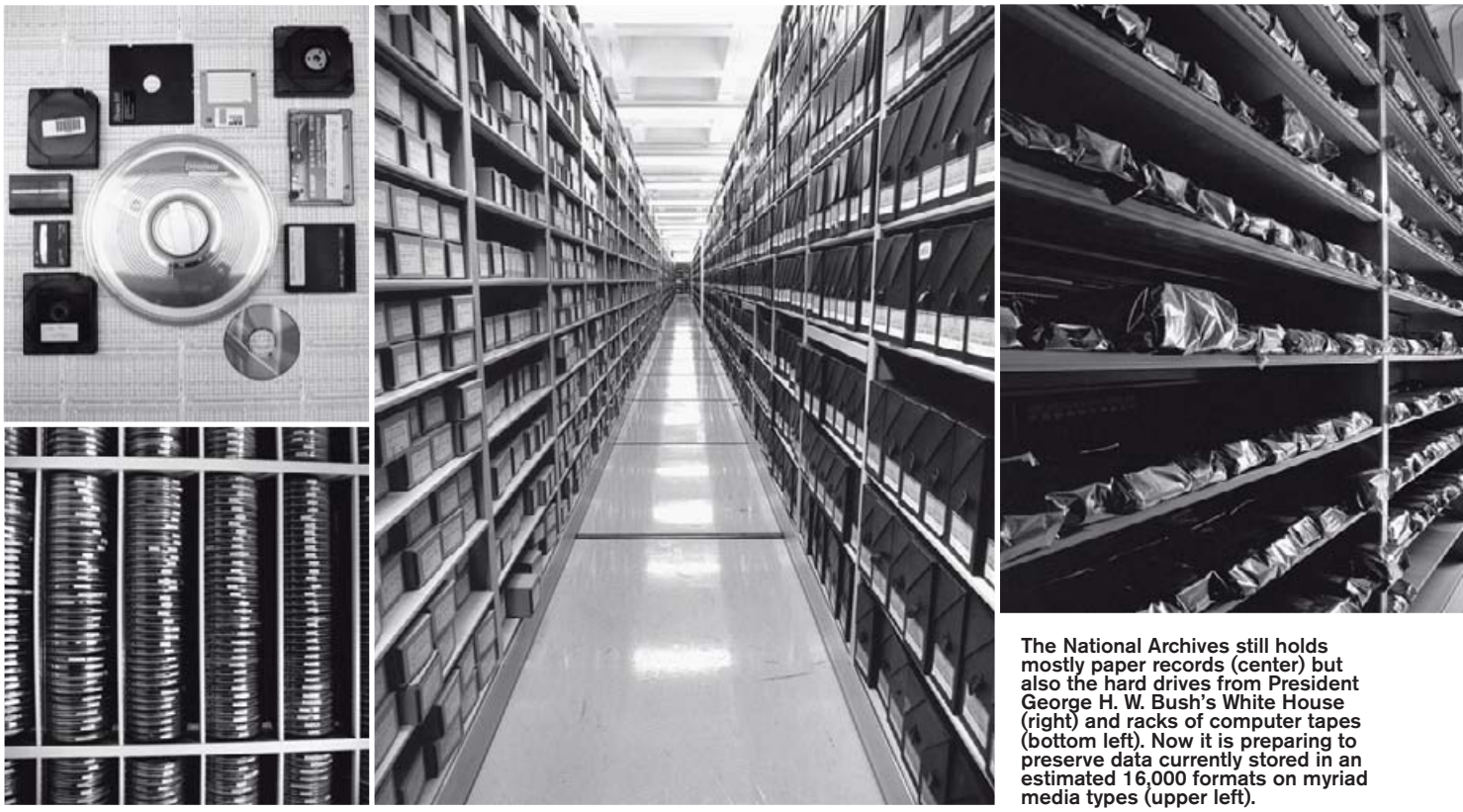
Gigabyte
1,024 megabytes. Roughly 100 minutes of CD-quality stereo sound.

Terabyte
1,024 gigabytes. Half of the content in an academic research library.

Petabyte
1,024 terabytes. Half of the content in all U.S. academic research libraries.

Exabyte
1,024 petabytes. Half of all the information generated in 1999.

SOURCE: UNIVERSITY OF CALIFORNIA, BERKELEY



The National Archives still holds mostly paper records (center) but also the hard drives from President George H. W. Bush's White House (right) and racks of computer tapes (bottom left). Now it is preparing to preserve data currently stored in an estimated 16,000 formats on myriad media types (upper left).

Still, NARA's problem stands out because of the sheer volume of the records the U.S. government produces and receives, and the diversity of digital technologies they represent. "We operate on the premise that somewhere in the government they are using every software program that has ever been sold, and some that were never sold because they were developed for the government," says Ken Thibodeau, director of the Archives' electronic-records program. The scope of the problem, he adds, is "unlimited, and it's open ended, because the formats keep changing."

The Archives faces more than a Babel of formats; the electronic records it will eventually inherit are piling up at an ever accelerating pace. A taste: the Pentagon generates tens of millions of images from personnel files each year; the Clinton White House generated 38 million e-mail messages (and the current Bush White House is expected to generate triple that number); and the 2000 census returns were converted into more than 600 million TIFF-format image files, some 40 terabytes of data. A single patent application can contain a million pages, plus complex files like 3-D models of proteins or CAD drawings of aircraft parts. All told, NARA expects to receive 347 petabytes *(see definitions on the previous page)* of electronic records by 2022 .

Currently, the Archives holds only a trivial number of electronic records. Stored on steel racks in NARA's 11-year-old facility in College Park, the digital collection adds up to just five terabytes. Most of it consists of magnetic tapes of varying ages, many of them holding a mere 200 megabytes apiece—about the size of 10 high-resolution digital photographs. (The electronic holdings include such historical gems as records of military psychological-operations squads in Vietnam from 1970 to 1973, and interviews, diaries, and testimony collected by the U.S. Department of Justice's Watergate Special Prosecution Force from 1973 to 1977.) From this modest collection, only a tiny number of visitors ever seek to copy data; little is available over the Internet.

Because the Archives has no good system for taking in more data, a tremendous backlog has built up. Census records, service records, Pentagon records of Iraq War decision-making, diplomatic messages—all sit in limbo at federal departments or in temporary record-holding centers around the country. A new avalanche of records from the Bush administration—the most electronic presidency yet—will descend in three and a half years, when the president leaves office. Leaving records sitting around at federal agencies for years, or decades, worked fine when everything was on paper, but data bits are nowhere near as reliable—and storing them means paying not just for the storage media, but for a sophisticated management system and extensive IT staff.

Data under the Desk

The good news is that at least some of the rocket science behind the Archives' "moon shot" is already being developed by industry, other U.S. government agencies, and foreign governments. For example, Hewlett-Packard, IBM, EMC, PolyServe, and other companies have developed "virtual storage" technologies that automatically spread terabytes of related data across many storage devices, often of different types. Virtualization frees up IT staff, balances loads when demand for the data spikes, and allows hardware upgrades to be carried out without downtime. Although the Archives will need technologies far beyond virtual storage, the commercial efforts form a practical foundation. The Archives may also benefit from the examples of digital archives set up in other nations, such as Australia, where archivists are using open-source software called XENA (for XML Electronic Normalizing of Archives) to convert records into a standardized format that will, theoretically, be readable by future technologies. NARA will also follow the lead of the U.S. Library of Congress, which in recent years has begun digitizing collections

ranging from early American sheet music to immigration photographs and putting them online, as part of a $100 million digital preservation program.

But to extend the technology beyond such commercial and government efforts, NARA and the National Science Foundation are funding research at places like the San Diego Supercomputer Center. There, researchers are, among other things, learning how to extract data from old formats rapidly and make them useful in modern ones. For example, San Diego researchers took a collection of data on airdrops during the Vietnam War—everything from the defoliant Agent Orange to pamphlets—and reformatted it so it could be displayed using nonproprietary versions of digital-mapping programs known as geographic information systems, or GIS *(see "Do Maps Have Morals?" June 2005)*. Similarly, they took lists of Vietnam War casualties and put them in a database that can show how they changed over the years, as names were added or removed. These are the kinds of problems NARA will face as it "ingests" digital collections, researchers say. "NARA's problem is they will be receiving massive amounts of digital information in the future, and they need technologies that will help them import that data into their ERA—hundreds of millions of items, hundreds of terabytes of data," says Reagan Moore, director of data-knowledge computing at the San Diego center.

Another hive of research activity on massive data repositories: MIT. Just as the government is losing its grip on administrative, military, and diplomatic history, institutions like MIT are losing their hold on research data—including the early studies and communications that led to the creation of the Internet itself. "MIT is a microcosm of the problems [NARA] has every day," says MacKenzie Smith, the associate director for technology at MIT Libraries. "The faculty members are keeping their research under their desks, on lots and lots of disks, and praying that nothing happens to it. We have a long way to go."

Now MIT is giving faculty another place to put that data. Researchers can log onto the Internet and upload information—whether text, audio, video, images, or experimental data sets—into DSpace, a storage system created in collaboration with Hewlett-Packard and launched in 2002 *(see "MIT's DSpace Explained," p. 50)*. DSpace makes two identical copies of all data, catalogues relevant information about the data (what archivists call "metadata," such as the author and creation date), and gives each file a URL or Web address. This address won't change even if, say, the archivist later wants to put a given file into a newer format—exporting the contents of an old Word document into a PDF file, for instance. Indeed, an optional feature in DSpace will tell researchers which files are ready for such "migration."

Because the software behind DSpace is open source, it is available for other institutions to adapt to their own digital-archiving needs; scores have already done so. Researchers at MIT and elsewhere are working on improvements such as an auditing feature that would verify that a file hasn't been corrupted or tampered with, and a system that checks accuracy when a file migrates into a new format. Ann Wolpert, the director of MIT Libraries (and chair of *Technology Review*'s board of directors), says DSpace is just a small step toward tackling MIT's problems, never mind NARA's. "These changes have come to MIT and other institutions so rapidly that we didn't have the technology to deal with it," Wolpert says. "The technology solutions are still emerging." Robert Tansley, a Hewlett-Packard research scientist who worked on DSpace, says the system is a good start but cautions that "it is still quite new. It hasn't been tested or deployed at a massive scale, so there would need to be some work before it could support what the National Archives is looking at."

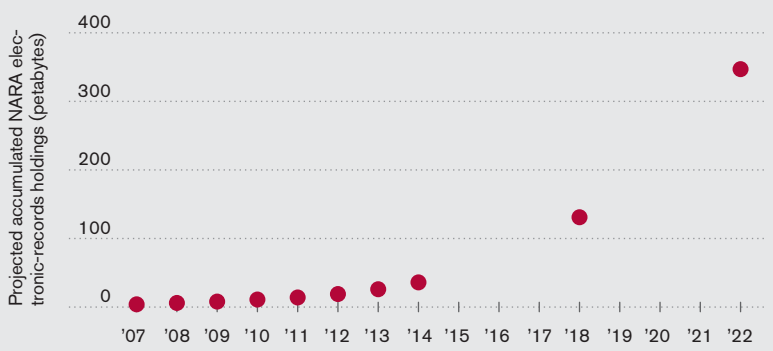
Digital Marginalia

But for all this promise, NARA faces many problems that researchers haven't even begun to think about. Consider Weinstein's discovery of the Hoover marginalia. How could such a tidbit be preserved today? And how can any organization that needs to track information—where it goes, who uses it, and how it's modified along the way—capture those bit streams and keep them as safe as older paper records? Saving the text of e-mail messages is technically easy; the challenge lies in managing a vast volume and saving only what's relevant. It's important, for example, to save the e-mails of major figures like cabinet members and White House personnel without also bequeathing to history trivial messages in which mid-level bureaucrats make lunch arrangements. The filtering problem gets harder as the e-mails pile up. "If you have 300 or 400 million of anything, the first thing you need is a rigorous technology that can deal with that volume and scale," says Chadduck. More and more e-mails come with attachments, so NARA will ultimately need a system that can handle any type of attached file.

Version tracking is another headache. In an earlier era, scribbled cross-outs and margin notes on draft speeches were a boon to understanding the thinking of presidents and other public officials. To see all the features of a given Microsoft Word document, such as tracked changes, it's best to open the document using the same version of Word that the document's creator used. This means that future researchers will need not only a new piece of metadata—what software version was used—but perhaps even the software itself, in order to re-create fonts and other formatting details

Plethora of Petabytes

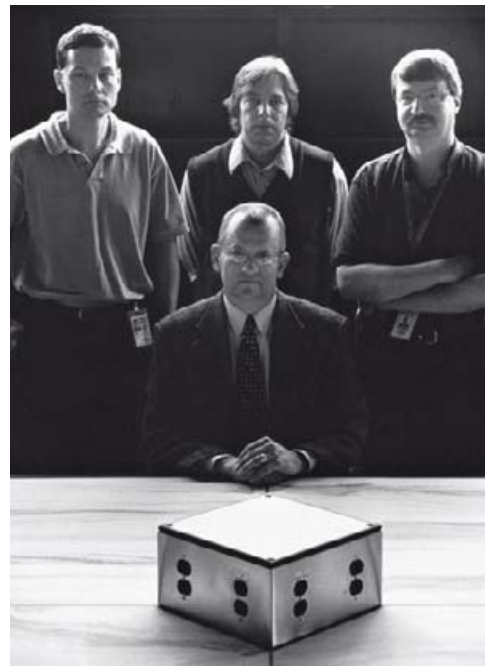
By 2022, NARA is expected to be responsible for 347 petabytes of electronic records.



SOURCE: U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

faithfully. But saving the functionality of software—from desktop programs like Word to the software NASA used to test a virtual-reality model of the Mars Global Surveyor, for example—is a key research problem. And not all software keeps track of how it was actually used. Why might this matter? Consider the 1999 U.S. bombing of the Chinese embassy in Belgrade. U.S. officials blamed the error on outdated maps used in targeting. But how would a future historian probe a comparable matter—to check the official story, for example—when decision-making occurred in a digital context? Today's planners would open a map generated by GIS software, zoom in on a particular region, pan across to another site, run a calculation about the topography or other features, and make a targeting decision.

If a historian wanted to review these steps, he or she would need information on how the GIS map was used. But "currently there are no computer science tools that would allow you to reconstruct how computers were used in high-confidence decision-making scenarios," says Peter Bajcsy, a computer scientist at the University of Illinois at Urbana-Champaign. "You might or might not have the same hardware, okay, or the same version of the software in 10 or 20 years. But you would still like to know what data sets were viewed and processed, the methods used for processing, and what the decision was based on." That way, to stay with the Chinese embassy example, a future historian might be able to independently assess whether the database about the embassy was obsolete, or whether the fighter pilot who dropped the bomb had the right information before he took off. Producing such data is just a research proposal of Bajcsy's. NARA says that if such data is collected in the future, the agency will add it to the list of things needing preservation.



Robert Chadduck (seated), research director for the National Archives' electronic-records program, with (from left) researchers Richard Lopez, Michael Skipper, and Mark Conrad

Data Curators

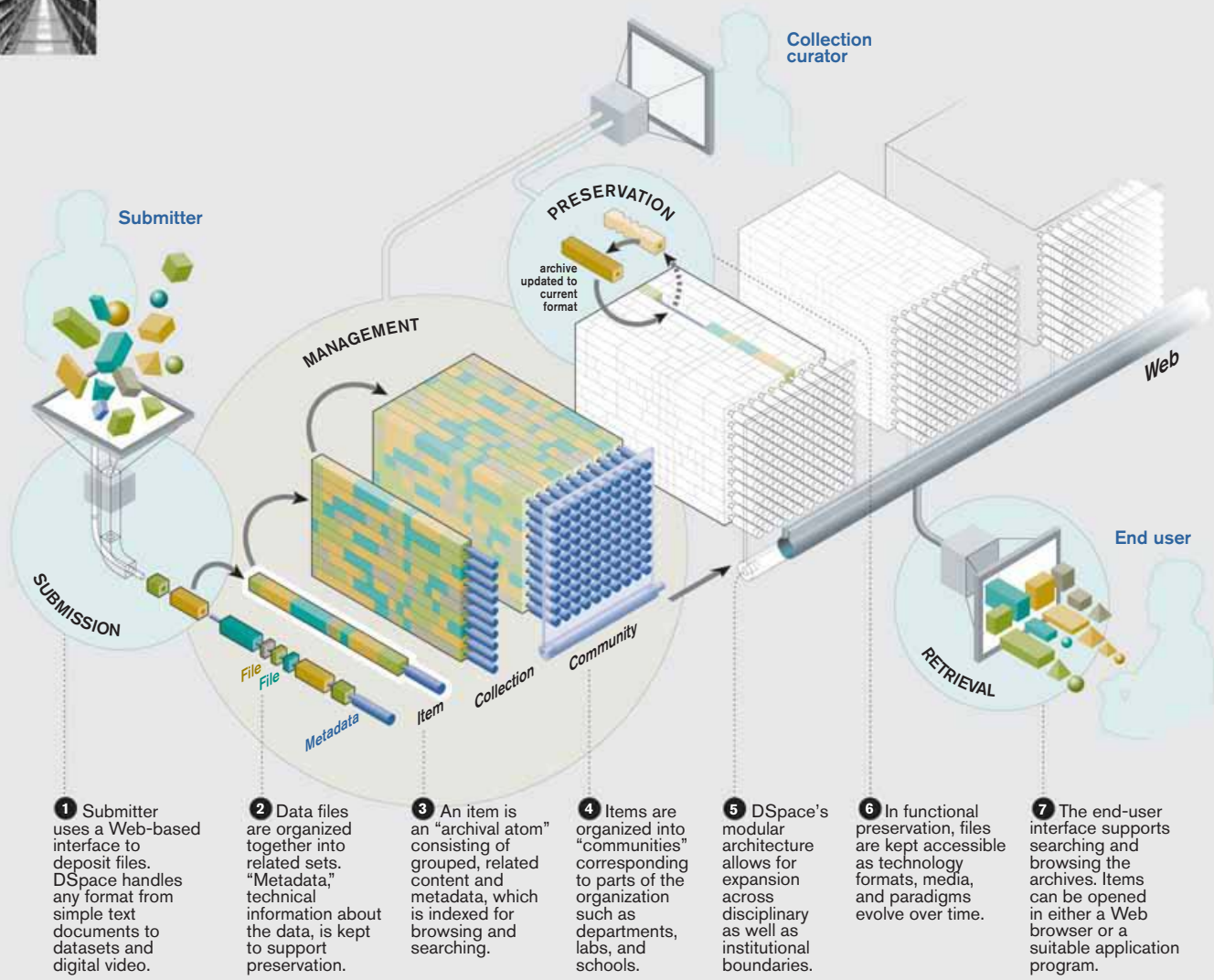
Even without tackling problems like this, NARA has its hands full. For three years, at NARA's request, a National Academy of Sciences panel has been advising the agency on its electronic-records program. The panel's chairman, computer scientist Robert F. Sproull of Sun Microsystems Laboratories in Burlington, MA, says he has urged NARA officials to scale back their ambitions for the ERA, at least at the start. "They are going to the all-singing, all-dancing solution rather than an incremental approach," Sproull says. "There are a few dozen formats that would cover most of what [NARA] has to do. They should get on with it. Make choices, encourage people submitting records to choose formats, and get on with it. If you become obsessed with getting *the* technical solution, you will never build an archive." Sproull counsels pragmatism above all. He points to Google as an example of how to deploy a workable solution that satisfies most information-gathering needs for most of the millions of people who use it. "What Google says is, 'We'll take all comers, and use best efforts. It means we won't find everything, but it does mean we can cope with all the data,'" Sproull says. Google is not an archive, he notes, but in the Google spirit, NARA should attack the problem in a practical manner. That would mean starting with the few dozen formats that are most common, using whatever off-the-shelf archiving technologies will likely emerge over the next few years. But this kind of preservation-by-triage may not be an option, says NARA's Thibodeau. "NARA does not have discretion to refuse to preserve a format," he says. "It is inconceivable to me that a court would approve of a decision not to preserve e-mail attachments, which often contain the main substance of the communication, because it's not in a format NARA chose to preserve."

Meanwhile, the data keep rolling in. After the 9/11 Commission issued its report on the attacks on the World Trade Center and the Pentagon, for example, it shut down and consigned all its records to NARA. A good deal of paper, along with 1.2 terabytes of digital information on computer hard disks and servers, was wheeled into NARA's College Park facility, where it sits behind a door monitored by a video camera and secured with a black combination lock. Most of the data, which consist largely of word-processing files and e-mails and their attachments, are sealed by law until January 2, 2009. They will probably survive that long without heroic preservation efforts. But "there's every reason to say that in 25 years, you won't be able to read this stuff," warns Thibodeau. "Our present will never become anybody's past."

It doesn't have to be that way. Projects like DSpace are already dealing with the problem. Industry will provide a growing range of partial solutions, and researchers will continue to fill in the blanks. But clearly, in the decades to come, archives such as NARA will need to be staffed by a new kind of professional, an expert with the historian's eye of an Allen Weinstein but a computer scientist's understanding of storage technologies and a librarian's fluency with metadata. "We will have to create a new profession of 'data curator'—a combination of scientist (or other data specialist), statistician, and information expert," says MacKenzie Smith of the MIT Libraries.

The nation's founding documents are preserved for the ages in their bath of argon gas. But in another 230 years or so, what of today's electronic records will survive? With any luck, the warnings from air force historian Mark and NARA's Thibodeau will be heeded. And historians and citizens alike will be able to go online and find that NARA made it to the moon, after all. ■

David Talbot is Technology Review*'s chief correspondent.*



1 Submitter uses a Web-based interface to deposit files. DSpace handles any format from simple text documents to datasets and digital video.

2 Data files are organized together into related sets. "Metadata," technical information about the data, is kept to support preservation.

3 An item is an "archival atom" consisting of grouped, related content and metadata, which is indexed for browsing and searching.

4 Items are organized into "communities" corresponding to parts of the organization such as departments, labs, and schools.

5 DSpace's modular architecture allows for expansion across disciplinary as well as institutional boundaries.

6 In functional preservation, files are kept accessible as technology formats, media, and paradigms evolve over time.

7 The end-user interface supports searching and browsing the archives. Items can be opened in either a Web browser or a suitable application program.

MIT's DSpace Explained

Electronic repositories stretch to meet scholars' needs.

IN 1978, LOREN KOHNFELDER invented digital certificates while working on his MIT undergraduate thesis. Today, digital certificates are widely used to distribute the public keys that are the basis of the Internet's encryption system. This is important stuff! But when I tried to find an online copy of Kohnfelder's 1978 manuscript, I came up blank. According to the MIT Libraries' catalog, there were just two copies in the system: a microfiche somewhere in Barker Engineering Library, and a "noncirculating" copy in the Institute Archives.

Google couldn't find anything. Nor could CiteSeer, an online database of scholarly papers in computer science. Finally I found an e-mail address for Kohnfelder himself in MIT's online alumni database. A few hours later, he informed me that a scanned copy of his thesis could be downloaded from the website theses.mit.edu. And as it turns out, a copy of Kohnfelder's thesis has also been entered into DSpace, the big digital-repository project that MIT Libraries and Hewlett-Packard started back in 2002. *That* copy is indexed by Google Scholar, Google's academic search engine. But I hadn't thought to check there.

DSpace is a long-term, searchable digital archive. It creates unchanging URLs for stored materials and automatically backs up one institution's archives to another's. Today, DSpace is being used by 79 institutions, with more on the way. But as my little story about Kohnfelder's thesis demonstrates, archiving data is only half the problem. In order to be useful, archives must also enable researchers to find what they are looking for. Sending e-mail to the author worked for me, but it's not a good solution for the masses.

Long-term funding is another problem that DSpace needs to solve. "The libraries are seeking ways of stabilizing support for DSpace to make it easier to sustain as it gets bigger over time," says MacKenzie Smith, the Libraries' associate director for technology. Today, development on the DSpace system is funded by short-term grants. That's great for doing research, but it's not a good model for a facility that's destined to be the long-term memory of the Institute's research output. Says Smith: "We need to know how to support an operation like this in very lean times."

Simson Garfinkel

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Discovering why so many people on a small island in Micronesia are overweight could help explain the genetics of obesity.

Wired to Eat

By David Ewing Duncan

MADISON "MAD" NENA nibbles on a tangerine picked from his garden on Kosrae, a tiny volcanic island in the Pacific Ocean some 4,670 kilometers southwest of Hawaii. The 53-year-old Nena is a rarity here. He's thin in a place where fatty, sugary foods imported from the United States have caused an alarming number of people to inflate like dirigibles; obesity-related diseases such as diabetes and heart disease have struck the island's 7,600 residents hard. Why Nena has stayed thin, and others have not, has drawn American researchers from Rockefeller University in New York City to this 109-square-kilometer patch of jungles, white beaches, mangrove swamps, and quiet villages for more than a decade, in a quest to tease out the genetic and molecular mechanisms of why humans are compelled to eat. And sometimes to eat and eat, far beyond what is healthy.

The Rockefeller team suspects that the proclivity of a person's body to approach a certain weight is determined far more by genes than was previously thought—specifically, genes that control the impulse to eat. Growing evidence indicates that an indi-

Photographs by Steven Oxenbury

vidual's weight is 40 to 70 percent decided by genes, which makes it about as heritable as height. (Height, however, is determined during infancy and childhood, whereas weight can continue to fluctuate throughout life.) Some people appear to be hardwired to be particularly ravenous. When access to food is unlimited, say hunger-gene experts, these people can will themselves to eat less, but their efforts will almost inevitably be overridden by the far more powerful force of genetics.

If true, this is not good news for many Kosraeans, or for anyone else unlucky enough to have the genes that compel him to gobble a second baked potato. "We have to realize that obesity is a disease, like cancer, that people have less control over than most of us think," says Jeffrey Friedman, an obesity researcher and leader of the Rockefeller team.

Not everyone buys this, of course. Those in the diet industry and many nutritionists make their living on the contention that people can readily choose to reduce calories and to stay thin. "There are too many cases where people have willed themselves to lose substantial amounts of weight and keep it off," says nutrition expert Marion Nestle of New York University.

Teasing out which perspective is right—or whether, as seems likely, obesity is a complex interaction of both genetics and lifestyle—will help determine our attitudes not only toward fat people but toward the effectiveness of dieting. Globally, more than one billion people are overweight, and that number is growing fast. Between 1991 and 2000, the average weight of Americans swelled by 10 pounds. The 1999–2000 U.S. National Health and Nutrition Examination Survey found that 64 percent of American adults are overweight or obese. Britain, Germany, and other Western countries are not far behind. Neither are developing countries that are rapidly modernizing, where diseases associated with obesity are increasing.

On Kosrae, more than 80 percent of adults are overweight or obese, and diabetes afflicts one in eight adults. Until the United States took control of Kosrae and the rest of Micronesia after World War II and began shipping in canned and processed foods, the people were predominately lean, eating fish, bananas, coconuts, and taro. For centuries before the arrival of the first European ship in 1824, the elites ate well. But most islanders lived a near-subsistence life, suffering through frequent droughts and stormy seasons that decimated crops. And they stayed thin.

The exact molecular mechanisms behind the rapid onset of obesity among island residents in this new dietary environment are still uncertain—and are the mystery that the Rockefeller researchers are intent on solving. Are many of the islanders genetically predisposed to large appetites, which, once food was plentiful, they were suddenly able to satisfy? Or as NYU's Nestle and Kosrae health officials maintain, is it simply a case of a population's sudden shift to an unhealthy lifestyle, which might be corrected by cutting down on frosted flakes and Spam? Kosrae's genetically isolated population and its abrupt changes in eating habits make it almost the perfect place to examine such issues.

"The local food is high in fiber and balanced in minerals," says Vita Skilling, who runs the public-health outreach program on the island. "But now it's so easy to get refined flour and refined sugar. It's also how we [now] prepare food. We take fresh bananas and we fry them with sugar." Skilling says that cars and a newly paved road ringing most of the island mean that few people walk as much as they used to. "We have plenty of food all the time," she says. "We don't exercise, because it wasn't the thing to exercise—that was work."

Christina and Madison Nena

On Kosrae, crates full of goods and canned and processed foods arrive regularly in a container ship from overseas. The supplies are paid for mostly by the salaries and assistance that a large U.S. grant to Micronesia—part of a compact agreed to as part of Micronesian independence in 1986—provides each year.

I see this Western bounty in Thurston's, a general store in the town of Lelu. Cooled by a massive fan, the cavernous store displays rows of canned and packaged foods familiar to Americans: pork and beans, canned peas, soft drinks, and Spam. Tails of turkey and chicken—the fatty portion at the rump—are also popular. The store sells a smaller stock of homegrown produce in a stall in front: bananas, taro, limes, and tangerines.

Skilling takes me on a tour of the island's 40-bed hospital, built in 1978 on a hill below a jagged volcano. Dozens of people wait in the dark, humid halls to have their blood pressure taken and their blood tested for glucose and other indicators of diabetes and hypertension. Others wait in line at the small air-conditioned pharmacy for insulin and other medications. "Most of the admissions for adults, other than day-to-day minor trauma, are really to do with complications from diabetes and hypertension," says Skilling. She says the hospital might perform several amputations a month and treats patients with heart disease, eye problems, kidney failure, and other diseases associated with diabetes and obesity. "I was told that 70 percent of the admissions to the surgical unit are due to complications from diabetes," she says.

The Gene Hunters Arrive

In the summer of 1994, Rockefeller biomedical researchers first arrived on Kosrae, led by Friedman, director of the university's Starr Center for Human Genetics. The group set out to measure islanders' weight, height, and waist size; to collect information on the history of family diseases; and to perform a battery of tests, including measurements of cholesterol levels, blood sugar levels, and blood pressure.

In addition to finding that more than half of Kosraean adults were obese and 88 percent were overweight, the Rockefeller study also found that about 12 percent of the adult population had diabetes, compared with 8 percent in the United States. About 17 percent had hypertension, and 20 percent had high cholesterol. These rates are lower than those found in the United States, but they represent health problems that until recently were rare in Kosrae and the rest of the developing world. In a second round of tests, in 2001, the researchers also drew blood to be frozen and shipped back to New York, where they could extract the islanders' DNA to search for genes for obesity, heart disease, and diabetes.

The Rockefeller team chose Kosrae for its isolation, and because most of its people are descended from just a few families. The first Polynesians arrived 2,000 years ago. In the mid-19th century, European diseases and abuse reduced the islanders' numbers from several thousand to about 300. Having just a few genetic lineages on the island means that each person's genomic makeup is far more similar to his or her compatriots' than, say, an American's would be. "Looking for a gene is like searching for a needle in a haystack," says Friedman. "On Kosrae, the small gene pool makes the haystack smaller."

Friedman believes the Kosraeans' ballooning weight is a manifestation of what geneticist James Neel in 1962 dubbed the "thrifty gene" theory. Neel posited that in an environment prone to famine, hunter-gatherers gained a selective advantage if their genes predisposed them to storing fat when food was available. Those with such "thrifty genes" were more likely to survive famines and pass on their genes. But in modern times, the thrifty gene has proved a liability. The theory also posits that people who lived in early agricultural societies, such as those in the Fertile Crescent in the Middle East, had a steady supply of food from plants and domesticated animals and thus didn't need to store fat. So in our world today, people with lean genes are protected from obesity, and those with fat genes are at the mercy of DNA.

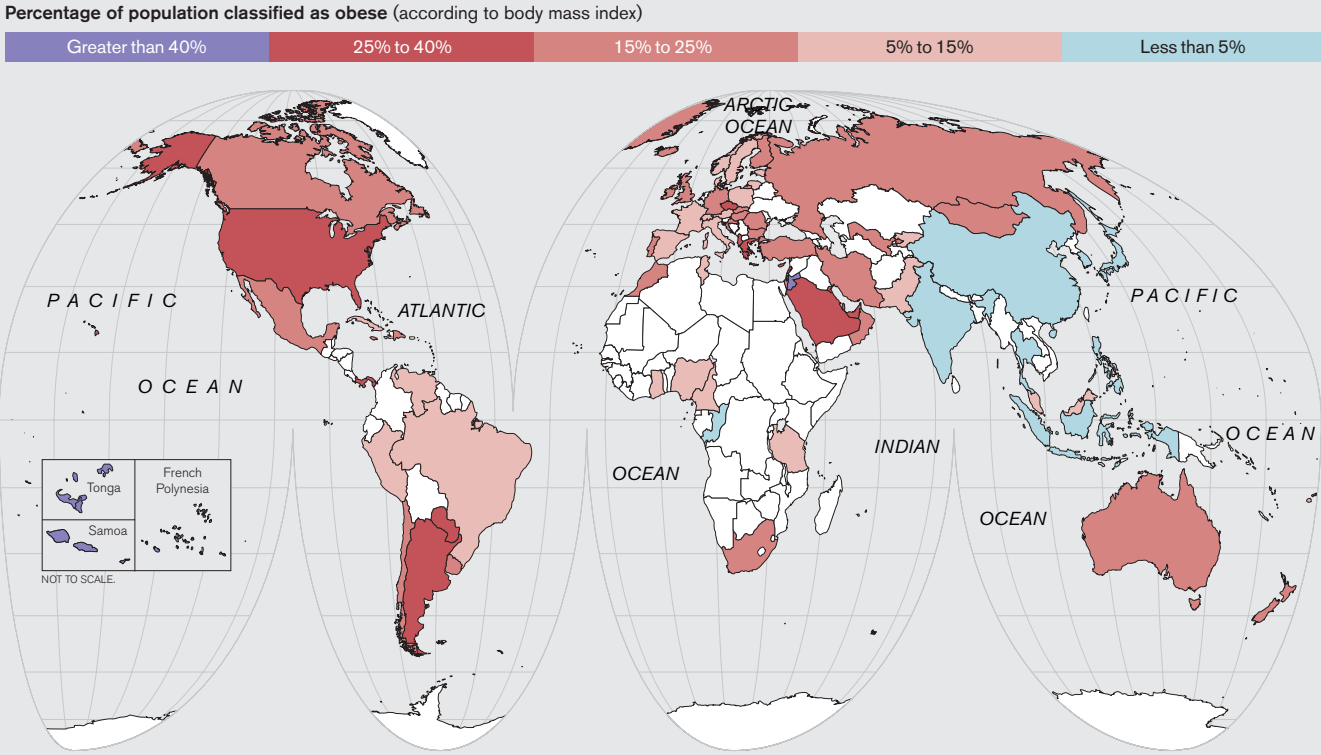
Friedman's search through the Kosraeans' genes recently became more precise with the use of a gene chip from Affymetrix, a Santa Clara, CA–based company. Researchers can use chips like Affymetrix's to scan genomes for differences in individual base pairs at specific locations—variations known as single-nucleotide polymorphisms (SNPs)—which can then be associated with differences in susceptibility to diseases such as obesity or diabetes. Friedman's team has joined with Affymetrix to run one of the first large-scale, genome-wide association studies, using the company's new 100,000-SNP chip to begin to analyze genetic differences among Kosraeans. This is a vast improvement over earlier chips that scanned 6,500 SNPs, according to Greg Yap, vice president of marketing at Affymetrix. "With the 100K chip, we get a much higher resolution across phenotypes," he says. "It's like GPS. Before, we could only see select parts of the world in a general way; now, you get great resolution in lots of places."

The gene-hunting effort is conducted in collaboration with a team at the Broad Institute, MIT and Harvard University's jointly operated center for genomic medicine. Led by David Altshuler, Broad's director of medical and population genetics, the researchers are about halfway through the SNP scanning process for the 2,000 Kosraean adults. The goal is to identify a library of SNPs that seem to correlate with the islanders' dispositions to be fat or lean. The researchers also hope to pinpoint patterns in the SNPs that will help support or refute the thrifty-gene theory.

Already, says Friedman, the preliminary data are pointing away from one of his theories—that the lean people on Kosrae are descendants of Caucasians with Fertile Crescent genes who mated with locals who had thrifty genes. "Early evidence sug-

A Growing Globe

Several Pacific Island nations, as well as some Middle Eastern countries and the United States, are among the most obese nations in the world.



DATA IS UNAVAILABLE FOR COUNTRIES COLORED WHITE. MOST DATA IS FROM 2000 OR LATER; A FEW COUNTRIES HAVE DATA FROM 1994–1999. BODY MASS INDEX (BMI) IS WEIGHT IN KILOGRAMS DIVIDED BY THE SQUARE OF HEIGHT IN METERS; OBESITY IS DEFINED AS HAVING A BMI OF 30 OR HIGHER. SOURCE: INTERNATIONAL OBESITY TASK FORCE



Vita Skilling (left), a health-care worker on Kosrae, regularly treats health problems caused by diabetes.

gests that there are fewer Caucasian genes than we thought," explains Friedman. One possible explanation is that the genetics of something as important as appetite and eating would exhibit a great deal of diversity; that would guarantee that a population could adapt readily to different environmental conditions. In other words, the thrifty-gene theory might hold true even within a small, isolated population. "We'll be studying this more thoroughly in the coming months, looking for an explanation," says Friedman.

A Hunger 'Set Point'

Dishes of jelly beans and peanuts sit in the office reception room of Friedman's lab at Rockefeller University in New York. I try not to take a yellow jelly bean, my favorite, making myself grab a handful of peanuts instead. Tall and lanky with a graying beard and glasses, wearing gray-green corduroys and a flannel shirt, Friedman takes a couple of red jelly beans, which his assistant buys by the bagful. As we talk, my eyes keep wandering to the jelly beans. Later, I can't help myself: I grab a few as we leave for lunch. I ask Friedman if the candy and peanut bowls are a test. He says no, though this is the core of his quest: determining how a person decides to eat or not to eat at a given moment in time. "Eating is binary," he says. "We either do it, or we don't. But where in the brain is this decision made, and what is the input that makes the decision?"

Several areas of the brain feed into this decision—behavioral and decision-making centers in the cerebral cortex, for instance, and the regions that process sensory input. But all of these, says Friedman, are trumped by the mechanism that drives organisms to eat. It is centered in the hypothalamus at the base of the brain, where two types of neurons appear to be the chief regulators of appetite. They tell us when we're hungry and when we're not. The so-called NPY neuron stimulates hunger, and the POMC inhibits it, each neuron turned up or down by chemicals that wash over them. "A dominant factor in controlling weight is this basic neural circuit," says Friedman. The chief chemical is leptin, a hormone produced by fat cells in the belly. As people put on the pounds, fat cells increase the levels of leptin, which tells the POMC neuron to suppress appetite. In times of privation—or dieting—body fat is reduced, which decreases the levels of leptin. Less leptin mean the POMC turns down and the NPY neuron predominates, which ramps up hunger in people. Other chemicals—fats, sugars, and neural transmitters—also influence the actions of these neurons, but leptin seems to be the key.

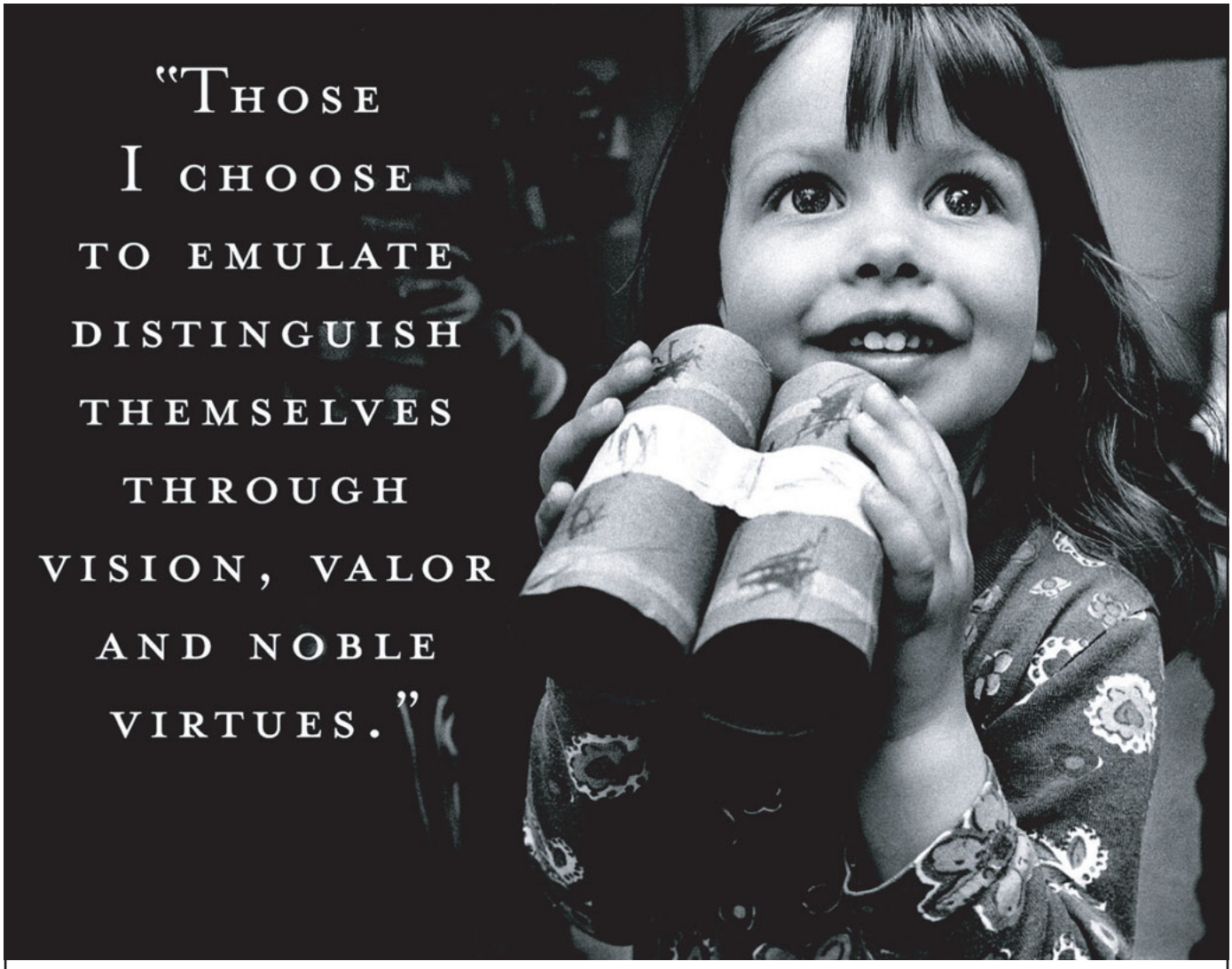
"Looking for a gene is like searching for a needle in a haystack.... On Kosrae, the small gene pool makes the haystack smaller."

Friedman is famous for his 1994 discovery of the gene that codes for leptin. For a brief moment in the mid-1990s, leptin seemed to be a potential wonder cure for obesity, when Friedman and others showed that a mutation affecting the leptin gene caused morbid obesity in mice and humans. But leptin injections work for only a small percentage of the obese. It turns out that the majority do produce leptin, though their bodies actually resist the effects of the hormone by blocking its ability to turn up the hunger-suppressing action of the POMC neuron. So their appetites remain large, and they keep eating—and gaining weight—until they reach the point at which the resistance stops. Where that point lies, Friedman believes, is determined by genetic makeup.

Why leptin resistance occurs in some people is poorly understood, Friedman says. It may be a relic of the thrifty-gene response, ramping up appetite in those whose ancestors lacked adequate food. The Rockefeller team measured leptin levels in the Kosraean population; Friedman is using that data to help correlate leptin resistance with genes that might be responsible for it. According to Friedman, each of us has a "set point" of hunger and satiation, which we inherited from our individual forebears. We are born with this setting, and we are driven to keep eating until we reach it.

Friedman's "blame the genes" hypothesis flies in the face of arguments mounted by nutritionists and the diet industry, and of the popular belief that eating habits—grabbing a handful of jelly beans, for instance—can be controlled through willpower. "We have some control over eating from our reasoning centers of our brain," says Friedman, "but this seldom overrides our basic instinct to eat when we're hungry." Friedman advocates an entirely new way of thinking about fat, saying it's pointless to tell most obese people that they can lose dramatic amounts of weight by force of will. "Obesity is a disease," he insists, comparing current attitudes to those once associated with ulcers and cancer. "Because it's largely genetic, and the drive to eat largely beyond our control, we should be sympathetic, not judgmental."

When I ask him whether more Big Macs are at least partly to blame, Friedman says, "Diets are important for heart disease and overall health, but there is no evidence that types of food affect obesity." Some people are just programmed to eat more, he says, and high-calorie fast foods simply allow them to do so quickly—and therefore cause a faster weight gain.



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Kosraean stores sell high-fat meats.

10,000-Step Program

On Kosrae, Skilling is skeptical that people have so little control over their weight. The Rockefeller study, she says, was an eye-opener for islanders, who didn't realize what was happening to them. The islanders were also subjected to something quite unexpected when results of the 1994 study were published in 2000: a mini media blitz that portrayed Kosrae as a land of fatties. The *Atlantic* published an article called "New World Syndrome," whose introductory blurb declared, "Spam and turkey tails have turned Micronesians into Macronesians."

"It is unfair," says Skilling. "You really have to come out and see. If you are just looking at the study files, you might think these people are really unhealthy, but you come out here and you see it's not so bad." But media scrutiny has also spurred many islanders to improve their diets and exercise more. "Ironically, this media attention may save us," says Skilling.

Nena has adopted a back-to-nature gambit to improve the diet of his family. "I have banned turkey tails from my house," he says, walking through his garden of breadfruit, tangerines, limes, and taro root. "We eat almost nothing from cans." Some years ago he learned that his wife, Christina, who was overweight, was an early-stage diabetic. "This was shocking to us. We had not thought of eating or what we ate as something bad." Soon after, he and his sons began expanding their garden, creating arable land from a patch of jungle above a mangrove swamp and a beach on a shore that even on this remote island is isolated. Christina emerges from the house, a short, typically stocky Polynesian woman wearing one of the ubiquitous loose-fitting dresses in colorful floral patterns introduced by the missionaries in the 19th century. Nena and Christina tell me that since changing their diet and exercising more, they feel better. "I wake up at dawn and walk and work in my garden," says Nena. "Before, I got tired more easily." Christina has slimmed down, too, he says, but she still has a mild form of diabetes. They show me a shrub that Nena says is a local remedy for diabetes: noni, or the Indian mulberry, whose fruit works better than Western drugs, they say.

Skilling says the island has launched a campaign to promote exercise. It has issued bumper stickers that ask, "Have you walked 10,000 steps today?" The Kosraean government, with grants from the U.S. government and money from Rockefeller University, has launched a public-health project at the island's main hospital and in village clinics to improve awareness of healthy diets and treatment of weight-related maladies.

"I don't force my patients to lose lots of weight," says Skilling. "I try to work with them to lose 20 percent of their excess weight rather than try for the ideal body weight. Even those that want to lose lots of weight on this island have not been able to get to their ideal weight. Is it obtainable to get to an ideal weight? I think it's more attainable to lose 20 percent of their excess fat." The campaign, says Skilling, is beginning to work. "People talk about eating sugar and eating fat and needing to exercise. Now we need a means to implement what we've learned."

Indeed, as I walk and drive around the island, I don't see an unusually high number of fat people, and I see more thin people than I expected. Does this mean that people have slimmed down since the original study in 1994? "We see people are eating more fish," says Skilling. "Many gatherings are now serving local foods, especially church groups. One hundred percent of the island dwellers are churchgoers, so much of the social life is church centered, and the churches are very influential, so this is a real plus." Each of the island's five villages has launched exercise groups. "The last time I counted the registries in three of the villages, we had over 300 people sign up for some sort of exercise," Skilling says. "This is mostly walking. They walk three times a week, in the morning, because it's cooler."

Friedman contends that exercise and better eating will make Kosraeans healthier but probably will not solve the obesity problem. Studies that measure the amount of calories burned during sessions of modest exercise indicate that hungry genes counter even the effects of physical activity. This contradicts a wealth of anecdotal evidence that exercising more slims waistlines, and Friedman concedes that more work is needed to understand the role of exercise in weight gain. But he does believe that the weight increases of the past 20 years in the United States represent a steady progression of people eating enough food to reach their set points, rather than a sudden spike in bad eating habits or more sitting around. What really intrigues Friedman is why everyone doesn't get chubby when there is plenty to eat. Analyses show that the number of lean people has remained steady for the past 30 years, he says. "One's size is not an environmental effect. Nor is it a matter of willpower."

Friedman acknowledges that what he suggests is counterintuitive, since people can resist jelly beans up to a point. But he insists that, for the majority of the obese, free will in weight control is an illusion. "This is a way of thinking that needs to change," he says, suggesting that for the overweight, drugs that modify weight-gain set points may be the only remedy. He says pharmaceutical companies are developing obesity drugs that work by influencing the NYP and POMC neurons or by tweaking chemicals such as leptin that might reduce the hunger impulse.

So who is right? Friedman? Or Nestle and, on Kosrae, Skilling, who believe the island is slimming down through a combination of attitude, change of diet, and exercise? Undoubtedly, both genetics and lifestyle play a role.

But once again, Kosrae could provide valuable clues. "Hopefully, there will be a follow-up," says Skilling of the Rockefeller study, which might reveal if the islanders have really willed themselves to slim down, or if their set points have prevailed. We'll have to wait and see if the fat habit can truly be shaken. If it can't, we need to radically rethink how we view a condition that may be a genetically determined disease that few can control. And we will need to stop treating it as a personal failing—a malady that we can fundamentally fix without pills and other medical interventions, in concert with improved diets and exercise. ■

David Ewing Duncan is a San Francisco–based biotech writer. In March, he wrote about brain chips for Technology Review.

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Its new silicon laser could add decades to Moore's Law.

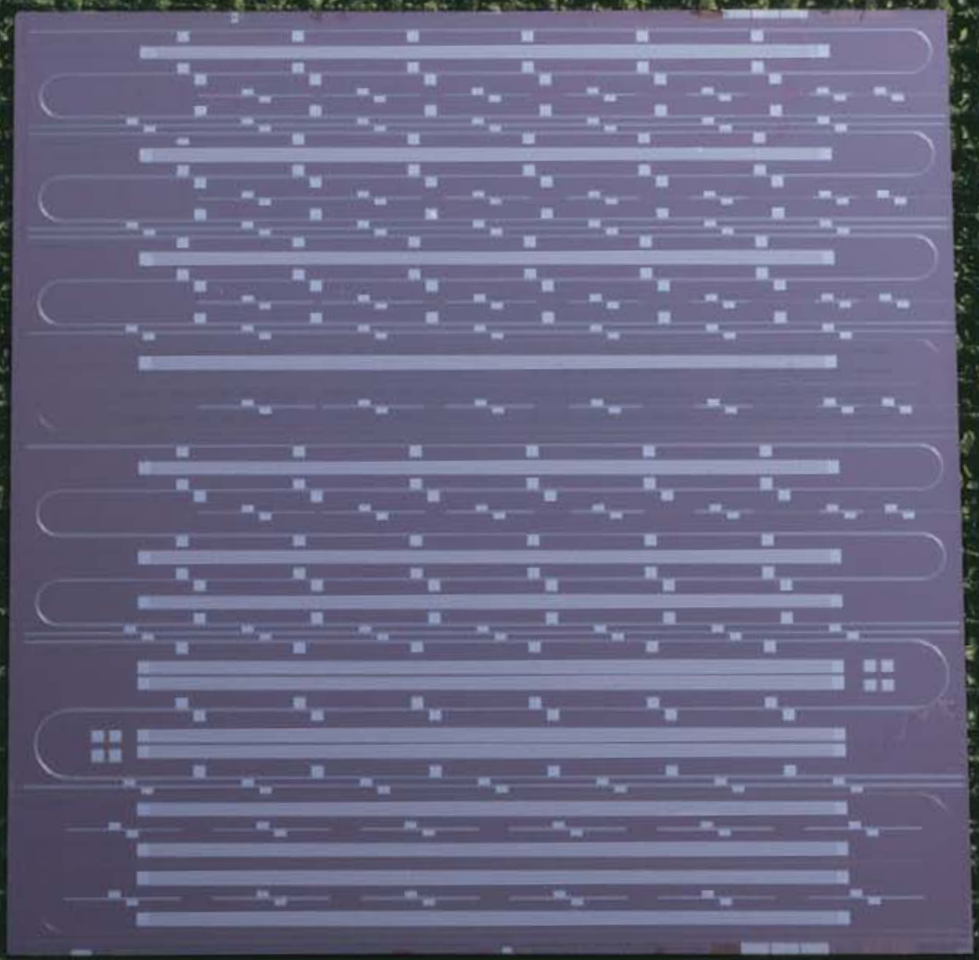
Intel's Breakthrough

By Robert Service

Photographs by Plamen Petkov

MOORE'S LAW, WHICH celebrated its 40th anniversary this spring, has been the semiconductor industry's greatest blessing. In 1965, Intel cofounder Gordon Moore projected that the number of transistors on a computer chip would double every two years. At the time, a chip held just a few dozen transistors. Today, Intel's high-end chip contains more than 1.7 billion transistors, and that number is expected to exceed 10 billion by 2012. This steady four-decade march has fueled the modern computer revolution and made Intel into a tech powerhouse.

But the ability to pack more and more transistors and other circuitry onto chips is exacerbating a host of problems that could, if they become severe enough, threaten the growth of the existing



silicon-based digital economy. Just a few of the trouble areas: heat buildup, electrical currents leaking out of circuits, electrical crosstalk between neighboring wires. The latest CPUs for desktop computers, for example, consume 100 watts of power. Laptop CPUs are generally more efficient, since they're intended to maximize battery life. But even they now consume as much as 75 watts. "It's like putting a toaster on your lap," says Pat Gelsinger, an Intel senior vice president. One fix that is expected to become widespread is to boost the number of transistors on a chip not by making them smaller, but simply by plunking down the same circuit pattern two or more times on the same slab of silicon. Intel released its first such "dual core" chips this spring. And Intel executives envision a future of "many core" chips, with up to a thousand processors side by side.

But there's a rub. The copper wires that convey the stream of digital *1*s and *0*s into and out of a computer, and between processors in some computers, can carry only so much data so quickly. "If I double the performance [of a processor], I need to double the performance on and off the chip," Gelsinger says. "Copper, our traditional interconnect technology, is running out of speed."

The problem is that electrical pulses traveling through a copper wire encounter electrical resistance, which degrades the information they carry. As a result, data bits traveling through copper must be spaced far enough apart and move slowly enough that devices on the other end of the wire can pick them up. This limitation is already producing data traffic jams on local-area networks that use copper wires to connect computers. And many experts predict it will create bottlenecks for data traffic between multiple processors within individual computers. The upshot is that even if Moore's Law continues to hold, computers will no longer be able to take advantage of the increased power it delivers, since they won't be able to move data onto and off chips quickly enough to keep up with the processors. It's a fundamental challenge: computers need to find a faster way to move a vast amount of data both within and between chips.

Enter the silicon laser. Optical connections can carry thousands of times more data per second than copper wires can. But existing optical components, which are made out of such exotic semiconductors as gallium arsenide and indium phosphide, are far too expensive for use in individual computers or even local networks. If you could make optical devices out of silicon, which is cheap and, at least for a company like Intel, easy to manufacture, that would change everything. The move to silicon optics would add a basic new capability to silicon chips: the ability to manipulate and respond to light. Companies would likely exploit that capability first by replacing copper connections with optical links in networks. But eventually, silicon photonics might also replace copper wires between processors within a single chip. Chip designers also envisioned using silicon optics in the internal clocks that microprocessors use to execute instructions, dramatically increasing clock speeds—and thus computing speeds.

Until recently, all that speculation about the potential of silicon optics was hypothetical: suitable silicon lasers didn't exist. But things changed last winter when the lab of Intel scientist Mario Paniccia reported the first continuous all-silicon laser. Built using the same manufacturing methods that produce silicon chips, the experimental device turned out a steady stream of infrared photons, an achievement that many researchers had believed impossible in silicon.

It's still early days for silicon photonics. But the Intel result, which built on findings reported over the past year in a flurry of papers describing advances in silicon-based optical components, is convincing many experts that it could become practical to closely link optical and electronic technology at the computer level. The progress made by Paniccia's team has been remarkable, says Graham Reed, a silicon-photonics pioneer at the University of Surrey in England. "Now all of the skeptics are starting to believe that silicon will have a real impact on optics."

Anticipated advances in silicon technology will almost certainly keep Moore's Law going for the foreseeable future, creating ever faster computers. By speeding immense amounts of data into and out of chips and between machines, silicon photonics could help people access this vast computational power.

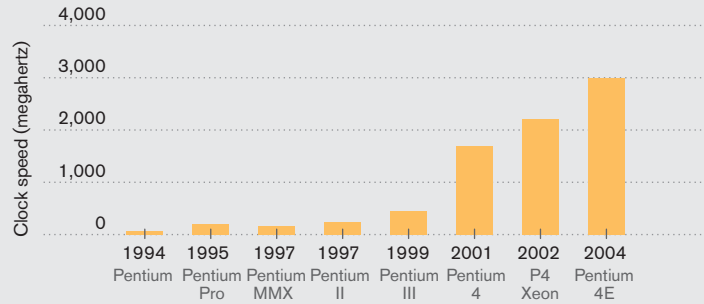
Lousy Emitter

Optical fibers constitute the backbones of long-distance telecommunications networks and are largely responsible for the speed of the Internet. But optical components don't come cheap. Optically sending and receiving data requires a laser that creates a light beam; a "modulator" that chops that beam into on/off bursts that represent digital *1*s and *0*s; "waveguides" that pipe the light through chips; and photodetectors that capture the light and convert it back into an electronic signal. Currently, these devices are not made out of silicon and cost thousands of dollars to put into place. Telecom providers can afford those prices, but making the technology feasible for moving data within a computer means reducing prices by orders of magnitude.

Silicon may be the answer. "Silicon to us, it's maybe not a religious experience, but it's pretty close," Gelsinger says. "Silicon has proven cost effective, scalable, durable, manufacturable and has all sorts of other wonderful characteristics." Photonic parts made of silicon would make optics more affordable and broaden potential uses. "Today, optics is a niche technology. Tomorrow it's the mainstream of every chip that we build," Gelsinger says.

The Clock Is Ticking for Chips

In the past ten years, the speed at which computer chips can process information has dramatically increased.



SOURCE: ROY LONGBOTTOM

Until about a year ago, it looked as if silicon would never play a significant role in optics. "Silicon is not intrinsically the best optical material," explains Reed. Among its most obvious deficits is that it's a lousy light-emitter. When the electrons in silicon are excited, instead of releasing photons they cause the silicon's crystal lattice to vibrate. The result is heat, not light. By contrast, semiconductors such as gallium arsenide and indium phosphide emit light when electrically excited. So while researchers have been fascinated by the prospects of an "optical chip" for years, the consensus was that silicon was not the right material to build it with.

Then, in the late 1990s, researchers reported a series of encouraging, albeit preliminary, advances in silicon optics *(see "Upstream," June 2001)*. At Intel, the progress made by Paniccia's team convinced executives to ramp up the company's silicon-photonics program. Intel's first breakthrough came in February 2004, when Paniccia reported in the journal *Nature* that his group had made a silicon modulator capable of converting a steady stream of light from a laser into rapid pulses of digital *1*s and *0*s at a rate of one billion hertz, or one gigahertz, a 50-fold advance over the previous experimentally demonstrated record for silicon. "But it still wasn't anywhere near fast enough," Reed says. Then this spring, Intel researchers led by materials scientist Ling Liao reported a silicon modulator that runs at 10 gigahertz, roughly on par with other optical modulators.

But the crucial silicon-photonic component was still the laser. Last September, four separate groups, including Paniccia's, reported silicon lasers that fire staccato pulses of light. Because silicon does a poor job of converting electrical charges into light, all these silicon lasers relied on external lasers as energy sources. Like all chip-based lasers, the silicon lasers work by converting energy—in this case, photons from another light source—into a burst of photons with essentially the same wavelength and phase. The Intel researchers exploited a long-known principle called the Raman effect, in which photons gain energy from collisions with vibrating atoms.

"Today, optics is a niche technology. Tomorrow it's the mainstream of every chip that we build," says Intel's Pat Gelsinger.

Pulsed lasers aren't great for transmitting data, though. Optics engineers much prefer continuous lasers, which they can slice and dice with modulators to create data signals. But all of the groups struggled with the same problem. As they increased the amount of continuous laser light they fed into the silicon chips, the likelihood that pairs of incoming photons would strike a single silicon atom at the same time also increased. When that happened, the silicon atoms kicked electrons out of their atomic orbits, and those mobile charges voraciously gobbled up photons. The incoming laser had to be pulsed to give the electrons the millionths of seconds they needed to give up their excess energy and relax back to their resting states.

Paniccia's team came up with an answer that was both brilliant and, for those familiar with silicon technology, conceptually simple. Etched into the Intel laser chip was a silicon waveguide channel in which light bounced back and forth, gaining in intensity. The researchers implanted electrodes on both sides of the channel. When they turned on a voltage between the electrodes, it created an electric field that herded the negatively charged electrons toward the positively charged electrode, effectively sweeping them out of the way. As a result, the photons were able to build up unhampered, until they produced a continuous laser beam.

Last winter, three days before Christmas, Paniccia's colleagues Haisheng Rong and Richard Jones saw the first sign that the strategy was working: a line on the display of an optical-spectrum analyzer showing that the infrared photons produced by the laser were coming out in a steady stream.

On the Inside

Intel researchers still have to find ways to manufacture silicon lasers alongside electronic components on chips. Electronic circuits are built through the painstaking process of laying down and etching dozens of layers of materials. Some of these steps require temperatures well over 1,000 °C or exposure to caustic chemicals. So Intel's engineers will need to ensure that the steps required to build up the optical devices don't degrade the electronic circuitry, and vice versa.

As an initial demonstration of the usefulness of silicon photonics, Paniccia plans later this year to integrate several modulators and other optical components onto a piece of silicon; this setup should enable data transfer speeds of 100 gigabits per second. Such a prototype, hopes Paniccia, will illustrate the potential of silicon photonics to carry data into and out of chips far more efficiently than anything currently on the market.

Walking through one of his newly renovated labs this spring, Paniccia showed off a mock-up of an optical Ethernet cable that would use silicon photonics. While Paniccia normally maintains the modest, careful demeanor of a scientist, it's clear he relishes using the prop to sell his vision of silicon's new role. On the end of the spaghetti-strand-thin cable sits a connector that resembles the end of a phone cord, with metal pads sitting under tiny slits in a silicon encasement. In a functional version of the cable, electrical signals would travel from a computer chip through those metal pads to a silicon photonic chip inside the tiny connector, where they would be converted into a stream of light pulses.

While on the outside the cable resembles familiar technology, adding cheap silicon photonics to it would bring unprecedented speed and power to computers. And it would allow Intel to add its famous "Intel inside" branding logo to yet another transforming technology. Realizing that vision won't be easy. Still, Paniccia is convinced it will happen. "There is no question anymore whether we can do this. It's when and how. That's been the change in the last year." And when the last technical barrier falls, he says, "silicon photonics will be everywhere." ■

Robert Service is Portland, OR–based writer who covers chemistry and materials science for Science.

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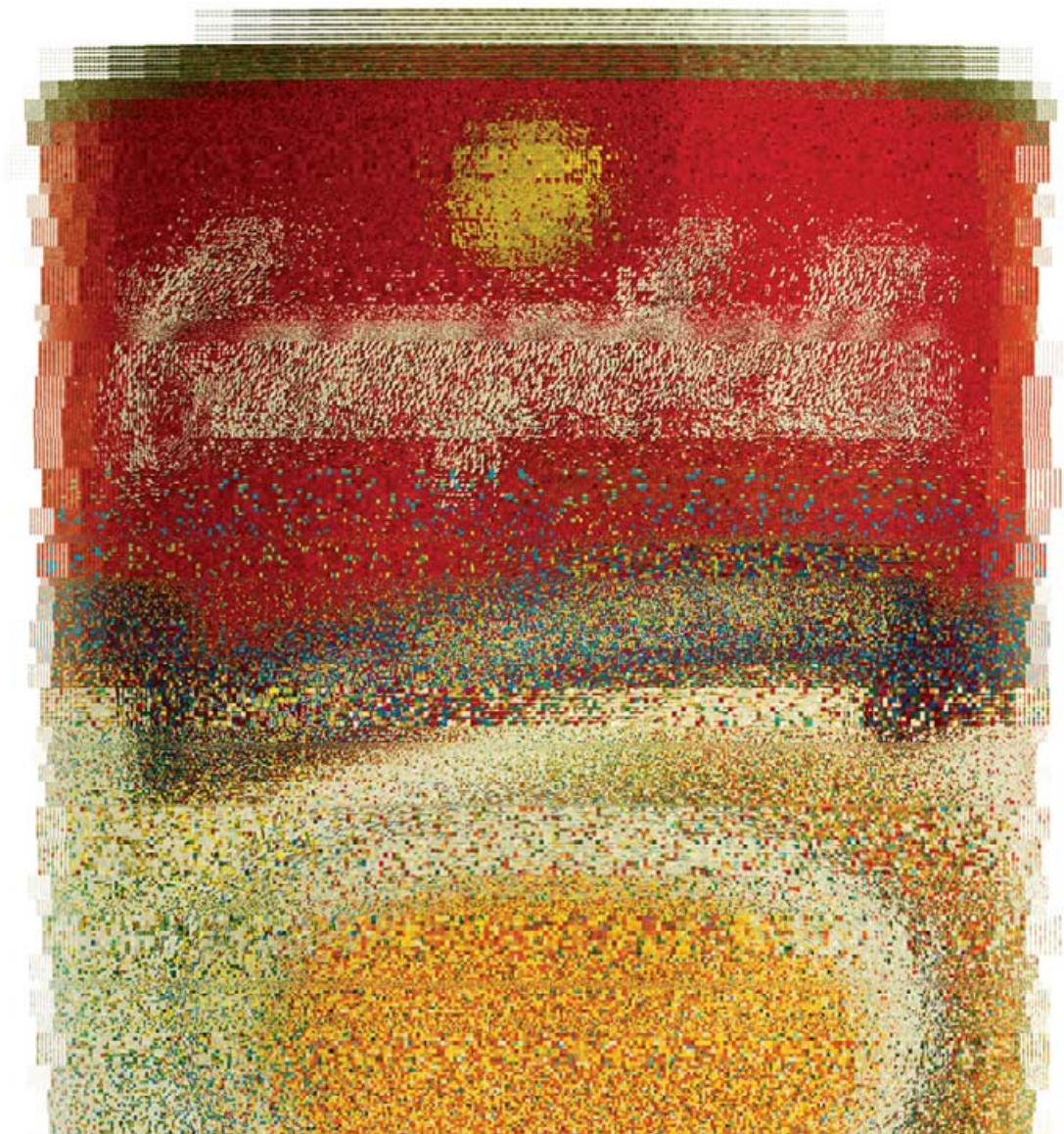
Art by Numbers

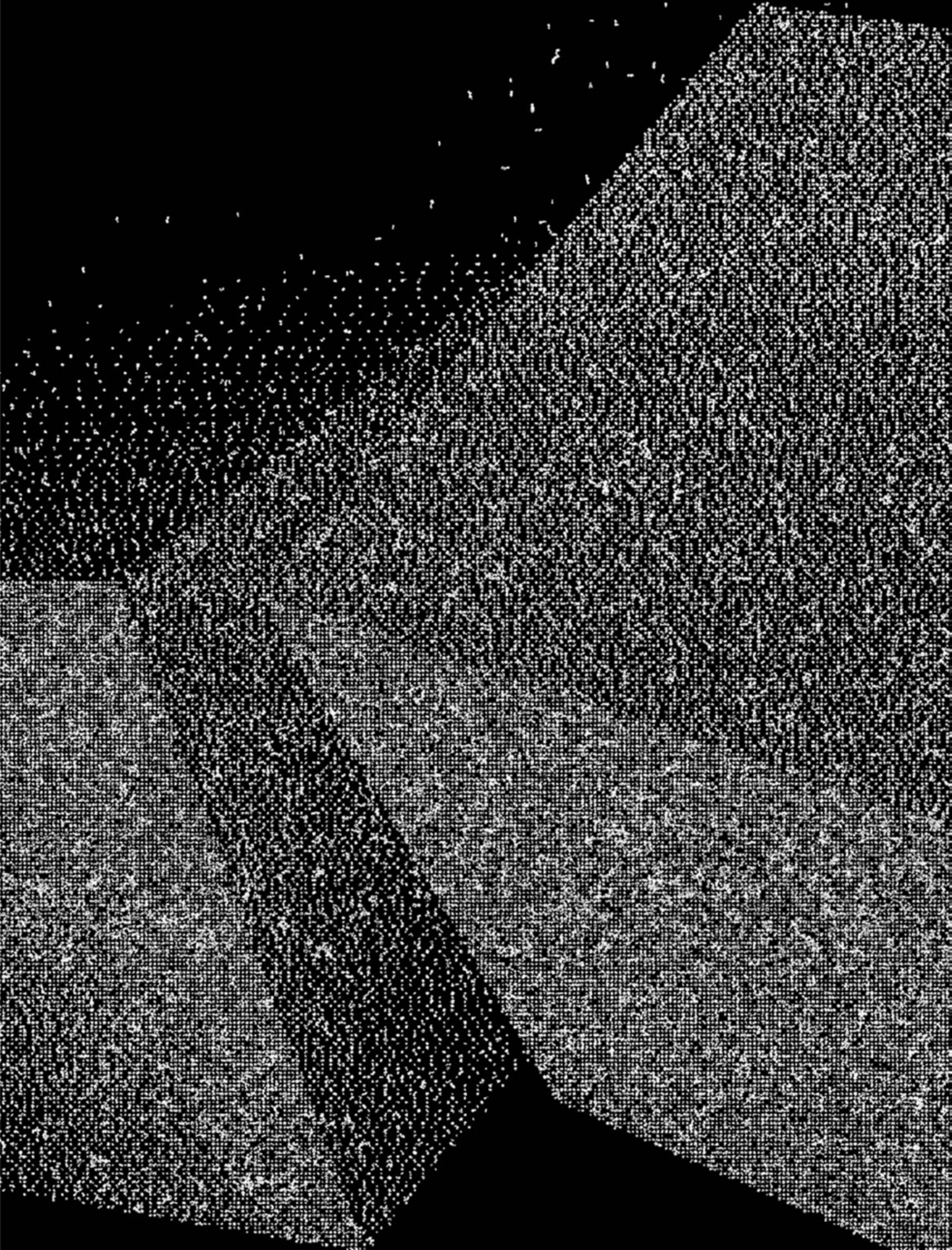
John Maeda, associate professor of design and computation at MIT's Media Lab, leads a new generation of techno-artists who are pushing the boundaries between computer programming and design. For his 2003 New York exhibit "F00D" (F-zero-zero-D), Maeda produced digital images of everyday edibles—condiments, snacks, canned goods. He then wrote image-processing software that broke the images into discrete pieces—say, the individual crystals in a sugar packet—which he could then rearrange at will. While computer science enables his art, the reverse is also true, as Maeda develops programming tools to fulfill his artistic ambitions.

Gregory T. Huang



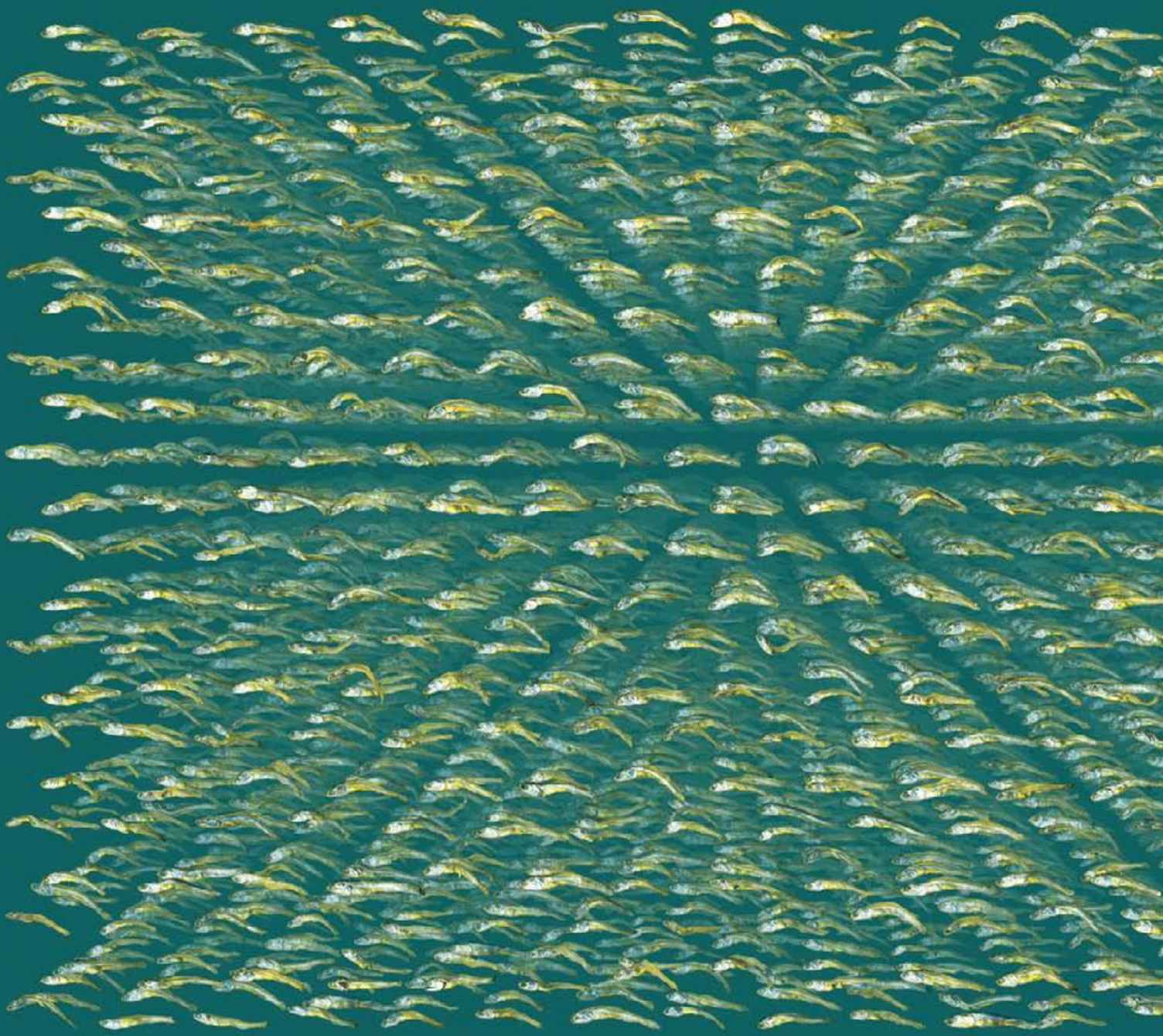
FACING PAGE: *Large Soup* blends 63 kinds of Campbell soup into a digital collage.

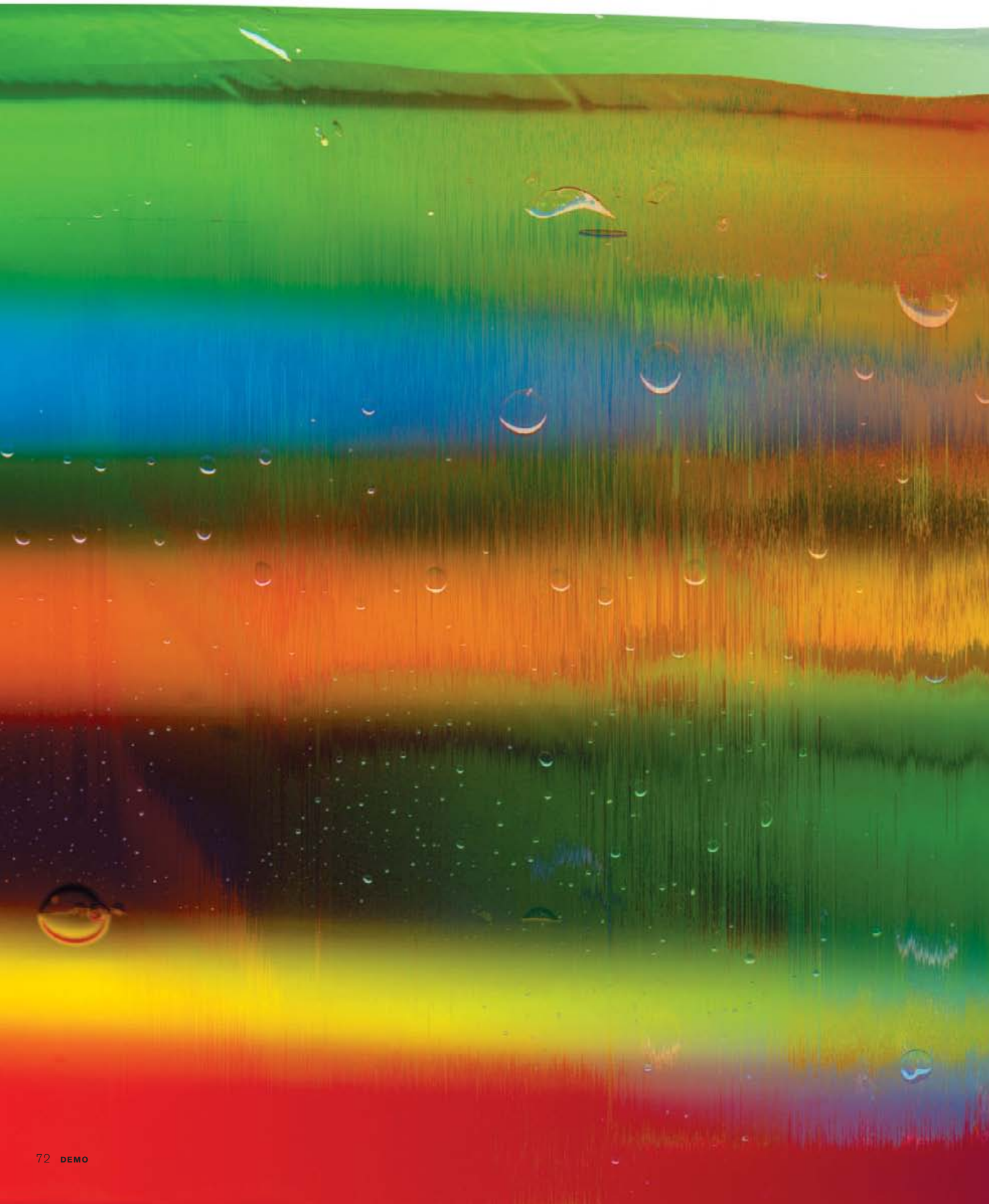
THIS PAGE: *Amber Waves* aligns the contents of six large orders of french fries.

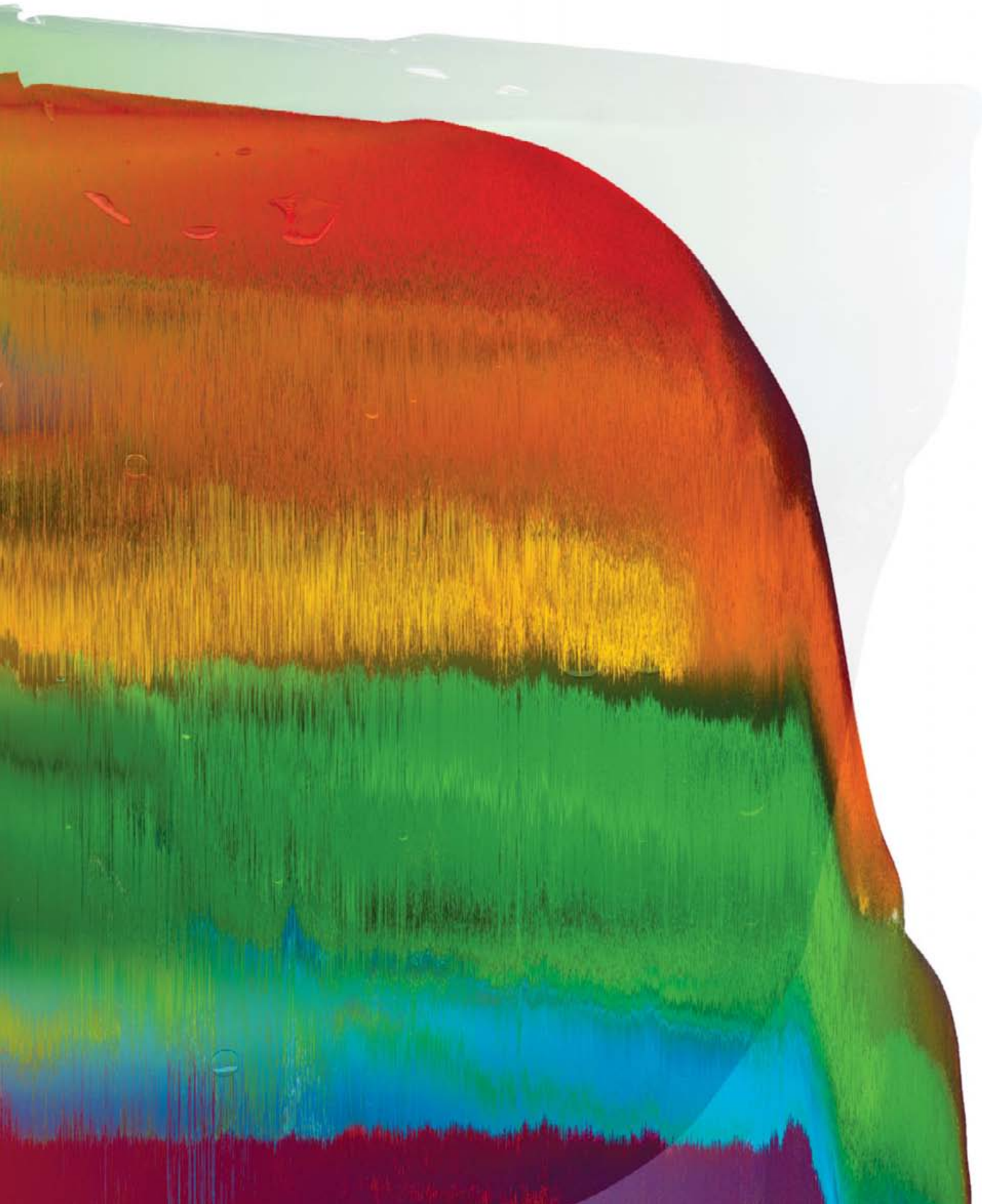


FACING PAGE: *Tea for Two* orders 70,000 sugar specks.

THIS PAGE: *Rebirth* suspends 200 dried anchovies in 3-D space.







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Armstrong left his footprints on the jazz world, wearing lace-up oxfords.

Not bad for a kid whose first experience with the trumpet was as a guest in a correctional home for wayward boys. If only today's schools were as enlightened and informed as that reformatory was.

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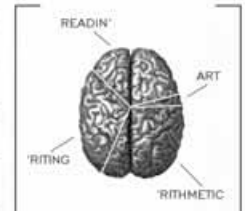

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AMERICANS for the ARTS

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Plain Technology

The Amish have something to teach us.

Of all of America's religious communities, few seem less likely to thrive in the 21st century than the Old Order Amish. They are forbidden not only to drive tractors and automobiles but also to install electrical wiring in their homes and businesses. Yet their numbers are doubling every 20 years, and there are 1,600 Amish-owned businesses in Lancaster County, PA, alone, according to Donald Kraybill, author of *The Riddle of Amish Culture* and coauthor of *Amish Enterprise*. He notes that more than 90 percent of Amish youth accept baptism and its obligations.

As Kraybill and others have shown, the Amish are so resilient in part because their society tempers discipline with flexibility. Within the decentralized leadership, each bishop allows experimentation before deciding whether an innovation will be sanctioned by the community's *Ordnung*—its oral body of customs and rules. For example, the bishops have generally permitted the use of electrical inverters in Amish shops so they can operate standard 110-volt AC machines like cash registers and typewriters with 12-volt batteries. The Amish receive modern medical care and encourage scientific study of their genetic diseases. Many of their famous black buggies are made of fiberglass. And some unbaptized youths experiment with automobiles and computers for a few years of *rumspringa* (running around) before they decide whether to join the church.

But although the Amish make certain technological concessions, their way of life, of course, imposes limits, which stem from their core value: *Gelassenheit*, which means yielding to God's will as manifested in the community's leadership. This principle informs their view of formal education: in an effort to reduce pride and competitiveness, the Amish do not educate children past the eighth grade.

Self-imposed limitations promote a basic, but valuable, form of innovation. Amish metalworkers have been at the forefront of a revival of horse-drawn agriculture in the United States; the number of horses on U.S. farms increased by 20 percent between 1997 and 2002. Amish shops are leading suppliers of innovative implements—for example, a horse-drawn plow with an external wheel that charges a hydraulic cylinder, which lets a farmer raise and lower the plow with little effort. (Models sold to non-Amish farmers may use rubber tires, forbidden in Amish agriculture.) Amish inventions are of special interest in developing countries, where draft-animal farming is still common.

Amish bishops set limits on the size of companies, so Amish shops tend to have 10 or fewer employees, who are generally Amish themselves. Labor relations are usually excellent, based on teamwork and shared values. When an Amish business grows beyond the prescribed size, the bishops often make the owner sell it, but this can be to the owner's advantage. He is spared the pains of the middle-sized company that needs professional managers and heavy outside financing. His workers learn a few technologies thoroughly. And Amish profits are often reinvested as low-cost loans within the community.

The ban on connecting to the power grid fosters great ingenuity in hydraulic and compressed-air technology, resulting in devices that are often more energy efficient than conventional electric motors. Since stationary diesel engines are permitted, Amish mechanics also gain valuable experience adapting off-the-shelf machinery to run on diesel-powered hydraulic pumps, air compressors, and battery chargers. Power outages have become more frequent in North America but leave Amish farms and businesses largely undisturbed: the freezing rain that shut down the electrical grid in Québec in winter 1998 had little effect on the Amish farmers who had established themselves in neighboring northern New York state.

The Amish do not all think alike. Many Amish farmers are enthusiastic users of pesticides, herbicides, and genetically modified seeds, which they regard as the God-given means of sustaining their farms and communities. Other Amish (Kraybill estimates 10 to 15 percent) are allied with the Green movement; the Yale University environmental historian Steven Stoll applauds organic Amish farmer David Kline, whose way of life Stoll calls postmodern: "traditional without being nostalgic, practical without nodding to technology."

Amish life might not be utopian, but it remains one of America's oldest and most robust technological experiments, with something to teach the rest of us. When all else fails, try a little *Gelassenheit*. ■

There's not much a man and his air-powered sliding compound miter saw can't do.

TODD WEDDLE/AP PHOTO

Reviews

Our reviews use any artifact—a book, a product, a government report, a movie, a research paper—as the occasion for a contemplative essay on some technological controversy.

The Myth of Jonas Salk

It was Albert Sabin's vaccine, not Salk's, that truly defeated polio.

BY ANGELA MATYSIAK

April 12 was the day, 50 years ago, that the U.S. Public Health Service licensed the killed-virus vaccine against poliomyelitis developed by Jonas Salk. In the decades since, a great myth has grown to dominate the popular imagination. Its name is "The Conquest of Polio," and Salk is its hero.

On the anniversary day and minute, the Smithsonian Institution tolled the bell on its oldest building 50 times to open an exhibit at the National Museum of American History centered on Salk and the vaccine. That morning, the science correspondent for National Public Radio extolled the polio conquest and the Salk vaccine in the first part of a three-part series. Publications marked the occasion—the New York *Times*, the Washington *Post*, the Chicago *Tribune*, the Los Angeles *Times*, *USA Today*, *Smithsonian* magazine, and a dozen others. In the weeks before, two new books had appeared. Six more are now in the works.

This retelling of the history of polio, however, is largely a distortion. The full, true story is far more complex. Its hero is Albert Sabin—for if any one man conquered polio, it was Sabin, who developed the oral attenuated live-virus vaccine. While Salk's vaccine did slow down the incidence of polio among middle-class Americans, its cost and its requirement of three injections and a booster meant that for years the disease continued to affect the poor and others lacking access to proper medical care. It was only after Sabin's oral vaccine, which was cheap, effective, and easy to administer, was licensed for production in 1962 that polio could be fully controlled in the United States.

But it seems some prefer the myth to the fact. Jeffrey Kluger's *Splendid Solution: Jonas Salk and the Conquest of Polio* pushes the myth to an extreme. Kluger is a senior writer at *Time*. In his version, the myth contains three assertions. First, Salk was a great scientist "with such a deep regard for scientific facts," Kluger writes, "a tectonic force in scientific history." Second, the Salk vaccine was effective and conquered polio in this country. If only it had been used for a few more years, it would have eradicated the disease. Third, the "temperamental" Albert Sabin, who was working on his own vaccine at the University of Cincinnati, sabotaged the killed-virus vaccine. Kluger implies that Sabin's opposition had no basis in science but arose from jealousy.

In contrast, contends Kluger, Salk was controlled in his demeanor: "Stupidity always made him angry; malevolent stupidity made him angrier still. He wouldn't show it; he never did. You couldn't run the kind of lab he ran and conduct the kind of research he conducted and allow yourself the luxury of pique." Kluger's reconstruction of the history, and especially of the controversy between Salk and Sabin, depends heavily, painfully, on innuendo and inference.

These charges demand careful attention. In the first place, Salk's research was altogether derivative. It arose from four crucial discoveries. In 1949, David Bodian, Isabel Mountain Morgan, and Howard Howe at the Poliomyelitis Laboratory at Johns Hopkins University first established that polio comes not in a single variety but in at least three. Then they showed that a preparation of killed virus could inoculate monkeys against the disease. In 1952, Dorothy Horstmann of Yale University School of Medicine and Bodian, independently, established that polio is a bloodborne disease. Also in 1952, Howe suggested that killed virus could produce good antibody responses in children.

D. A. Henderson—the man who organized the worldwide eradication of smallpox—was then at the U.S. Communicable Disease Center (now the Centers for Disease Control and Prevention) in Atlanta. In a recent interview, he told me, "So Jonas came in at this point with pretty much everything done except for moving on to wider-scale human trials."

But by the early 1950s, Sabin and many other immunologists and epidemiologists were convinced that an oral attenuated live-virus vaccine would be more effective. Soon after Salk's vaccine became available in the spring of 1955, many recognized that it had serious problems.

For Sabin, the problems were three: safety, efficacy, and practicality. Early on, Sabin held that one particular strain Salk had used—a highly virulent strain called Mahoney—would be hard to

The real story of the polio vaccine involves both Salk (right) and Sabin (left).

kill and thus dangerous. The question of efficacy was whether any killed-virus vaccine could produce lifelong immunity. And finally, even though the vaccine did stimulate production of antibodies, three shots were necessary, plus a later booster. Sabin put the point most succinctly: "The need for inoculating large amounts and the need for repetition are bad." In contrast, an oral vaccine with a small dose of the attenuated versions of each of the three strains, administered once, would give lifelong immunity.

Then came the shock of the Cutter incident. On April 24, 1955, just days after the Salk vaccine went into use, polio broke out among children who had received shots from a batch made by Cutter Laboratories in California. Eleven died. It is usually asserted that the Cutter incident was caused by particular lots of vaccine that still contained live polio virus, but the presence of the live virus has never been satisfactorily explained. Joshua Lederberg, who received a Nobel Prize in 1958 for his work in bacterial genetics, was involved in polio-virus research in the early 1950s. Lederberg told me in March 2002 that the Cutter incident is "still a little bit of a mystery." The virus strains in the Salk vaccine were inactivated with formaldehyde. Lederberg said that the chemistry of the formaldehyde-virus interaction has never been adequately studied. "It is my opinion that under some conditions, it is a reversible reaction," he said. "In fact I know that it is." He went on, "The question is [with] what reagents or under what conditions a formaldehyde will come off the inactivated complex and thus restore its infectivity." And so, Lederberg said, because nobody understood the reasons for the "Cutter catastrophe," research continued into alternatives to the Salk vaccine. (After the Cutter incident, production methods were changed. No further safety problems with the vaccine have been reported.)

The force behind Salk and his vaccine was the National Foundation for Infantile Paralysis—later rechristened the March of Dimes—and in particular its president, Basil O'Connor, who was not a scientist. In an interview in 1984, Salk said, "I would say that the fact that the vaccine became available in 1955 was attributable to the existence of Basil O'Connor, that without him the story would have been quite different....He had it within his power to cause almost anything to happen." As Sabin dug deeper

Medical Mythmaking

Splendid Solution: Jonas Salk and the Conquest of Polio
By Jeffrey Kluger
Putnam, 2004, $25.95

Polio: An American Story
By David M. Oshinsky
Oxford University Press, 2005, $30.00

into his vaccine research, he began openly to oppose the foundation, for he believed it ignored important scientific conclusions and was unrealistically pushing for a quick solution.

Sabin was particularly critical of O'Connor, charging that he was biased. In a letter dated June 25, 1955, he asked O'Connor, "Would it not be better if you as President of the National Foundation of Infantile Paralysis observed a more impartial attitude regarding the scientific work and contributions of all scientists whose work is supported by the donations from the American people through the Foundation which you so ably lead?" On August 1, in another letter, Sabin attacked O'Connor's interpretation of safety: "A killed-virus vaccine for poliomyelitis must be safe without qualifications. If it is admitted that it can be made safer, then it is not sufficiently safe." He referred to the Cutter incident: "When such a tragedy occurs you do not continue operations as usual."

David Oshinsky's *Polio: An American Story* is a richer and more complex book than Kluger's. Oshinsky's position on the myth-making? "I am trying to stay away from it," he said in a recent conversation.

Salk emerges here as a complex scientist. He was an outsider, Oshinsky writes. "Salk was marooned out there in Pittsburgh, fiddling with an old-fashioned killed-virus vaccine and doing the dog's work that his betters refused to do." Yet he was close to the National Foundation for Infantile Paralysis and to O'Connor. He was meticulous in his science. "It was a game of trial and error, testing and tinkering, and few knew it better than Jonas Salk." He was confident about his work but aware of its dangers. "'When you inoculate children with a polio vaccine,' he said later, 'you don't sleep well for two or three months.'" He was sensible and accommodating, yet he could be insensitive and egotistic, especially when dealing with his laboratory team. "Once the goal was reached, the group would split apart amidst charges that Salk had not appreciated, much less acknowledged, the collaborative nature of his success." He shied away from the media yet craved publicity. "One of his greatest gifts was a knack for putting himself forward in a manner that made him seem genuinely indifferent to his fame, a reluctant celebrity, embarrassed by the accolades, oblivious to the rewards."

All this Oshinsky unfolds in the context of the National Foundation's politicking and lobbying, and of the larger politics of the day. In the end, Oshinsky's Salk emerges as someone we care to know something about, most notably his left-wing leaning early in life (which Oshinsky learned about from FBI files), his apolitical stance in midlife, and his mystical tendencies in old age. Yet Oshinsky's account has problems of its own. Although early concerns about Salk's vaccine were scientifically motivated, those at the end of the 1950s were broadly social. An immunity gap among different social and economic classes had developed; Oshinsky knows this but gives the subject only two pages.

In 1959, epidemiologists reported findings on the pattern of the disease. These suggested a shift in incidence according to age, geography, and race. By 1960, less than one-third of the population under 40 years of age had received the full course of three doses of the Salk vaccine plus a booster. Most of those who had were white and from the middle and upper economic classes. The disease raged on in urban areas among African Americans and Puerto Ricans and in certain rural locales among Native Americans and members of isolated religious groups.

The gap had to do with access to vaccination. Pediatricians were not well compensated. "This was the one thing they could do which was a guaranteed reasonable flow of cash," explained Henderson. The physicians resisted losing that cash; they argued for a vaccine that required their professional training.

Late in 1960, at the mid-winter clinical session of the American Medical Association, the surgeon general of the United States presided over a symposium on the state of polio immunization. E. Russell Alexander, chief of the surveillance section at the Communicable Disease Center, said, "The residual pattern of disease represents a measure of our failures to apply vaccine completely enough." A. D. Langmuir, chief of the epidemiological branch at the center, said, "[P]olio seems far from being eradicated. The dreamed-for goal has not been achieved. In fact, many students of the problem question that eradication of poliomyelitis infection with inactivated vaccine is a scientifically tenable concept." One of the main concerns was that the Salk vaccine did not prevent infection in the gut and thus did not break the chain of transmission.

By the mid-1960s, Sabin's vaccine was the only one in use in the United States. It was the Sabin vaccine that closed the immunity gap and effectively put an end to polio in the United States.

Beginning in January 1962, pediatricians in two Arizona counties, Maricopa and Pima, containing the state's largest cities, Phoenix and Tucson, conducted separate but similar voluntary mass immunizations using Sabin's vaccine. "Previous programs in the county, using the Salk vaccine, had failed to bring polio immunization to a satisfactory level," they reported a year later in the *Journal of the American Medical Association*. The program was called SOS (Sabin Oral Sundays). More than 700,000 people were immunized—75 percent of the total population in both counties. The vaccine was given at the cost of 25 cents, for those who could pay. It was given to population groups that were socially, racially, and culturally diverse, on Indian reservations and military posts and in urban and rural areas. The program became a model for subsequent U.S. mass-immunization programs. By the mid-1960s, Sabin's vaccine was the only one in use in the United States. It was the Sabin vaccine that closed the immunity gap and effectively put an end to polio in the States.

Yet Sabin's vaccine, too, has a problem. Attenuated live virus can mutate back into a virulent form. This has happened in a small number of cases. In the United States, therefore, after the decades in which the Sabin vaccine extinguished polio, the Salk vaccine is, ironically, once again preferred for immunizations. But the Sabin vaccine, cheap and easy to administer, is still the one used in the current campaign to eradicate polio worldwide. This campaign has extinguished the disease in the rest of the Western Hemisphere and in Europe, and almost entirely in Asia, though recent flare-ups in central Africa remain ominous. ■

Angela Matysiak is completing her PhD at George Washington University, in history of science, and is writing a biography of Albert Sabin.

CHRISTOPHER HARTING

Wishful Medicine

The placebo effect is real, but what is it?

BY STEPHAN HERRERA

THE WESTERN MEDICAL establishment and drug industry have an uneasy relationship with the placebo effect. Both acknowledge that patients often benefit from their own expectations. But neither seems willing to support efforts to study the underlying physiology of the effect.

After reading Jerome Groopman's *The Anatomy of Hope* and Daniel Callahan's *The Role of Complementary and Alternative Medicine*, and much of the body of peer-reviewed research on the biological basis of the placebo mechanism, one begins to understand why placebo-enhanced healing gives doctors pause. There is growing evidence of its existence but little conclusive data as to how and why it works. And there is even less research on how to best manipulate the effect for the welfare of patients.

Groopman is a Harvard Medical School physician and a *New Yorker* writer whose articles offer a rare glimpse of the difference between the way medicine is taught and the manner in which it is practiced. For almost 20 years, Groopman suffered chronic and debilitating back pain. As we come to learn in Groopman's memoir, the placebo effect, set into motion by the encouragement of a straight-talking yet exceedingly empathetic doctor at a small physical-therapy clinic near Boston, played a pivotal role in his recovery. *Anatomy of Hope* describes Groopman's road to recovery and the lessons he learned from it that now inform his work as both a teacher and a clinician. The book is a testament to the power of the human spirit—and to the health and economic value of the placebo effect—from a highly credentialed member of the medical establishment.

Callahan approaches the issue of healing from a different vantage. He is not a physician but a philosopher. Callahan is cofounder of the Hastings Center in Garrison, NY, which is devoted to the study of bioethics. He is very much outside of the medical establishment but has featured prominently in every major biomedical debate in the United States in the last 35 years. This book is a collection of essays and reviews on the subject of alternative medicine and the placebo effect. Callahan says in his introduction that he compiled the book in an attempt to understand why a "large and prestigious group of clinicians and biomedical researchers seems so utterly hostile to [alternative medicine] while a large portion of the public (and the educated public at that) seems so attracted to it."

These two authors each have their own reasons for being intrigued by the power of the placebo effect. But a common theme can be found in both books—namely that the placebo effect is not a figment of a patient's imagination. And there are now technology and studies to prove it.

Placebos, not pills

The Anatomy of Hope: How People Prevail in the Face of Illness
By Jerome Groopman
Random House, 2004, $14.95

The Role of Complementary and Alternative Medicine: Accommodating Pluralism
Edited by Daniel Callahan
Georgetown University Press, 2002, $29.95

Feeling Is Believing

Latin for "I shall please," the placebo takes many forms, the most common of which are the sugar pill, the saline injection, and distilled water. There are even placebo surgeries wherein patients are anesthetized, cut open, and stitched up to look as if they have had surgical interventions, even though they haven't. The belief and expectation that a treatment will heal produces in many patients genuine feelings of relief. In some patients, there is even physical evidence of a benefit.

Doctors and researchers first discovered in 1931 that the placebo effect was a useful prop for better understanding the safety and efficacy of medicines in development. It was well known that some patients would say that they felt better at the very suggestion that they were being given a remedy. Researchers trying to measure the effects of a drug called sanocrysin on patients with tuberculosis wanted to control for this anomaly. Their solution was to give patients a glass of distilled water and tell them they were drinking sanocrysin. Ever since, placebo-controlled, double-blind studies have been embraced by the medical profession as a standard way of evaluating drugs in clinical trials.

But what has long puzzled researchers is whether the sense of healing that some patients feel when given a sugar pill is a func-

tion of human biology or psychology. It turns out that it's both. New research indicates that in cases of maladies like chronic pain, asthma, and depression, a person's expectation of healing sets off a chain reaction of neurochemical changes in the body that can alleviate physical symptoms.

As Groopman writes of Ted Kaptchuk's placebo work at Harvard Medical School, "a change in mind-set can alter neurochemistry, both in a laboratory setting and in the clinic. When we are patients, suffering from pain and debility, we look to our doctors and nurses for the words and gestures that reinforce our belief in medicine's power and solidify our expectation that we may benefit from an intervention. Recent research shows just how catalytic those neurochemical changes can be."

Groopman writes that "belief and expectation—the key elements of hope—can block pain by releasing the brain's endorphins and enkephalins, mimicking the effects of morphine" and can affect "fundamental physiological processes like respiration, circulation, and motor function." As Groopman notes, hope can trigger a placebo effect whose biology "can be imagined as a domino effect, a chain reaction in which each link makes improvement more likely."

Research supporting the biological basis of the placebo effect has been appearing with greater frequency in peer-reviewed journals like *Science*, *Nature*, and the *New England Journal of Medicine* and in nearly all of the leading specialty journals in the depression and pain treatment field.

One of the definitive analyses of the placebo effect's role in treating depression remains a 1998 meta-analysis—a study that reviews previous studies in search of themes and conclusions—by Irving Kirsch and Guy Sapirstein called "Listening to Prozac but Hearing Placebo: A Meta-Analysis of Antidepressant Medication," which appeared in *Prevention and Treatment*. Deciphering the data on the subject, Kirsch and Sapirstein discovered, suggests that the placebo effect might account for up to a third of the clinical benefit of modern antidepressants.

The analysis raises an obvious question: might more clinical benefit be achieved if the placebo effect could be harnessed and directed? And given the physical, emotional, and economic cost of depression, why isn't the government funding more research on the placebo effect's potential role in treating it?

"Belief and expectation—the key elements of hope—can block pain by releasing the brain's endorphins and enkephalins, mimicking the effects of morphine."

Pain is the object of most placebo-effect studies, many of which use brain imaging to compare and correlate the biological activity produced by opiates like morphine with treatments that stimulate the placebo effect. One such study appeared in the Feb. 20, 2004, issue of *Science*, describing work done by the University of Michigan's Tor Wager (now at Columbia University) and colleagues from Princeton University, Harvard University, the University of Wisconsin, and the Veterans Affairs Medical Center at the University of Michigan. The team of researchers discovered in two functional magnetic-resonance imaging experiments that placebo analgesia is related to decreased brain activity in pain-sensitive brain regions, including the thalamus, insula, and anterior cingulate cortex.

The researchers also observed increased brain activity in the prefrontal cortex when pain—or pain relief—was anticipated, which would seem to offer some evidence that placebos alter the experience of pain. In July 2002, the *New England Journal of Medicine* published a study that found that patients who underwent a placebo surgical procedure instead of a type of arthroscopic surgery did just as well as patients who actually received the surgery.

The importance of these and other recent findings is twofold. First, they show that more researchers and scientific publications are taking seriously the placebo effect. Second, it is clear that researchers are now seeking to go well beyond correlation studies, instrumental as they are for defining the broad reach of the placebo effect. The new goal of placebo-effect researchers is to establish and identify a direct cause-and-effect link between the placebo effect and physical healing in a wide variety of diseases.

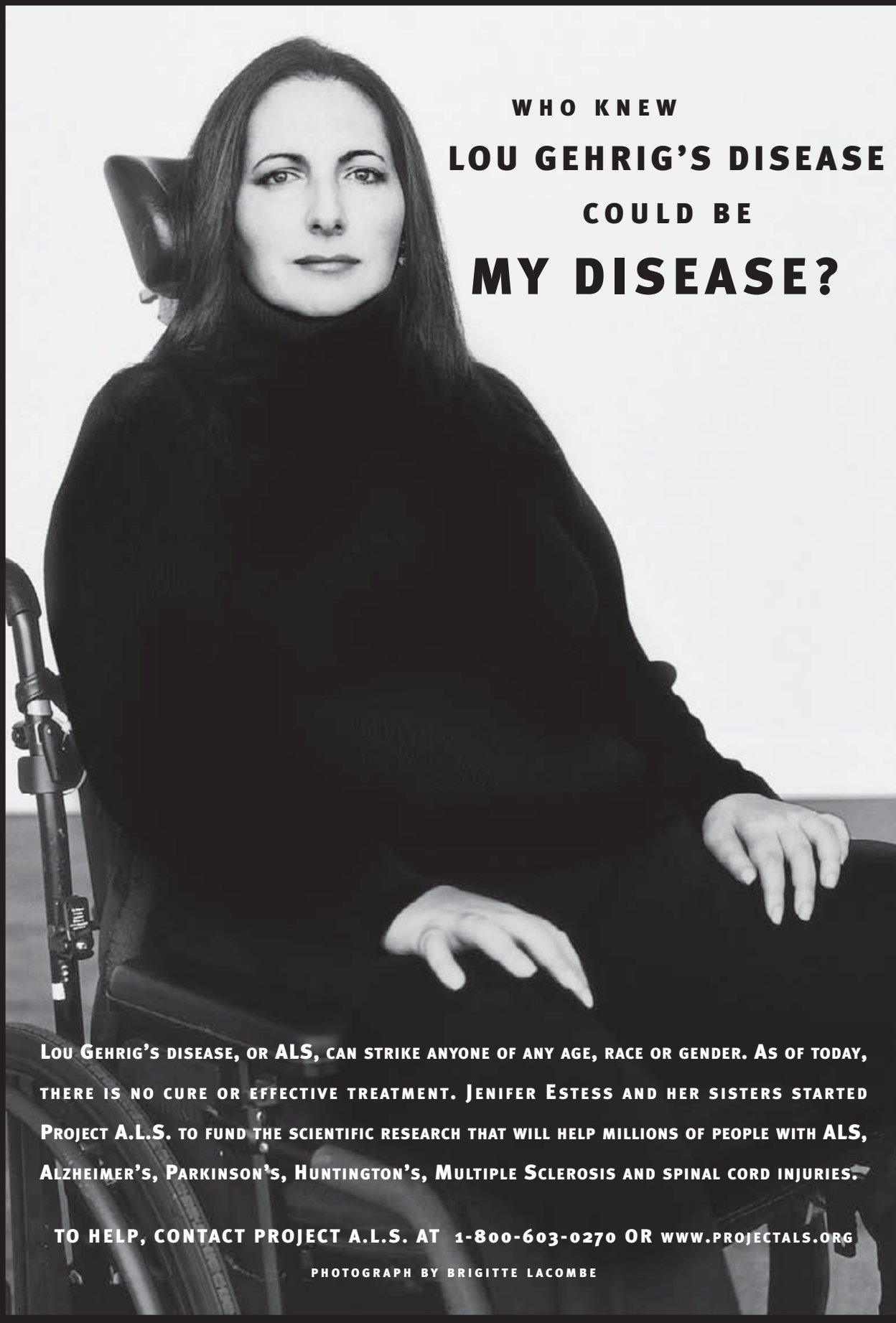
Suspended Disbelief

Many experts point out that recent brain-imaging studies purporting to prove the existence of a placebo response are suggestive but far from conclusive. Howard Brody, whose chapter on the placebo effect appears in Callahan's book, warns against reading too much into brightly colored brain scans that seem to show how certain regions of the brain "light up" when the placebo effect is induced. Brody, who is a family physician and researcher at Michigan State University, says, "I support the idea that PET [positron emission tomography] scanning data are helpful because they suggest which brain centers are involved in placebo effects and thereby suggest possible neural mechanisms that can be explored in future studies." But, Brody adds, "I don't agree with the notion that the placebo effect can now be proven to be real [just] because we can see it on a PET scan."

To pinpoint the mechanisms responsible for the physiological changes associated with placebos, defenders of the effect will have to work more closely with their skeptical peers. Proponents have made much scientific progress and picked up some key endorsements. But they need to work harder to identify the type of research that will fully explain the phenomenon. In turn, the medical community needs to be more open to the potential benefits offered by placebos.

The most obvious common ground between the two camps is the economic imperatives they both face. If enthusiasts of the placebo effect want more notice and respect, they must prove the financial advantages of promoting the effect as a way to boost and supplement mainstream treatments. They must show that higher expectations will mean faster healing and better quality of care and will save money. That's a message that will surely carry weight in the economically stressed health-care industry. As Groopman's book illustrates, the practice of medicine ultimately comes down to what happens at the bedsides of patients. And there, Groopman reminds us, it's worth keeping in mind the value of hope as a powerful and very real medicine. ■

Stephan Herrera is a contributing writer for Technology Review *who often writes about the business and politics of health care.*



On Display: the Unthinkable

A museum tries to make sense of the bomb.

BY MARK WILLIAMS

How is a nuclear bomb like an ancient African battle elephant? On a recent visit to the National Atomic Museum in Albuquerque, NM, I found hidden among the predictable exhibits—metal casings identical to those used in the Little Boy and Fat Man devices dropped on Hiroshima and Nagasaki, films of mushroom clouds expanding over atomic- and hydrogen-bomb test sites, photos of Robert Oppenheimer and the gang at Los Alamos, CA—a reproduction of a 16th-century Flemish tapestry with a placard beside it that tried to answer this riddle.

The tapestry depicts elephants striding among Roman legionnaires and their foes. The placard explains, "One of the best-known ancient arms control agreements was negotiated between Rome and Carthage following Scipio Africanus's victory over Hannibal in the Battle of Zama in 202 B.C. This treaty required the Carthaginians to surrender all their war elephants."

Museum visitors, then, are told that thermonuclear bombs and the battle elephants from the classical world are analogous examples of weapons systems that were regulated by the mutual agreement of warring groups. "Society has always placed limits on the ability of one side to wage war on another," the sign claims.

This is a dubious reading of history: war was almost always waged without constraint. Elephants saw centuries of use in warfare before and after the battle of Zama. But the Atomic Museum's comparison of pachyderms and nuclear bombs is less risible than what I found when I first visited the museum in 2001.

Back then, the museum resided on the dry New Mexico plain outside Albuquerque, across the road from Sandia National Laboratories. (The museum's current location is temporary; a move is planned for 2006.) Sandia is responsible for providing a measure of the country's surety; it started in 1945 as the Manhattan Project's "Z Division," charged with engineering the U.S. nuclear arsenal to be fail-safe. When I entered the museum, one of the first things I saw was pictures of battle elephants. Straight-faced, the director of the museum explained that, in their time, these creatures had been considered absolute weapons, too dreadful to be used. Ever since that visit, I've wondered: were the people responsible for this display really *serious*?

Of course, *no one* has found it easy to think about the bomb. In 1946, in the first book published on nuclear strategy, *The Absolute Weapon*, Yale University's Bernard Brodie wrote, "Everything about the atomic bomb is overshadowed by the twin facts that it exists and that its destructive power is fantastically great." Deterrence, Brodie argued, was the only rational military policy; yet that required a plausible nuclear war–fighting capability.

Brodie moved to the Santa Monica, CA, nonprofit think tank Rand in the early 1950s. Over the next decades, Rand's defense avant-garde constructed doctrines of nuclear deterrence. As in any avant-garde, stars emerged who espoused novel variations of doctrine. Arnold Wohlstetter, for instance, elaborated on U.S. vulnerability to a Soviet first strike and the concept of escalation. Herman Kahn stressed civil defense, underground shelters, and thought experiments like the Doomsday Machine, parodied in the film *Dr. Stangelove*. Brodie himself took varying positions, but before his death in 1978, he returned to where he began: the bomb was so dreadful that it could not be subjected to intellectual manipulation. (In "Nuclear Accountability," on page 43, a current nuclear professional struggles to think about the unthinkable.)

Grave Site

The National Atomic Museum
1905 Mountain Road NW
Albuquerque, NM
www.atomicmuseum.com

And yet, as things turned out, the strategic nuclear elite carried through the most brilliant and sustained—though also the most perilous—gamble in human history. After winning a Cold War that never came to direct military conflict, the United States became the only superpower, in 1991. Indeed, comparisons can be made with Rome's situation in 202 B.C.E., after the battle of Zama gave it supremacy in the classical world.

Such a comparison would have seemed obvious to those who shaped U.S. nuclear strategy in the Cold War. Over the past 35 years, they and their protégés have shaped *all* aspects of U.S. policy. Some of them—like Donald Rumsfeld, Dick Cheney, and Paul Wolfowitz—the world knows well. Others are known only by Washington insiders. Having played successfully for high stakes during the Cold War, none in this elite will be timid about formulating America's strategic aims during the 21st century. ■

Little Boy, the first nuclear weapon, was used at Hiroshima on August 6, 1945.

COURTESY OF THE NATIONAL ATOMIC MUSEUM

From the Lab

EDITED BY MONYA BAKER

Each month brings new investigative tools, new ideas for revolutionary technology, and revolutionary applications of existing technology. No one can know today which will matter most tomorrow. But these represent *Technology Review*'s best prediction.

Large groups of servers can be expensive to keep cool.

COURTESY OF VIRGINIA COMMONWEALTH UNIVERSITY

INFORMATION TECHNOLOGY

The Heat Is Off

Data centers keep cool

CONTEXT: Server computers are housed by the thousands in buildings called data centers. All those servers humming together generate a vast amount of heat, which can make them malfunction. A 30,000-square-foot center can run up a bill of $8 million a year just for cooling, so data centers' floor plans are designed to make cooling more efficient. The servers are also governed by algorithms that optimally distribute work to reduce the total amount of power used. These methods, however, do not accommodate for temperature variations across a data center. Now researchers from Duke University and Hewlett-Packard Labs have shown that assigning tasks to servers based on such variations can slash cooling costs.

METHODS AND RESULTS: When temperature in a data center isn't uniform, energy is wasted cooling the entire room just to keep machines in hot spots from overheating. Justin Moore and colleagues designed two algorithms that avoid creating local hot spots. One algorithm gives a server less work as its surroundings get hotter. The other surveys the entire data center and assigns fewer tasks to servers more prone to recirculate hot air.

WHY IT MATTERS: Moore and colleagues' work could drop the costs of doing business and keep servers from crashing. Computer models show that using the algorithms could reduce cooling costs by 25 percent, an annual savings of $1 million to $2 million for a large center. Data centers power today's Internet economy; with the new algorithms, they would be more reliable and use fewer resources.

Source: Moore, J., et al. 2005. Making scheduling "cool": temperature-aware workload placement in data centers. Paper presented at Usenix Annual Technical Conference. April 10–15. Anaheim, CA.

Speedy Security

Making safe data transmission faster

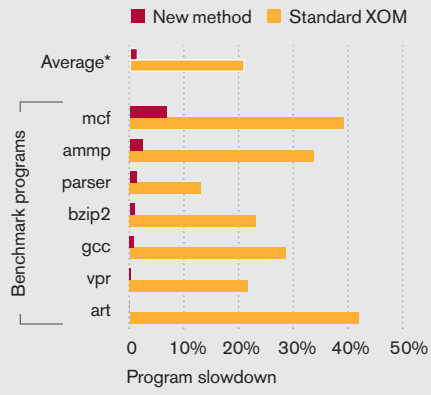
CONTEXT: Many software companies use encryption to protect their programs from tampering or copying, but even those protections can be circumvented by a hacker who's skilled and motivated enough. In a conventional computer, protected software is decoded and stored in memory until the processor calls for it; hackers can tap into decoded instructions as they move from memory to the processor by listening to the channel between the two. Safeguards exist—namely, the XOM (execution-only memory) processor, which keeps information encrypted until it gets to the processor—but systems that use them are painfully slow.

METHODS AND RESULTS: The bottleneck in most XOM systems is the decryption procedure: encrypted instructions are first

fetched from memory, then decoded, then executed. Jun Yang, an assistant professor of computer science at the University of California, Riverside, and colleagues at Riverside and the University of Texas at Dallas use a security scheme called a one-time pad that can start decryption without the data. The new procedure fetches data and starts the decryption in parallel, so that the processor can act on instructions almost as they arrive. In a simulation, the extra time needed for decryption dropped from 20.8 percent of the computation time in current XOM processors to a mere 1.3 percent.

Just as Secure, but Faster

Programs that, say, compress files and compile code run faster with Jun Yang's new method than they do on a standard decryption (XOM) chip.



*OF 11 BENCHMARK PROGRAMS.

WHY IT MATTERS: Until now, the XOM fix caused a performance slowdown of as much as 42 percent. For some applications, like ATMs and other financial systems, it's worth the cost. But for interactive applications like video games, sluggish response times—reminiscent of surfing the Internet in the early days—simply are not acceptable. Yang and colleagues' technique faces sizable hurdles to adoption: devices will need updated software and new processors with extra on-chip memory. Nevertheless, the researchers' method for improving the performance of encrypted software might be the breakthrough required to produce systems that are both secure and fast.

Source: Yang, J., et al. 2005. Improving memory encryption performance in secure processors. *IEEE Transactions on Computers* 54:630–640.

Timing Text

Mobile messaging on cue

CONTEXT: Some text messages, like birthday wishes or driving directions, make sense only in particular contexts. But cell phones send messages immediately, not when they are most timely. Younghee Jung, Per Persson, and Jan Blom of Nokia have now designed cell-phone software that lets senders dictate when and where their text messages should be delivered.

METHODS AND RESULTS: Cell phones already track what time it is, where they are, and who has called recently. Jung and colleagues wrote software that monitors this information and withholds messages until certain delivery conditions are met. They designed a user interface that lets senders choose conditions such as time of day or a recipient's location. Finally, they loaded the software onto phones, gave them to seven Finnish teens, and monitored their use over several weeks.

More than 10 percent of all sent messages used this "context-enhanced" delivery. Just over half of these were triggered by the recipient's location—in, say, the vicinity of a common rendezvous point. Most of the rest specified when a message should be delivered, and many were timed to reach friends when they were in between known engagements.

WHY IT MATTERS: Context-specific delivery could change the way people use cell phones. However, the change could be as much a curse as a benefit. Although the teens' biggest complaint was that they couldn't be sure friends received their messages, the researchers haven't yet identified a way to verify delivery that protects the recipient's privacy. If a phone sends a confirmation when a message is read, it will also reveal where the recipient is. Vendors might also be tempted to send messages that would be delivered as users neared their shops' locations, creating a boom in text-message spam.

Source: Jung, Y., et al. 2005. DeDe: design and evaluation of a context-enhanced mobile messaging system. Paper presented at Conference on Human Factors in Computing Systems. April 2–7. Portland, OR.

Smoothing Out Speech

Internet phones get clearer

CONTEXT: People trying to converse over wireless local-area networks (WLANs)—using them to connect to voice-over-Internet-protocol, or VoIP, systems—are often confounded by the poor quality of the transmission. Those frustrations may soon clear up, thanks to researchers at the University of California, Santa Barbara, who report a method to improve the clarity of VoIP conversations.

METHODS AND RESULTS: Information is sent over a WLAN network in units called packets. But wireless signals can deteriorate over distance, interfere with each other, or otherwise introduce errors into the packets. If that happens, the transmission standard IEEE 802.11 requires that the packets be re-sent. The subsequent delay garbles real-time communication. While zero error tolerance makes sense for e-mail, it might be too strict a standard for voice: Ian Chakeres and colleagues have shown that digitized voice data can

Nokia's cell-phone interface (1) lets users specify times and locations for delivering text messages. A scroll-down menu (2) displays the status of the user's contacts (3, 4).

COURTESY OF NOKIA

suffer some errors without degrading call quality. The researchers used a computer simulation of a network to test reliability. They then combined various network layouts, hardware settings, and traffic scenarios with different levels of permitted packet error and charted the resulting voice drop-out. This gave them the combination that allowed for the highest packet error and the best conversational quality.

WHY IT MATTERS: Users tap into WLANs via handheld devices with radio connections. Because of its ease, low cost, and mobility, voice transmission over WLAN is becoming more common, and video transmission is following suit. But current technology can't yet deliver smooth, clear voice or video communications, a drawback that keeps consumers from adopting it. The researchers' method could help bring WLAN voice, video, and multimedia into the mainstream.

Source: Chakeres, I., et al. 2005. Allowing bit errors in speech over wireless LANs. *Computer Communications* (in press).

BIOTECHNOLOGY

Better Genetic Fix

Precision tools for therapy

CONTEXT: For a genetic engineer, putting an entire gene into a cell is much easier than correcting a few misspellings in DNA. The relatively blunt tools of recombinant DNA are ill-suited for fine tasks like editing specific DNA sequences in living cells. Now, researchers at Sangamo BioSciences in Richmond, CA, have invented the most precise tools to date for altering DNA sequences in living cells.

METHODS AND RESULTS: Michael Holmes and colleagues assembled collections of proteins known as zinc fingers. Different combinations of zinc fingers can recognize DNA sequences of up to 30 letters, which is enough to pinpoint specific spots in the genome. To change the DNA at the intended site, the researchers add an enzyme that cuts DNA and triggers a natural process that repairs breaks in DNA by copying sequences from matching strands. The last part of the DNA-changing machinery is the DNA sequence to be copied. The researchers demonstrated their technique by inserting the DNA-binding machines into human white blood cells that had mutations that cause severe combined immune deficiency. The machines fixed the mutations in nearly a fifth of the cells, a phenomenal success rate.

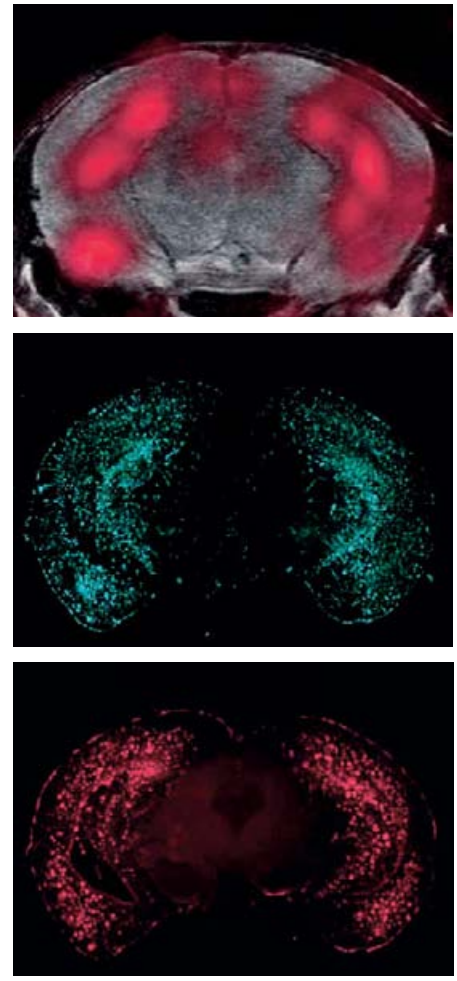
WHY IT MATTERS: Experimental therapies for cancer, transplant rejection, and immune disorders remove blood cells or stem cells, alter their DNA, and infuse them back into the patient. In the past, such techniques have caused fatal side effects because researchers could not uniformly control where those genetic alterations took place. The Sangamo technique avoids this risk by pinpointing exactly where a new DNA sequence will go. It could also effectively erase a gene. Sangamo hopes to turn off a gene for a protein on white blood cells that HIV uses to enter cells. But the benefits go beyond possible therapies: the Sangamo technique promises to become a standard precision tool for biotechnology.

Source: Urnov, F. D., et al. 2005. Highly efficient endogenous human gene correction using designed zinc-finger nucleases. *Nature* (in press).

Watching Alzheimer's

How to image brain plaques

CONTEXT: The sticky plaques characteristic of Alzheimer's disease build up in the brains of patients well before cognitive symptoms appear. But the most reliable noninvasive method for detecting these plaques—positron emission tomography (PET)—is prohibitively expensive and unwieldy, requiring hard-to-handle, short-lived radioactive materials. Now, two groups of researchers have demonstrated more-practical methods for monitoring the plaque development characteristic of Alzheimer's disease. One of them promises higher-resolution images than PET.



Images of plaques in the brains of living mice, made using a dye and magnetic-resonance imaging (top), correlate well with the results of dissection (middle, bottom).

METHODS AND RESULTS: Conventional imaging chemicals do not work well with amyloid plaques because the brain is separated from potentially toxic chemicals in the blood by the blood-brain barrier; nor can the typically water-loving chemicals readily access the fatty plaques. Martin Hintersteiner of the Novartis Institutes of Biomedical Research in Basel, Switzerland, found a dye that crosses the blood-brain barrier in mice and binds to plaques. In a procedure called near-infrared imaging, the dye yields a quantitatively stronger signal as the number of plaques in the brain increases. In a separate study, Makoto Higuchi and colleagues at Riken Brain Science Institute and Dojin Laboratories in Japan found another dye that works in conjunction with magnetic-resonance imaging, a technique common in both research and the treatment of pa-

COURTESY OF *NATURE NEUROSCIENCE*

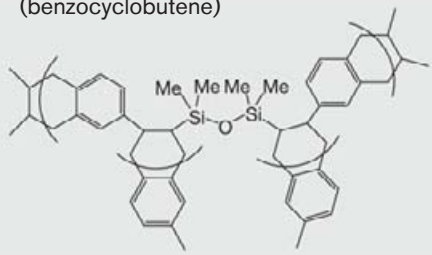
tients. The resulting images correlated well with images of the same mice obtained after staining slices of their brains.

WHY IT MATTERS: Usually, researchers studying Alzheimer's must dissect animal brains to see the effects of treatments. But monitoring a living brain over time would yield much more useful information and might even help in early diagnosis. Because Hintersteiner's and Higuchi's imaging techniques cost as little as a fiftieth as much as PET, and because the chemicals are easier to work with, live experiments once considered out of reach can now be performed on animals—and, with the MRI technique, potentially even people.

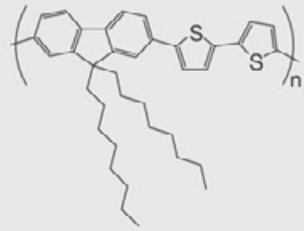
Sources: Higuchi, M., et al. 2005. ^{19}F and ^{1}H MRI detection of amyloid ß plaques *in vivo*. *Nature Neuroscience* 8:527–33.

Hintersteiner, M., et al. 2005. *In vivo* detection of amyloid-ß deposits by near-infrared imaging using an oxazine-derivative probe. *Nature Biotechnology* 23:577–83.

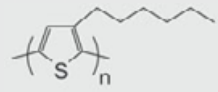
BCB divinyltetramethylsiloxanebis (benzocyclobutene)



F8T2 Poly (9,9-dioctylfluorene-*alt*-bithiophene)



P3HT Poly(3-hexylthiophene)



The chemical structure of a newly fabricated insulator (BCB) lets electrons flow through transistors made from semiconducting plastics (F8T2, P3HT).

NANOTECHNOLOGY

Plastic That Performs

Organic transistors get up to speed

CONTEXT: Organic transistors, which are made from semiconducting plastics, are cheap to manufacture. Although they enable thin, bendable electronics, so far they can't implement the fastest, most efficient circuit designs, because the plastics can't transport electrons. Instead, they rely on a flow of positive charges, or electron "holes," to pass current, which limits their use. Now, in a surprising discovery, Lay-Lay Chua at the University of Cambridge and Peter Ho at the National University of Singapore have shown that the transistors' inability to move electrons is due not to the plastic itself but to an interaction with other materials in the transistor.

METHODS AND RESULTS: In a transistor, current passes through a semiconductor under the control of a gate electrode. The gate electrode is separated from the semiconductor by an insulator, typically silicon dioxide. In conventional silicon transistors, electrons pass through the semiconductor without interacting with the insulator. But in most plastic semiconductors, atoms at the interface between the insulator and the plastic trap electrons, so they can't flow through the transistor. By carefully designing an alternative insulator to replace silicon dioxide, Chua, Ho, and colleagues demonstrated that organic semiconductors can indeed conduct electrons. The discovery could make for simpler, higher-quality organic transistors that can implement the most commonly used designs.

WHY IT MATTERS: Organic transistors can be built using relatively cheap fabrication technologies such as ink-jet printing. The new insulator should let such cheap transistors perform many more tasks. The first application that beckons: electronically active tracking labels known as radio frequency identification (RFID) tags. With the new understanding of organic transistors provided by Chua and his colleagues, fast and cheap plastic electronics could soon be as ubiquitous as ink.

Source: Chua, L.-L., et al. 2005. General observation of n-type field-effect behaviour in organic semiconductors. *Nature* 434:194-9.

Contents under Pressure

Modeling motor oil could lead to lighter, more efficient engines

CONTEXT: Since the late 1930s, zinc dialkyldithiophosphates—or ZDDPs—have been added to motor oils to prevent wear in steel engines, but no one knows why they works so well. The puzzle is more than academic: the auto industry would like to build engines from aluminum, but aluminum wears quickly, and there is currently no antiwear additive that works for aluminum as well as ZDDPs work for steel. Now a group from the University of Western Ontario has developed a computer model that could lead to new additives that make nonsteel engines feasible.

METHODS AND RESULTS: Nicholas Mosey and colleagues performed a quantum mechanical simulation of how zinc phosphates—the molecules created when ZDDPs decompose in oil—react to the intense pressures generated when engine components slide against each other. They discovered that zinc phosphate molecules, when squeezed together, form a dense network that withstands friction created by rapidly moving engine parts. Strong materials like steel can stand up to the high pressures needed to create this network, but such pressures are too much for aluminum. Before the zinc phosphates organize into the protective network, they become very hard—harder than aluminum—and would cause abrasive wear.

WHY IT MATTERS: Using aluminum in engines could boost fuel economy. With an understanding of how ZDDPs work, additives could be designed for aluminum engines, making them more practical.

Source: Mosey, N. J., et al. 2005. Molecular mechanisms for the functionality of lubricant additives. *Science* 307:1612–5.

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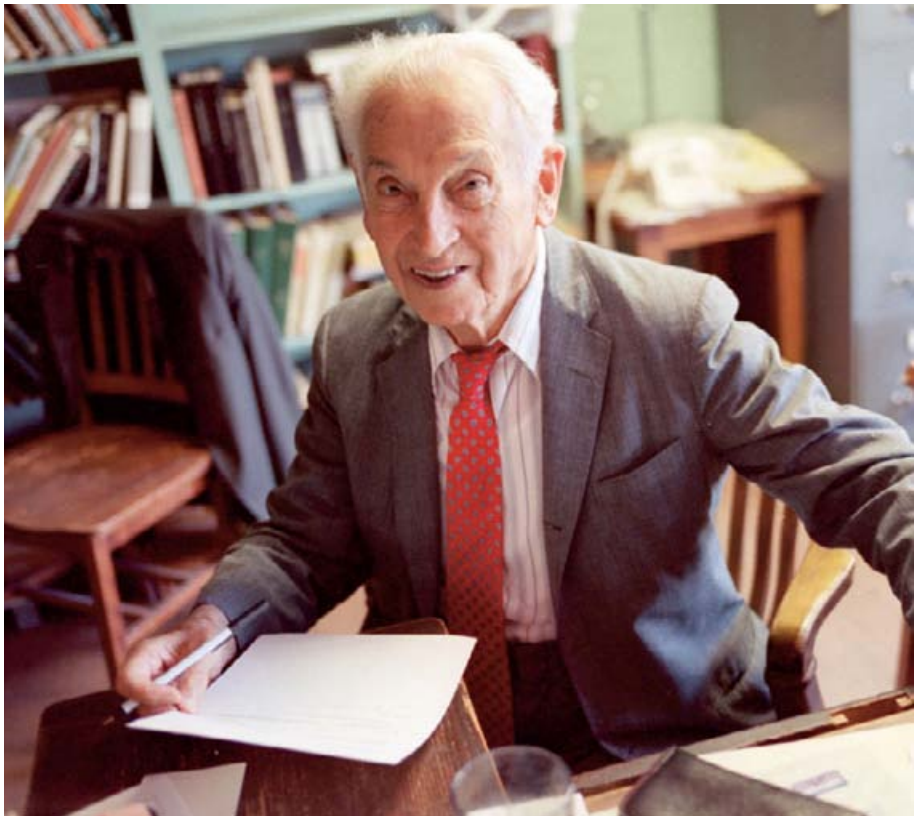

Darwin's Disciple

Ernst Mayr was the leading evolutionary biologist of the 20th century.

BY ANDREW P. MADDEN

Ernst Mayr, a biologist who expanded upon Darwin's theory of evolution, died on February 3 at the age of 100. While he also earned acclaim as an ornithologist, naturalist, and historian of biology during his eight-decade career, Mayr will be best remembered as a champion of evolutionary theory.

Mayr's major contribution came in 1942, when his book *Systematics and the Origin of Species* was published. Here, Mayr laid one of the cornerstones of the then new synthetic theory of evolution, which unified Charles Darwin's theory of evolution by natural selection with Gregor Mendel's theory of heredity. One of the shortcomings of Darwin's theory was that it didn't explain how new species appear. Geneticists who advanced Mendel's theories on heredity, meanwhile, began to look for explanations of speciation at the level of the gene.

Mayr's approach was first to define a species as an interbreeding population that is "reproductively isolated" from another interbreeding population. This improved upon the previous definition of a species as a population whose members share similar traits and characteristics. Mayr then argued that new species arise when a particular population is separated from the rest of its species; genetic mutations eventually make interbreeding with the original group impossible.

Born in 1904 in Kempten, Germany, Mayr enjoyed a career marked by extraordinary good fortune. In the tradition of a family with many doctors, he began studying to become a physician in 1923. But a childhood spent on nature outings with his father, Otto, had also instilled in Mayr a passion for bird-watching. On one solitary expedition near his home, Mayr spotted two rare ducks, red-crested pochards, that had not been seen in Europe in nearly 80 years.

Eager to officially confirm the sighting, Mayr was able through a chance acquaintance to meet Professor Erwin Stresemann, a distinguished ornithologist in Berlin. Stresemann was so impressed by Mayr's intellect that he invited him to spend the summer working at Berlin's Museum of Natural History and eventually convinced Mayr to abandon his medical studies and complete a doctorate at the University of Berlin. In exchange, Stresemann offered to send Mayr on an expedition to collect specimens, in the tradition of Darwin and other naturalists.

Mayr completed his doctorate in 1926, and in 1928, his formative expedition was arranged after he met with Lord Walter Rothschild, who was building a collection of bird skins at his private museum in Tring, England. Lord Rothschild, who was known to get around town in a zebra-drawn carriage, had recently suffered the death of his bird collector in New Guinea; Mayr leapt at the opportunity to succeed him, exploring six New Guinea mountain ranges, collecting 3,400 bird skins, and discovering 38 new species of orchids.

In 1931, Mayr was hired by the American Museum of Natural History in New York. He went on to curate the museum's bird collection until 1953, when he was lured away by Harvard University to become a professor of zoölogy. Mayr remained at Harvard for the rest of his career, establishing his reputation as the preëminent neo-Darwinist and as a scientist of extraordinary intellectual range.

A prominent figure in the field of the philosophy of biology, Mayr criticized what he saw as the excesses of reductionism in biology, maintaining that natural selection acted on individual organisms rather than on individual genes. He formally retired in 1975 but continued his prodigious writing and research right up to the time of his death. ■

KRIS SNIBBE/HARVARD NEWS OFFICE

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