SPECIAL ISSUE

SCIENTIFIC AMERICAN

September 2011
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We have seen a brighter future, and it is urban

INSIDE

How Cities Boost Creativity

The Power of Cyber-Connected Crowds

New Heights for Skyscrapers 10 Years after 9/11

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SCIENTIFIC AMERICAN

Volume 305, Number 3

ON THE COVER

Projections say that nearly 70 percent of the global population will be urban by 2050. Cities face huge challenges, but they are also engines of culture, creativity and economic activity. And some are leading the way to limiting and planning for global climate change. This special issue examines the city's strengths from unexpected angles. Cover image by Christopher LaBrooy.

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The Shifting Urban Landscape
Find exclusive online-only content relating to the feature articles in this special issue, as well as a collection of other articles on cities and urban life.
Go to www.ScientificAmerican.com/sep2011/cities

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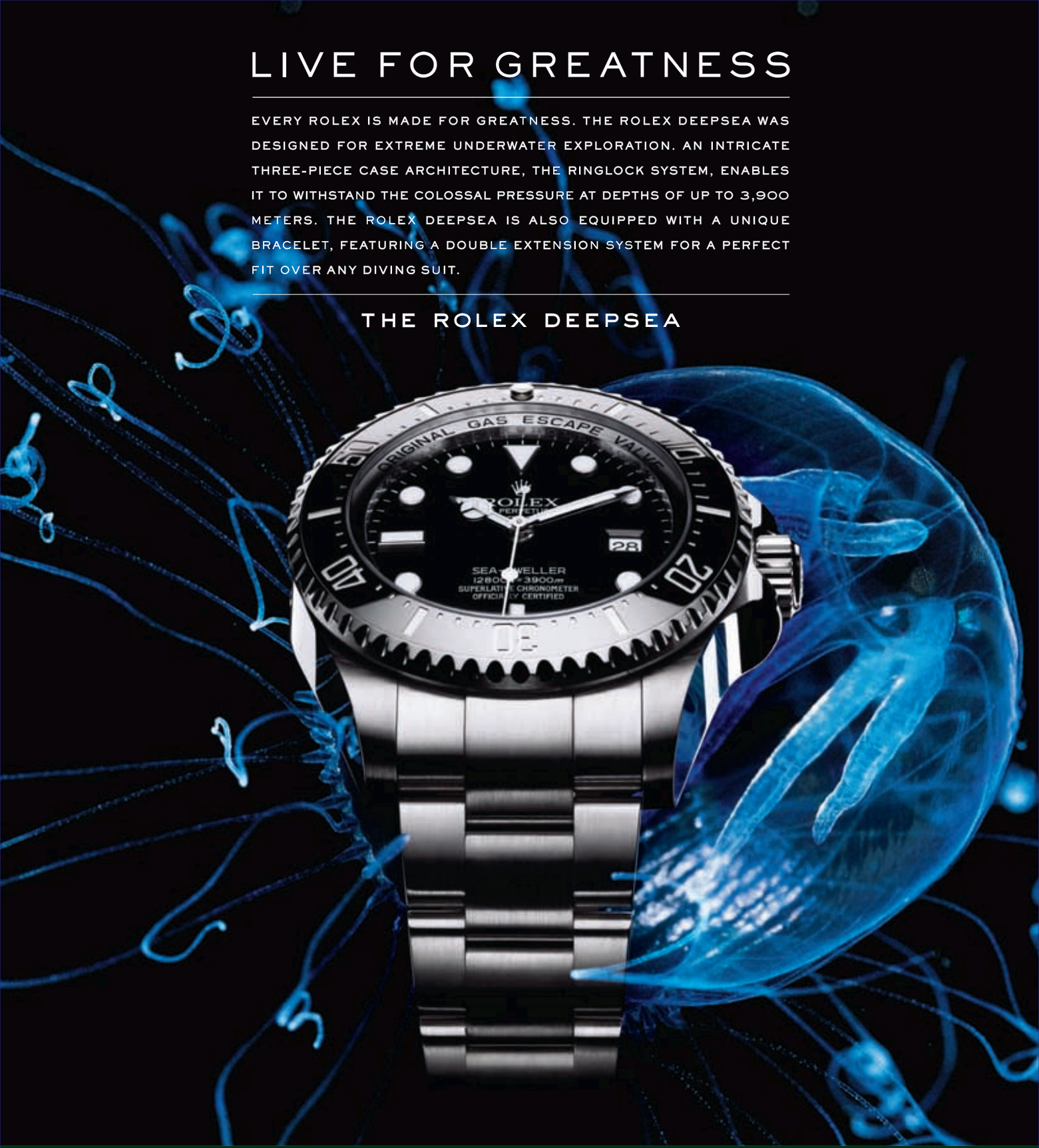

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Mariette DiChristina is editor in chief of *Scientific American*. Find her on Twitter @SAeditorinchief

Left to right: **DiChristina, Shah, Hodge, Bose and Google's Chief Internet Evangelist Vint Cerf.**

City Lights

Everywhere I look are the skeletal steel beams of new skyscrapers rising in a Dr. Seussian jumble of shapes. Everywhere I go is the sound of hammering, the tang of asphalt, the sight of construction workers masked against choking dust and intimidating heat—peaking at 116 degrees Fahrenheit during my visit.

For me, burgeoning Doha, Qatar, on the Persian Gulf beside the punishing Arabian Desert, evoked humankind's continuing hope for a better future against the harsh realities we are grappling with today. Faced with water scarcity and reliance on food imports—and flush with oil wealth that the nation knows can't last forever—Qatar sees science and a "knowledge-based economy" as the ways forward. The country intends to harness its abundant solar energy with photovoltaics, powering both desalination and irrigation of the sandy surroundings. The plan is ambitious. But as this special issue on cities makes clear, the gathering of inventive humans into this urban setting will likely help spur advances. To learn why, turn to page 38 for an introduction to the features.

One way to improve our odds for a better future is to foster a love of science in young people. I saw a reassuring amount of that at the first annual Google Science Fair, where I was chief judge and master of ceremonies for the awards on July 11 in Mountain View, Calif. Students from 91 countries had submitted some 7,500 entries, which were winnowed to 15 finalists in three age categories. My fellow judges—who included Nobel laureate biochemist Kary Mullis, co-inventor of the Internet Vint Cerf, Segway inventor Dean Kamen and New York University nutritionist Marion Nestle—had the difficult challenge of picking the winners.

Three girls drew top honors. In the 13- to 14-year-old age category, Lauren Hodge won for examining different marinades' effects on the production of carcinogenic compounds in grilled chicken. Naomi Shah's studies on common indoor air pollutants' effects on asthma patients got her the award for the 15- to 16-year-old group. Top honors for both the 17- to 18-year-old category and the grand prize went to Shree Bose, who discovered that an energy protein of the cell, AMP kinase, plays a role in developing resistance to a drug commonly used to treat ovarian cancer. Turn to page 22 to see our interview with her. (Full details are available at www.google.com/sciencefair.) Congratulations to the all the participants, as well as to the winners. Looking at these young people during the event, I couldn't help but think: our future is in good hands. SA

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Illustration by Nick Higgins

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CAUGHT TOO EARLY

In discussing the search for better detection of breast cancer in "Beyond Mammograms," Nancy Shute misses one key problem: when tests become too "perfect." As we have learned from our experience in detecting prostate cancer by testing for high levels of the prostate-specific antigen protein, finding cancers at extraordinarily early stages raises new issues. Are we now left to treat cancers that have no clinical relevance? We already often diagnose breast cancers at one to three millimeters in size. Do women with such cancers need radiation and hormone therapy for five years after a lumpectomy? Is performing a mastectomy too radical in such cases? I believe the future of cancer therapy is getting a much better grasp of the malignant potential of these tiny tumors so that we can begin separating out those individuals who can be spared the toxicity of needless treatment rather than seeking new ways to find that first malignant cell.

Joseph P. Imperato
Department of Clinical Radiation Oncology
Northwestern University Feinberg School of Medicine

TRUST WHOM?

In "Trust Me, I'm a Scientist" [Forum], Daniel T. Willingham omits one very important, and seemingly increasing, influence on people's belief in scientists' findings: vested interests. These usually well-financed lobbies loudly deny the validity of scientific studies and findings, proclaim the studies to be "flawed" or produce their own studies, clearly biased and done by their own hired guns, to validate their claims. This is particularly true in such sensitive areas as the environment, global warming and food safety—areas in which studies that could lead to tighter controls would cost the vested interests money.

K. A. Boriskin
Bellingham, Mass.

"Finding cancers at extraordinarily early stages raises new issues."

JOSEPH P. IMPERATO *NORTHWESTERN UNIVERSITY FEINBERG SCHOOL OF MEDICINE*

UNWILLING HEROES

It struck me while reading the issue that two articles mention the use of lab animals in a careless, emotionless and, at least for me, unethical way. In Ignacio Provencio's "The Hidden Organ in Our Eyes," disabled lab mice are described as being bred to solve the puzzle of many mammals' ability to adjust their schedule to night and day without vision; in "Fast Track to Vaccines," Alan Aderem bluntly mentions that "monkeys can be deliberately infected … in studies, whereas it is unethical to do so to humans." I would see a clear role for the editors of *Scientific American* to ask authors to explain why and how many lab animals were used and what approaches were taken to reduce their suffering.

Maurice Lousberg
Sittard, the Netherlands

SUPERWEEDS VS. SUPERCROPS

Jerry Adler notes in "The Growing Menace from Superweeds" that resistance to the herbicide glyphosate in weeds has become a problem. Doug Gurian-Sherman of the Union of Concerned Scientists questions where genetically engineered crops like Roundup Ready soybeans have gotten us and argues that we should return to Gregor Mendel's conventional breeding methods for improving crops.

An expert panel convened by the National Academies recently explored Gurian-Sherman's question. Its conclusion was that, in general, these crops have gotten us "substantial net environmental and economic benefits to U.S. farmers compared with [conventional] crops." The panel also concluded that we could still do better—not by returning to Mendel but by developing other new crops, promoting more sustainable management and conducting additional research on the possible impacts. My own research suggests farmers valued the benefits of Roundup Ready soybeans at around three quarters of a billion dollars in 2008, even with more than half already concerned about weed resistance and with soybean growers planning to manage a third of their crop with additional herbicides.

Given the available research, my guess about the future of agriculture is that glyphosate resistance will become a lesson learned and that genetically engineered crops will become increasingly important.

Terrance Hurley
Department of Applied Economics
University of Minnesota

Adler's characterization of ragweed and pigweed (Palmer amaranth) as monsters is plain silly. These plants are just doing their amazing thing: surviving. Ragweed, for one—and I am allergic—is a wonderful survivor and great colonizer of bare ground. Carl Linnaeus was not kidding when he chose the name *Ambrosia* for it: achene, its nutritious fruit, provides lots of calories to wildlife. So do amaranths, which have been a human food staple as well. We have known about chemical resistance since about five minutes after we started using chemicals to kill pests. (Thank you, genetic diversity!) Yet we are using the same chemicals in ever greater quantities. I say, "Go weeds!"

"sayornis"
commenting at ScientificAmerican.com

ERRATUM

Melinda Wenner Moyer wrote in "Cancer Testing? There's an App for That" [Advances] that a microscope could decipher details as small as 1/1,000th of a meter; the correct value was 1/1,000th of a millimeter.

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NESRIN OZALP'S OFFICIAL TITLE IS PROFESSOR OF MECHANICAL ENGINEERING AND DIRECTOR OF THE SUSTAINABLE ENERGY RESEARCH LABORATORY.

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Qatar Foundation is proud to be home to leaders like Prof. Nesrin Ozalp. Together, we are making Qatar a center of knowledge that is helping the entire world move forward. Learn more about Prof. Ozalp's work and discover the people of Qatar Foundation at qfachievers.com.

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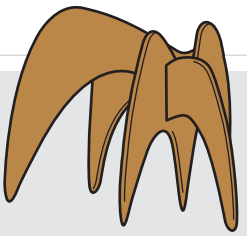

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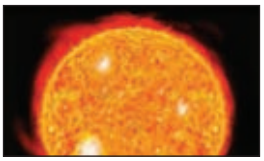

SOLAR SCIENCE

Speaker: Pål Brekke Ph.D.

A Cosmic Voyage Through the Universe

Since the ancients' observations and Galileo's discoveries, humans have been driven to explore the universe. Deep-space finds by sophisticated telescopes and satellites stoke our curiosity. Using imagery from modern space-based telescopes, take a cosmic journey. We'll boldly go where new solar systems are born and visualize black holes, neutron stars, and supernovas.

The Stormy Sun — How Does it Affect our Technology Based Society?

100 years ago, solar storms occurred without humans noticing the damage they caused. Today with satellite systems, GPS, and electrical grids vulnerable to solar weather, it's a different story. Learn about the impact of solar weather activity as well as forecasting, early-warning, and prediction resources. Find out what's hot in sun science!

The Northern Lights: A Message from the Sun

What is more beautiful than the aurora borealis dancing across the sky? Spanning the myths and modern science behind the northern lights, we'll discuss coronal mass ejections, the magnetosphere and solar wind, and the Earth's magnetic field and solar particles. Learn where to see this phenomenon that has fascinated through the ages, and how to predict its appearances.

Does the Sun Contribute to Climate Change?

In the last 150 years the Earth has warmed ~0.7°C. In the same period both concentrations of atmospheric greenhouse gases and the level of solar activity increased. Related phenomena? It's not a trivial task to untangle the two. Dr. Pål Brekke summarizes current understandings and discusses his opinion that the future holds surprising answers on why solar activity varies and the relationship of solar activity and Earth's climate.

ALPINE ARCHAEOLOGY

Speaker: Patrick Hunt, Ph.D.

Medicine in the Ancient Western World

What is the the most profound secret about medicine in the ancient world? Arguably, that while deep superstition and ignorance were elements of medicine in antiquity, logic and rationality entered medical practice early on. Egypt, Mesopotamia, Greece, and Rome have long medical traditions. Hear how significant aspects of ancient medicine are surprisingly familiar.

Science in Archaeology: New Perspectives on Old Problems

Ötzi the Iceman was discovered as a frozen 5300 year-old "ice mummy," high in the Alps in 1991. Through Ötzi's case learn how forensic investigations in microbiology, chemistry, physics, and geology help bring ancient wonders to life.

Four Horsemen of the Apocalypse: Climatic Problems, Famine, Disease, War, and Mass Death in History

Human history records apocalyptic cycles of connected catastrophes through environmental or human causation. Through such disasters, humans have always been susceptible to food-supply famine, which brings malnutrition and at times disease. Dr. Hunt discusses history and current work on paleoclimatic environments as a potential model for understanding the multifactorial and interconnected nature of the impact of global warming. Learn why and what big-picture thinking is required.

Tracking Hannibal

Where did Hannibal lead 38,000 infantry, 8,000 cavalry, and 37 war elephants through the Alps in 218 BCE? The mystery of Hannibal's route has consumed archaeologist Patrick Hunt for over a decade. Hear about Dr. Hunt's quest for the route, using scientific, satellite imaging and historical materials, and his own hair-raising explorations of the Alpine passes.

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PARTICLE PHYSICS

Speaker: Frank Linde, Ph.D.

Quantum Questions

Welcome to the world of the infinitely small and the weird phenomena that come with it, like slow-running clocks and anti-particles. Dr Linde leads us through the discoveries, concepts, and studies in the puzzling world of quantum mechanics in a session certain to spark your curiosity about the paradoxes and possibilities quantum physics poses.

Past and Present at CERN

To orient us to the Large Hadron Collider (LHC)'s significance, Dr. Linde recaps the highlights of CERN's "low energy" LEP accelerator which studied the Standard Model of particle physics. Learn how physicists think the LHC experiment will address current challenges in particle physics: the origin of particle masses; the mystery of dark matter and the apparent absence of antimatter in our everyday life.

Particle Physics Matters

What has particle physics done for you today? Dr. Linde discusses the societal benefits of his research. Learn how the particle physics field leads to the development of novel technologies and applications in medicine, information technology, energy, finance and commerce, and more. Find out how basic particle research, whose significance might not be obvious, touches on all our lives.

Astroparticle Physics

Parked at the intersection of particle physics, astronomy, and cosmology, astroparticle physics is evolving rapidly. Dr. Linde guides you through the strange terrain of astroparticle physics research rooted at CERN. Hear how deep-sea neutrino telescopes search for ripples in the space-time fabric itself and how huge cosmic-ray observatories are seeking answers to the big questions.

COGNITIVE NEUROSCIENCE

Speakers: Stephen Macknik, Ph.D. & Susana Martinez-Conde, Ph.D.

How the Brain Constructs the World We See

All our understandings of our life experiences are derived from brain processes, and are not necessarily the result of an event in the real world. Neuroscientists are researching the cerebral processes underlying perception to understand our experience of the universe. Discover how our brain constructs, not reconstructs, the world we see.

Windows on the Mind

What's the connection behind eye movements and subliminal thought? Join Drs. Macknik and Martinez-Conde in a look at the latest neurobiology behind microsaccades: involuntary eye movements that relate to perception and cognition. Learn how microsaccades suggest your bias toward certain objects, their relationship to visual illusions, and the pressing questions spurring visual neurophysiologists onward.

Champions of Illusion

The study of visual illusions is critical to understanding the basic mechanisms of sensory perception, and helps with cures for visual and neurological diseases. Connoisseurs of illusion, Drs. Macknik and Martinez-Conde produce the annual "Best Illusion of the Year Contest" . Study the most exciting novel illusions with them, and learn what makes these illusions work.

Sleights of Mind

Magic fools us because humans have hardwired processes of attention and awareness that are hackable. A good magician uses your mind's own intrinsic properties against you. Magicians' insights, gained over centuries of informal experimentation, have led to new discoveries in the cognitive sciences, and also reveal how our brains work in everyday situations. Get a front-row seat as the key connections between magic and the mind are unveiled!

SCIENTIFIC AMERICAN Travel HIGHLIGHTS

PRIVATE, INSIDER'S TOUR OF CERN

April 20, 2012 — From the tiniest constituents of matter to the immensity of the cosmos, discover the wonders of science and technology at CERN. Join Bright Horizons for a private post-cruise, custom, full-day tour of this iconic facility.

Whether you lean toward concept or application there's much to pique your curiousity. Discover the excitement of fundamental research and get a behind-the-scenes, insider's look of the world's largest particle physics laboratory.

Our full day will be led by a CERN physicist. We'll have an orientation; visit an accelerator and experiment; get a sense of the mechanics of the large hadron collider (LHC); make a refueling stop for lunch; and have time to peruse exhibits and media on the history of CERN and the nature of its work.

This tour includes: • transfer from Basel (end of cruise) to our Geneva hotel (April 19) • hotel (3 nights) — the nights of April 19, April 20, and April 21 • full breakfasts (3) — April 20, 21, and 22 • transfer from hotel to CERN and back to the hotel on April 20 • lunch at CERN • cocktail party the evening after our visit to CERN (April 20) • free day in Geneva; transfers to/from downtown provided (April 21) • transfer to airport for return home (April 22)

The price is $799 per person (based on double occupancy). This trip is limited to 50 people. NOTE: CERN charges no entrance fee to visitors

INSIDER'S TOUR OF THE MPIA

Private tours of Max Planck Institute for Astronomy (MPIA) and the newly opened Center for Astronomy Education and Outreach on April 16, 2012 (mid-cruise) ($275 pp, includes elegant lunch)

We'll board a bus to Heidelberg right after breakfast. Our tour will include a visit to the Max Planck Institute for Astronomy, a presentation at the Center for Astronomy Education and Outreach including a planetarium show about the latest astronomical research done in Heidelberg, followed by a brief visit to the historical instruments of the Landessternwarte founded by Max Wolf in 1898. We'll conclude our excursion with a memorable lunch in downtown Heidelberg.

A FULL DAY IN AMSTERDAM

What makes Amsterdam a perennial favorite? InSight Cruises invites you to find out on a private, full-day tour of "the Venice of the North". Discover the unique charms of Amsterdam as you get oriented with a coach tour of cultural touchstones. Then anchor your vacation album with images from your cruise through the city's tree-lined UNESCO World Heritage canals, getting a superb view of 17th century gabled homes, old bridges, and bicycles and more bicycles. We focus on the finest, savoring an Old Dutch welcome and contemporary cuisine at one of Amsterdam's best restaurants, and then paint ourselves into the scene at the Rijksmuseum with a visit to "The Masterpieces" exhibit. Start your Bright Horizons memories and fun and join us! $275 pp.

In Fairness to Cities

The U.S. needs to level the playing field between city, suburb and countryside

Not long ago New York, Chicago, Boston and Washington, D.C., were poster children for urban decay. But these cities came roaring back: they tapped deep wells of experience in finance, communications and technology to flourish in a globalized world. They illustrate perfectly the power and resilience of the city as brain trust. Although they have their problems, urban areas continue to lure new residents because of the economic, health and educational benefits that accrue from face-to-face social networking. But if cities are so beneficial, then why are U.S. policies stacked against them?

In matters of housing, education, transportation, the environment and social services, existing rules and spending priorities give cities a raw deal. Cheap gas, highway subsides, tax incentives for home ownership, complacency over urban education and the apportionment of legislators all give preferential treatment to suburbs and rural areas. Even national leaders who should be cheerleaders for an evenhanded urban policy have faltered. Barack Obama, the most urban president since Theodore Roosevelt, skewed the stimulus bill toward more dollars for rural America. The five least populated states got twice as much money per capita as the rest.

Antiurban policies hurt denizens not just of downtown urban cores but also of broader metropolitan regions—and, arguably, the nation as a whole. Cities contribute to economic growth out of proportion to their populations. When they are dragged down, everyone pays the price; when they do well, so do their hinterlands. The rebound of Boston, for example, has enriched the entire state of Massachusetts, which depends heavily for its well-being on the new ideas and technologies hatched on the banks of the Charles River.

To be fair, the dividing line between city and suburb is fuzzy, and it would be easy to make too much of the distinction between urban cores and the rest of the country. The real concern is one of imbalance. Analysts have suggested a number of ways to rectify it. First, cap the home mortgage deduction, which represents a subsidy for homeowners (mostly suburban) at the expense of renters (mostly urban). Such a move should be complemented by steps to increase the supply of middle- and low-income apartments in city centers, which have become too expensive for many Americans. Second, raise gas taxes and put in place congestion pricing in urban areas so that society no longer subsidizes driving. These revenues could enhance mass transit, which, despite being more environmentally friendly, now often costs more than driving to work. Third, consider radical steps to fix gargantuan, unwieldy urban school systems saddled with the challenge of educating tens of thousands of rich and poor within their districts. Urban economist Edward Glaeser, who has two articles in this issue, suggests that solutions to such a tall order might come from either the left or right of the political spectrum: a nationwide high-quality school system, as in France, or a serious effort to put in place a voucher system.

Greener than ever: City dwellers tend to have smaller carbon footprints—one of the arguments for an evenhanded urban policy.

GLEN WEXLER *Gallery Stock*

Ultimately, the trouble is that the U.S. political system is rigged against densely populated areas. The system of earmarking funds by Congress means that infrastructure money gets allocated based on political horse trading rather than on the demographics of where people actually live and work. Letting the people of Iowa and New Hampshire always go first in the presidential primary season has much to recommend it—the citizens of those states take their privileged role seriously—but it means that candidates have little incentive to speak to urban concerns such as housing policy or decaying infrastructure.

The basic issue is fairness. Why should government policy favor owning over renting, driving over mass transit, or kids in one school district over another? The current incentives encourage people to settle in the outskirts when they might otherwise prefer to live downtown—a bias that makes little sense even when you leave out its environmental costs. And those costs are enormous. To keep our carbon emissions in check, we will need to edge closer to our neighbors. From the perspective both of simple fairness and of rational, science-based public policy, eliminating the incentives for citizens to spread out should be our goal. SA

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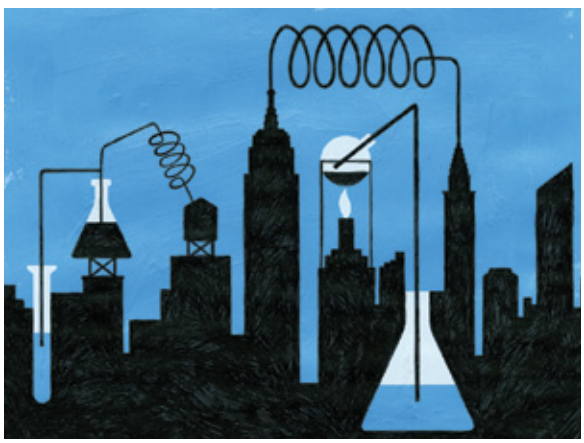
The Best and the Brightest

New York City's bid to attract science talent could serve as a model for other cities

Two hundred years ago it was enough to rely on natural advantages to build a great city. Cities were built on the intersections of rivers or along gentle bays that launched commerce and trade on mighty oceans. Those days are long gone. Today our greatest competitive advantages are the qualities that attract the best and brightest from around the world to come here: our freedom, our diversity, our tolerance and our dynamism.

New York became the world's greatest city because New Yorkers dared to dream it and build it. Today we are looking far into the future once again—and launching one of the most promising economic development initiatives in the city's long history.

This summer we released a Request for Proposals to universities to provide prime New York City real estate, plus up to $100 million in infrastructure upgrades, in exchange for a university's commitment to build or expand a world-class science and engineering campus here in our city.



This is not the first time government has offered land and funding in exchange for university development. In 1862 the U.S. government created a land grant program for the creation of new universities. President Abraham Lincoln and Congress sought to promote innovation and expertise in agriculture and engineering—because they knew those fields were critical to the nation's economic growth. Cornell University, M.I.T., the University of California, Berkeley, the University of Michigan and many other major universities grew out of that land grant program, and along with them came pioneering discoveries that helped America become the world's largest economy.

For most of our history, New York City was the technology capital of the U.S. and of the world. When Robert Fulton built the first commercially viable steamship in 1806, he spawned a shipping industry that would employ countless New Yorkers for generations to come. The discoveries and innovations of Fulton, Samuel Morse, Charles Pfizer and Alexander Graham Bell, among many others, fueled the industries that employed generations of New Yorkers. We became the country's economic engine because our entrepreneurs were the most innovative, and their ideas and investments built our city into a global powerhouse.

But despite that legacy of innovation, like most American cities, New York struggled in the face of fundamental changes to the national economy. In expanding New York's applied science capabilities, what we are proposing is our most ambitious attempt yet to counteract a decades-long economic trend that once threatened the very future of American cities.

Between 1966 and 2001, New York City went from about 800,000 jobs in manufacturing to about 150,000. Three out of every four jobs were lost—most of them middle-class jobs that did not require a college degree. Although New York fared far better than the nation as a whole, at the same time our economic health became ever more dependent on Wall Street's booms and busts.

When I came into office in 2002, we committed to diversifying New York's economy, and when the markets collapsed in 2008 we made a decision to double-down on that strategy. We held meetings with industry leaders in every major sector of our economy to understand what more we could do to help. We asked CEOs, entrepreneurs, university leaders, and other major employers what their key needs were—and the most common refrain we heard was: technology capacity is critical to our growth—and there is just not enough of it here.

In the past several decades, places such as Boston and Silicon Valley had surpassed New York as America's innovation hub. That trend, however, is reversing. Last year we passed Boston to become the second-largest recipient of venture capital funding for technology start-ups, behind only Silicon Valley. Boston leaped ahead of us historically, mostly for one reason: the strength of its research institutions, especially M.I.T. Every year researchers there develop technological advances that are spun off into new businesses. In fact, active companies founded by M.I.T graduates generate annual revenues of about $2 trillion. That's roughly equal to the GDP of Brazil, the seventh-largest economy in the world.

We estimate that in its first 30 years, a new applied science campus in New York could spin off some 400 new companies and create more than 7,000 construction jobs and more than 22,000 permanent jobs. With this important applied sciences and engineering initiative, we will ensure that New York City will be at the forefront of America's innovation economy for generations to come. SA

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Illustration by Thomas Fuchs

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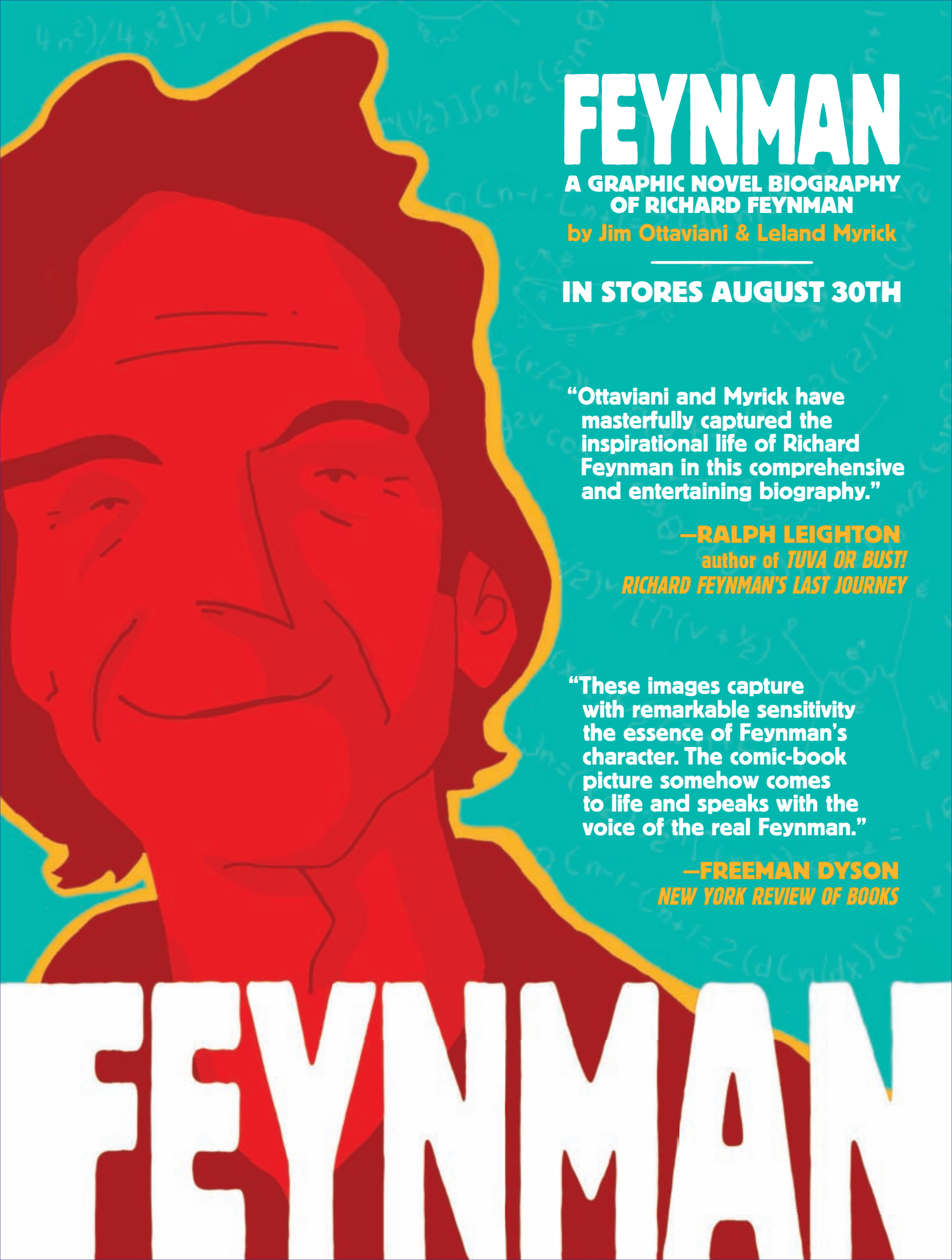
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NEUROSCIENCE

The Stress of Crowds

City dwellers may handle pressure differently from those who live in less populated areas

Urban life can be trying—cars and buses honk, passersby jostle, concrete and brick win out over grass and trees. Researchers have known for decades that residents of densely populated areas have higher rates of mental illnesses, including anxiety disorders and schizophrenia. But do the brains of city dwellers function any differently from those of rural folk? Studies are showing that they do.

German researchers recently asked subjects from large cities, small cities and the countryside to undergo a standard psychological stress test—doing arithmetic under time pressure—while having their brain imaged with functional magnetic resonance imaging. Current city living, testing found, correlated with a boost in activity in a brain region called the amygdala, which is associated with memory and emotional intelligence, with a particularly large effect in people from big cities. Even more surprising, subjects who had grown up in a city showed higher activation of a brain area called the anterior cingulate cortex, essentially the amygdala's boss, even if they had later moved to the suburbs or country. The findings were published this past summer in the journal *Nature*. (*Scientific American* is part of Nature Publishing Group.)

Both the magnitude and the specificity of the effect are surprising, says Andreas Meyer-Lindenberg, director of the Central Institute of Mental Health in Mannheim, Germany, and the study's lead author. But he does not yet understand why these brain regions were more active in urbanites under stress. Another recent study suggests that the amygdala and anterior cingulate cortex become activated when one's personal space is invaded. "Maybe it has to do with crowding," Meyer-Lindenberg says.

The activation could reflect the neural machinery involved in managing human interactions, suggests Lisa Feldman Barrett, a psychologist at Northeastern University. She recently correlated amygdala volume with the size of a person's social network. Does a larger or more strongly activated amygdala help you remember new people?

Knowledge of the underlying mechanism should help investigators answer this and other questions more quickly. Traditional epidemiology requires large numbers of subjects to identify broad effects, such as the link between urban life and mental illness. But now researchers can study smaller groups of subjects to see how specific factors—for example, noise in the home or proximity to a green space—play into mental illness and, more broadly, urban stress. Meyer-Lindenberg calls this newer field "neuroepidemiology." That, in turn, could help city planners determine which design features would provide the most solace.

—Alla Katsnelson

CHRISTIAN SCHMIDT *Gallery Stock*

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MEDICINE

New Help for Smokers

An antinicotine vaccine is moving closer to regulatory approval

As any smoker can tell you, quitting is relatively easy. The hard part is avoiding relapse—the urge to light up weeks or even months after you have supposedly kicked the habit. The patch, the gum and all the other tricks smokers use to get through the first few months are often powerless against those later urges.

That is one reason why an antinicotine vaccine now wending its way through clinical trials has public health officials so excited. Like all vaccines, NicVAX, made by NABI Biopharmaceuticals, works by stimulating the body's immune system to produce antibodies against a certain target—in this case, nicotine. Because immune responses are generally lifelong, the vaccine makers say it could serve as a long-term antismoking aid.

Normally nicotine molecules are small enough to evade detection by the immune system. They are even small enough to slip past the blood-brain barrier and bind to receptors on brain cells, where they trigger a chemical cascade that leads to addiction. NicVAX floods the body with nicotine molecules that have been chemically attached to large, carrier proteins, forcing the immune system to recognize and deploy antibodies against the cigarette ingredient. Then, when ordinary nicotine molecules enter the system, those antibodies bind to them, making them too large to cross the blood-brain barrier.

The vaccine doesn't work for everyone. An earlier trial showed that 16 percent of heavy smokers who were vaccinated and had high antibody levels remained abstinent from cigarettes one year after quitting, compared with 6 percent of the placebo group. Those who produced high antibodies but did not quit cut their smoking in half, from around 20 cigarettes a day to 10.

Results from wider, or "phase III," trials are expected as early as September. For these studies, researchers recruited 1,000 smokers who consume at least 10 cigarettes a day. The volunteers received five to six injections spaced roughly one month apart and were asked to quit after 14 weeks, when around 80 percent of subjects have high antibody levels. (Why 20 percent of subjects fail to produce a high antibody response to the vaccine is unclear.). "The idea is to ensure that when we tell them to quit, they have the tools—the antibodies—to help them," says NABI CEO Raafat E. F. Fahim. He and his team have yet to determine how long patients will need to get shots.

If results from the phase III trials are as good as everyone expects, the vaccine could hit pharmacy shelves soon after. Meanwhile researchers are already at work on other antiaddiction vaccines, including one against cocaine that employs the same strategy as NicVAX.

—Jeneen Interlandi

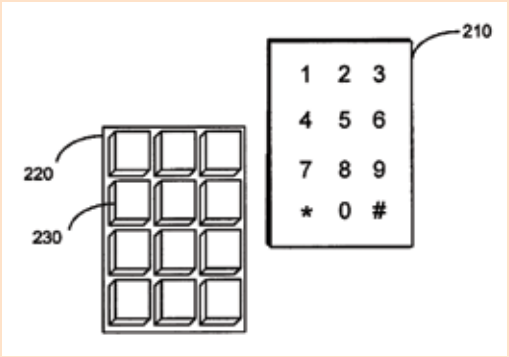
MARTIN DIEBEL *Getty Images (cigarettes);* COURTESY OF U.S. PATENT AND TRADEMARK OFFICE *(keypad)*

PATENT WATCH

Haptic computer interface: It's great that your smartphone allows you to dial a cell number or adjust the volume on your favorite song just by tapping the screen, but it's something of a one-sided relationship. No matter where you tap, it feels the same; no tactile feedback whatsoever. Don't you ever hanker for something more?

A proposed interface from Verizon would change the smartphone experience. The idea, described in patent No. 7,952,498, is to create a mechanical apparatus below the screen that could elevate discrete portions of the surface in the shape of any graphic displayed in the pixel grid. Need to call home? A keypad would sprout in the shape of phone buttons. Want to skip a track on that Beatles album? Pause and fast-forward controls would rise up. Not only would these elevated portions provide more sensory stimulation, they would make keys easier to distinguish from one another, cutting back on mistakes. "What you would feel is a subtle, raised area on the screen," says George Higa, a user-interface designer at Verizon who was recently granted the patent. The patent does not specify what Verizon would use to elevate the buttons on the screen, but "technology moves so quickly, it could be any number of things," Higa says.

Researchers have demonstrated the ability to provide tactile feedback with an array of pins, air jets and an electric current. "Haptic feedback," or feedback that is based on the sense of touch, "is the future of computing interfaces," says Allison M. Okamura, a professor of mechanical engineering at Johns Hopkins University.



But creating that feedback on a pocket-size gadget remains challenging. Researchers at Northwestern University have designed a device called the TPaD that can ultrasonically vibrate the screen, making delineated portions feel "slippery" and allowing programmers to modulate the friction on different parts of the screen, Okamura explains. But last she knew, the smallest of these devices was six inches high and a couple of inches thick. "While it would be terrific to have a device like the one [Verizon] describes, I just don't know how it would fit into a phone," Okamura says. *—Adam Piore*

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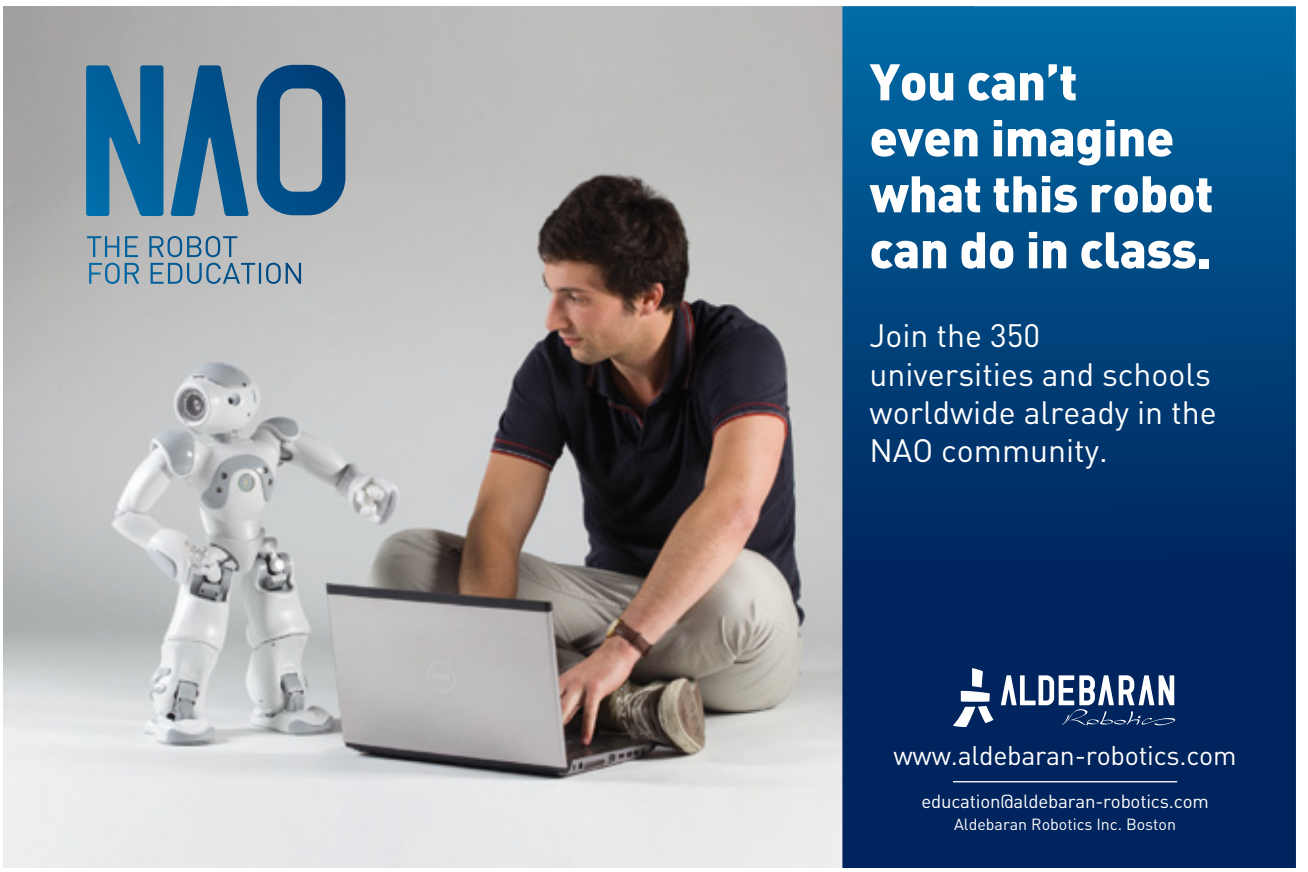
WHAT IS IT?

A hole in the sky: Anyone who has ever seen a streaky line of vapor, known as a contrail, behind a high-flying aircraft knows that airplanes can produce their own clouds. But in rarer cases, aircraft can also punch round holes, such as the one over Antarctica pictured here, or carve long channels through existing, natural clouds. Those formations arise from the strong cooling effects of airflow over a plane's propeller blades or a jetliner's wing. A study published recently in the journal *Science* reports that cooling can spontaneously freeze water droplets in the cloud and stimulate precipitation. The phenomenon requires a specific set of cloud conditions and is thus unlikely to have significant large-scale effects, but it could affect regional weather near airports. —*John Matson*



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EDUCATION

Her Summer Pastime? Cancer Research

High school student Shree Bose discusses her win at the first Google Science Fair

PROFILE

NAME
Shree Bose

AGE
17

TITLE
Senior, Fort Worth Country Day School

LOCATION
Fort Worth, Tex.

How did you hear about the Google Science Fair?
I did science fairs before, but it was mostly the "cut paper out and paste it on a board" sort of thing. And I saw this little ad on the Google home page introducing the first ever Google online science fair. And so I thought, well, I love Google and I love science fairs, so maybe this could work for me.

What was your project's focus?
My project was about finding a link between this protein in the cell called AMP kinase, which is an energy protein of the cell, and the development of drug resistance of ovarian cancer cells to this drug called cisplatin. Basically, we found that this protein might be playing a role in cancer cells becoming resistant to the drug.

That would actually mean that for a patient with ovarian cancer who first responded well to treatment but then came back years later with a resistant strain of the disease, if we added in an AMP kinase inhibitor, we could boost the efficiency of their drug therapy almost back up to where it was when the cells were still responding to the drug.

What drew you to this topic?
Well, two summers ago, actually, my grandfather passed away from cancer. I had already known I wanted to do research, but I didn't know what field, and that just kind of decided it for me. I knew I wanted to go into cancer research.

Where did you do this research?
I worked at the University of North Texas Health Science Center. It's a graduate school for biomedical sciences in Fort Worth. I e-mailed professors there, and one accepted me. Her name is Dr. [Alakananda] Basu. She specializes in breast and ovarian cancer, so she made me do some background research. We came up with this project, and I put it all together. And she allowed me to work in her lab all summer. So I was really lucky to find her.

You spent your whole summer working on this project?
It took about three months, and then I worked a little bit on weekends, but I'm already a high schooler who doesn't sleep. So that did not help. I spent all summer, and I spent over 40 hours in the lab every week, but it was worth every second.

Do you plan to pursue higher education in the sciences?
Yes. I want to major in biology, I hope, as an undergrad, and then my dream job would be an M.D./Ph.D., which is a medical researcher, where I could combine treating patients by being a physician with coming up with the treatments for the patients as a researcher. But if that falls through, I would love to just be a doctor and make the world just a little bit better.

Other than a scholarship award of $50,000, a free trip to the Galápagos Islands and an internship at CERN in Geneva, what will you take away from this year's Google Science Fair?
The one thing I will always remember are the other finalists. [These 14 people are] the most incredible minds that I have ever had the pleasure of meeting. And I am sure that I will definitely be friends with a lot of these people, if not for my entire life, then definitely for a really long time.

—John Matson

Winning: Bose before and after claiming two trophies, one for her age group.

ANDREW FEDERMAN

COMMENT AT ScientificAmerican.com/sep2011

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FOOD

Cooking That Sucks

Vacuum pumps in the kitchen

Nature, famously, abhors a vacuum. But some cooks have learned to feel differently. Step through the swinging doors at the back of a top restaurant like Alinea in Chicago, and you may find vacuum pumps being used to reduce cooking juices into concentrated sauces, to distill essential oils from fruits and vegetables, to dehydrate chips or to brew coffee.

Many of these techniques originated in chemistry laboratories or industrial food-processing operations, and the equipment involved still evokes the bench scientist more than the top chef. But with all those Erlenmeyer flasks, innovative cooks have discovered ways to achieve culinary feats that are impractical by any conventional means.

Consider the common problem of concentrating the flavors and aromas that are in a dilute liquid mixture, such as a broth. The old-fashioned method—a long stovetop simmer to boil off the water—allows many of the most piquant and fragrant compounds to escape with the steam. The kitchen may smell great—but at the cost of a duller sauce. A lengthy sit over the heat also chemically alters many of those compounds that remain, so they no longer taste or smell fresh. A vacuum-reduction setup does a better job because it uses low pressure, rather than high heat, to accelerate evaporation. Pour the liquid into a Pyrex flask that has a side port and connect the flask to a vacuum pump with a rubber hose. Then drop in a magnetic rod, stopper the flask and put it on a hot plate, which uses a spinning magnet to stir and gently warm the broth while the pump reduces the air pressure inside the flask. As the pressure drops, the boiling point of the liquid falls as well; the goal is to sustain a mild, low-temperature boil.

A tomato consommé

RYAN MATTHEW SMITH *Modernist Cuisine LLC*

That relatively simple setup greatly reduces chemical changes, but it still permits some aromatics to escape through the hose. A more expensive and complex bit of gear, called a rotary evaporator, can capture those vaporized essences and condense them back into liquid form. The cooks at our research kitchen in Bellevue, Wash., use this technique to concentrate apple juice, cabbage juice and vinegar to make a fantastic red coleslaw. Concentrated watermelon juice is also a delight.

—W. Wayt Gibbs and Nathan Myhrvold

Myhrvold is author and Gibbs is editor of Modernist Cuisine: The Art and Science of Cooking *(The Cooking Lab, 2011).*

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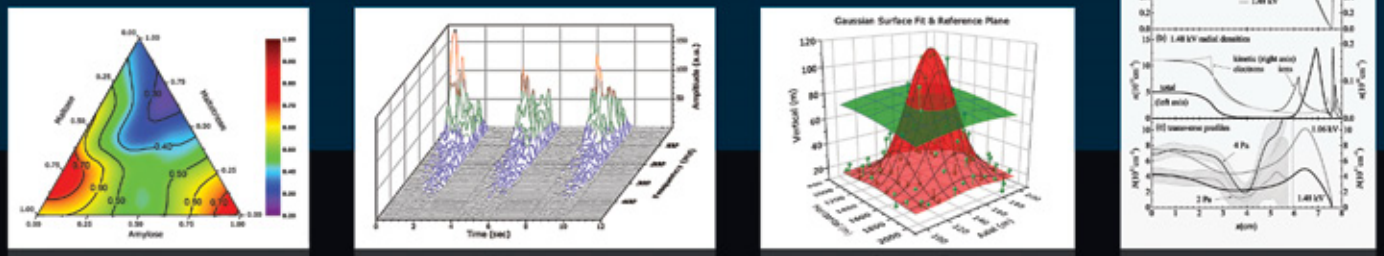

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PHYSICS

Can You See Me Now?

A new x-ray technique may herald improved baggage screening and mammograms

X-rays can help reveal anything from bombs hidden in luggage to tumors in breasts, but some potentially vital clues might be too faint to capture with conventional methods. Now a new x-ray technique adapted from atom smashers could resolve more key details.

Conventional x-ray imaging works much like traditional photography, relying on the light—in this case, x-rays—that a target absorbs, transmits and scatters. To make out fine details, one typically needs a lot of x-rays, either over time, which can expose targets to damaging levels of radiation, or all at once from powerful sources such as circular particle accelerators, or synchrotrons, which are expensive.

Instead physicist Alessandro Olivo of University College London and his colleagues suggest imaging an object by looking for very small deviations in an x-ray's direction as it moves through that object. Their idea is to take such x-ray phase-contrast imaging, which has been used in synchrotrons for more than 15 years, and use it with conventional x-rays.

The scientists rig conventional x-ray sources with gold grates that are 100 microns or so thick—one in front of a target and one behind it. The holes on one grate do not line up exactly with the holes on the other, meaning x-rays that passed in straight lines through the first grate would get filtered out by the second, lowering background noise. The detector then analyzes only the photons that deviated in direction as they passed through the object. This can lead to at least 10 times greater contrast than conventional imaging—"all details are more clearly visible, and details classically considered very hard to detect become detectable," Olivo says of findings reported recently in *Applied Optics*. Whereas bombs are usually visible in conventional x-ray imaging, they can be confused with other materials such as plastics or liquids. The scientists are now pushing imaging sensitivity even further with new grating designs and are working on 3-D scanning techniques by coming at the target from multiple angles.

This system can generate images in just seconds, far quicker than other x-ray phase-contrast techniques, which cannot exert as much power during scanning and thus require minutes, says radiation physicist David Bradley of the University of Surrey in England, who did not take part in this study. But it remains unclear if this system could work fast enough for security scanning, says materials scientist Philip Withers of the University of Manchester in England. Withers does think the technology could lead to better medical imaging, as well as improvements in detecting defects in materials used in aerospace work.

—Charles Q. Choi

Olivo's x-ray of a chive plant

COURTESY OF ALESSANDRO OLIVO ET AL. *University College London*

ANTHROPOLOGY

The Shape of a Nose

Cold-weather noses may function differently from those that evolved in hot and humid climates

Scientists have long been interested in the relation between a nose's form and its function. New research is showing that climate may have played an important role in how the nose's internal structure evolved.

Researchers in Germany recently showed that individuals from cold, dry climates, such as Greenland or Siberia, had higher and narrower nasal cavities than those from hot, humid climates, such as Papua New Guinea or Gabon. The German team, led by Marlijn Noback of Eberhard Karls University of Tübingen, took computer-aided measurements of the nasal cavities of 100 skulls representing 10 human groups living in five different climates. They found that the nasal cavities of cold, dry climate populations are relatively high and show a larger and more abrupt change in diameter in the upper part of the cavity than those of hot, humid climate populations. Her research was published online in the *American Journal of Physical Anthropology* this past June.

This narrowing of the nasal passage enhances contact between the air and the mucosal tissue, which helps to warm and humidify that air, Noback notes. Cold, dry climate populations also show a relatively longer nasal cavity, giving this population more space in which to bring incoming air in line with body temperature. Microscopic hairs called cilia, which line the nasal passage, help to keep out pathogens and dust that may infect or irritate the lungs, and the cilia work more efficiently when incoming air is moist. "Proper heating and humidification of air in colder climates are important for respiratory health," says paleoanthropologist Nathan Holton of the University of Iowa. In warm-climate-adapted populations, inhalations are not directed toward the narrow upper part of the nasal cavity for warming. So "people from warm climates, moving into cold climates, could be more susceptible [to] colds and related diseases," Noback says.

Which sort of nose do you have? Although you can't tell much about the external shape of the nose when looking at its internal structure, a narrow, longer internal cavity is generally linked to a relatively narrower and more projecting nose, Holton says. ***—Joan Raymond***

Illustrations by Thomas Fuchs

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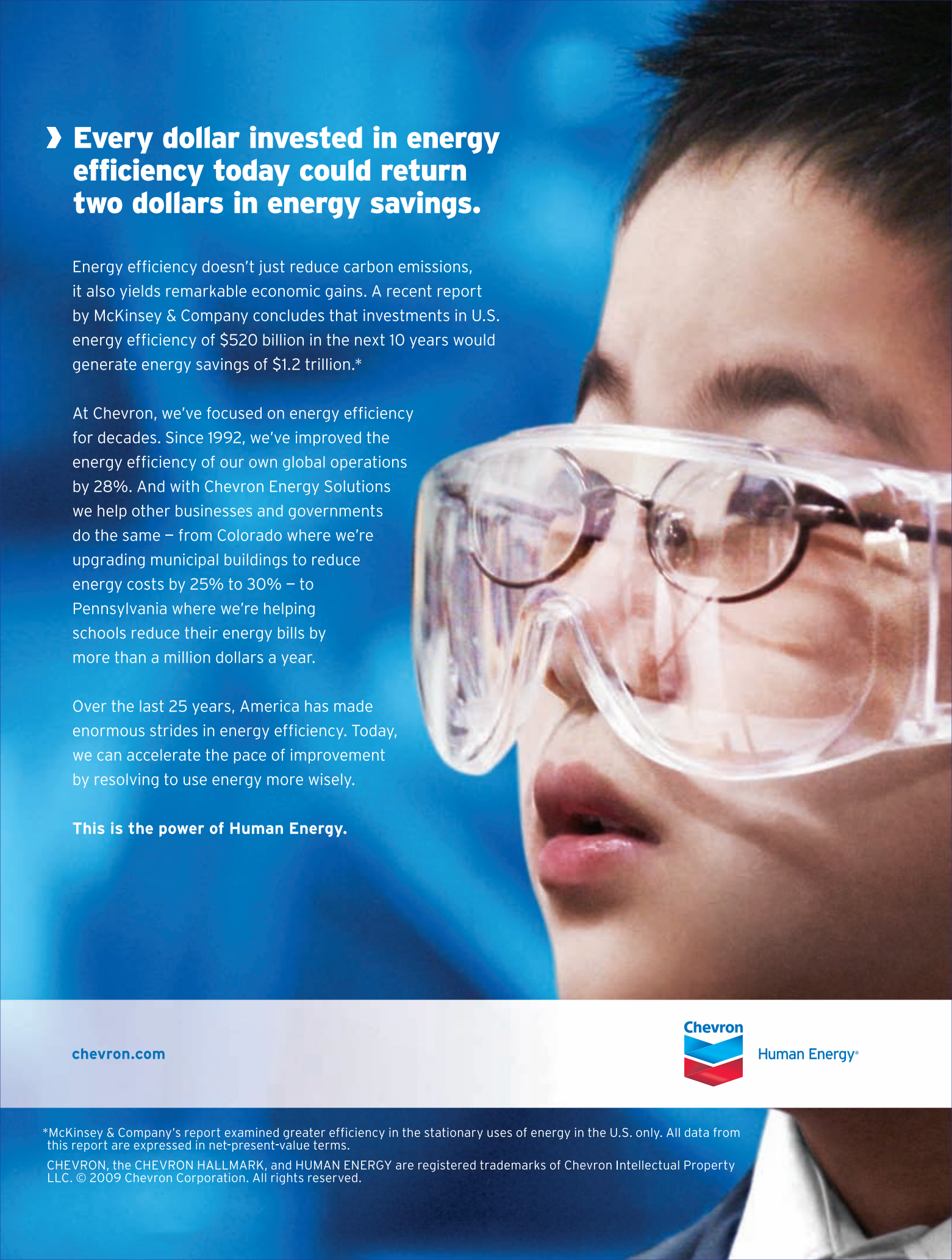

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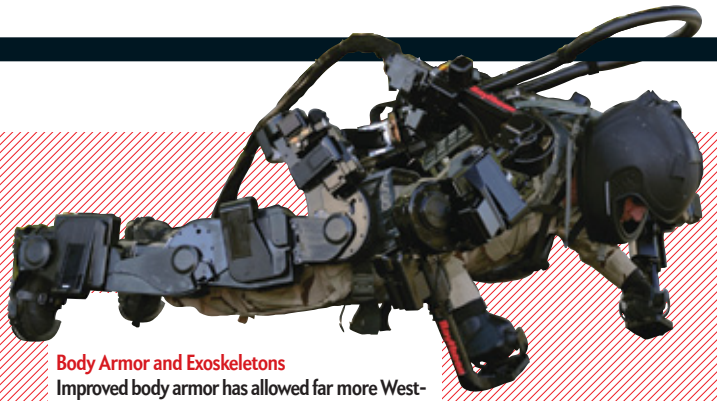
TECHNOLOGY

After Shock and Awe

All the gear $1.3 trillion can buy

Since the attacks of September 11, Congress has approved nearly $1.3 trillion for military spending. Much of that money has gone into mounting Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom. But some of the funds have been used to dream up and develop futuristic-sounding military devices such as exoskeletons. SCIENTIFIC AMERICAN looked at some of these new and emerging technologies.

—Larry Greenemeier



Body Armor and Exoskeletons

Improved body armor has allowed far more Western troops serving in Afghanistan and Iraq to survive improvised explosive devices (IEDs) and direct-fire engagements. Now Raytheon, Lockheed Martin and other defense contractors are developing hydraulic-powered exoskeletons that soldiers will wear to ease heavy loads while increasing strength and endurance.

Smart Grenade Launcher

About the size of a rifle, the XM25 Counter Defilade Target Engagement System has been used in Afghanistan since late 2010. The weapon fires bullets with microchips that can be programmed to detonate when they reach a specific distance.

Satellite-Guided Parachutes

Delivering food, water and ammunition to troops in the mountainous regions of Afghanistan is a challenge. That's why the military developed the Joint Precision Airdrop System (JPADS), a steerable parachute with an onboard computer and GPS, deployed in 2006.

Unmanned Aerial Vehicles

UAVs are used to perform surveillance, reconnaissance and attack missions in Afghanistan, Iraq and Pakistan. The biggest advance since 9/11 has been the ability to control UAVs with a joystick and computer monitor thousands of kilometers from a combat zone. Next-generation models will vary in size from as small as a bee to as large as a dirigible.

Missile-Guidance Systems

Thanks to improvements in accuracy and a doubling of missile range, the U.S. and its allies can now "destroy a particular corner or room of a house with a rocket fired from 70 kilometers away," says Kristian Gustafson of West London's Brunel University.

NEWS SCAN

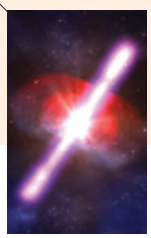
Genius

A major study conducted on twins shows that environmental factors may be at least as important as genes in causing autism.

Because of their "always on" technology, set-top DVRs consume $3 billion of electricity a year—enough juice to power the entire state of Maryland. Cable companies have resisted building in a "sleep" mode, citing costs.

Scientists find more proof that sex is good. Worms that mate rather than reproduce asexually mix genes, which allows them to adapt quicker to environmental changes.

Astronomers spy one of the brightest and longest gamma-ray bursts ever seen, caused by a black hole swallowing a star.



The six crew members of the International Space Station prepared to abandon ship when NASA spotted a piece of space junk hurtling toward them at 29,000 miles per hour.

—George Hackett

Folly

COURTESY OF RAYTHEON (*exoskeleton*); COURTESY OF U.S. ARMY (*grenade launcher*); COURTESY OF MASTER SERGEANT THOMAS GLOECKLE U.S. *Air Force (parachute)*; COURTESY OF LIEUTENANT COLONEL LESLIE PRATT U.S. *Air Force (UAV)*; COURTESY OF LOCKHEED MARTIN (*missile*); MICHAEL BLACKBURN (*Stockphoto (twins)*; COURTESY OF D. BERRY NASA (*gamma ray*); DON BISHOP *Getty Images (button)*

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PSYCHOLOGY

The Pitfalls of Positive Thinking

How rosy thoughts can lead to negative outcomes

From superstar athletes to self-help devotees, advocates of positive thinking—imagining yourself succeeding at something you want to happen—believe it is a surefire way to help you attain a goal. Past studies have backed that idea, too, but now researchers are refining the picture. Paint your fantasy in too rosy a hue, and you may be hurting your chances of success.

One possible explanation is that idealized thinking can sap motivation, as outlined in a study published earlier this year in the *Journal of Experimental Social Psychology*. Researchers asked college student volunteers to think through a fantasy version of an experience (looking attractive in a pair of high-heeled shoes, winning an essay contest, or getting an A on a test) and then evaluated the fantasy's effect on the subjects and on how things unfolded in reality. When participants envisioned the most positive outcome, their energy levels, as measured by blood pressure, dropped, and they reported having a worse experience with the actual event than those who had conjured more realistic or even negative visions. To assess subjects' real-life experiences, the researchers compared lists of goals that subjects had set for themselves against what they had actually accomplished and also relied on self-reports. "When you fantasize about it—especially when you fantasize something very positive—it's almost like you are actually living it," says Heather Barry Kappes of New York University, one of the study's co-authors. That tricks the mind into thinking the goal has been achieved, draining the incentive to "get energized to go and get it," she explains. Subjects may be better off imagining how to surmount obstacles instead of ignoring them.

The approach may also apply to sports. A report published in the July issue of *Perspectives on Psychological Findings* suggests that talking oneself through the fine details of an athletic task may work better than picturing an optimal outcome. "It's positive thinking, plus instructions," says lead author Antonis Hatzigeorgiadis of the University of Thessaly in Greece. *—Alla Katsnelson*

STAT

34 Number of metals that are recycled at a rate of less than 1 percent, out of 60 studied by the United Nations Environment Program

18: Number of metals that are recycled at a rate of more than 50 percent. In a recent report, the UNEP urged consumers to recycle their electronics instead of hoarding them

MARINE BIOLOGY

Less Bang, More Bubbles

Light curtains of air may protect fish from the din of humans

Noise pollution in the oceans has risen dramatically because of an increase in commercial shipping, oil and gas prospecting, and other activities. Evidence is mounting that low-frequency noise from these and other sources can pulp delicate organs in squid, octopuses and cuttlefish.

One way of protecting ocean dwellers would be to raise solid, heavy and potentially expensive barriers around either the sources of sound or the areas one would want protected. Acousticians now think they might be able to use bubbles instead of barriers, and several are experimenting with light curtains of air that absorb and reflect sound waves.

Low-frequency waves have long wavelengths, which means you would need big bubbles—10 centimeters or larger. But freely rising ones—like those pumped into home aquariums—that are wider than about 10 centimeters break up into smaller ones. To keep the bubbles big, investigators encapsulate them in thin latex and string them together like balloons. Tests performed on these latex bubbles inside laboratory tanks show that layers of them could muffle sound by 44 decibels—the difference between a busy city street and a library. Mark S. Wochner of the University of Texas at Austin and his colleagues presented that research at a recent Acoustical Society of America meeting in Seattle. They now plan to test latex bubbles around a barge at a lake in Texas and, down the road, on larger seagoing ships and offshore wind farms.

The bubbles alone may not fully solve the problem. They may dampen sound traveling through the water from above, but about 10 percent of the noise from underwater pile driving would still get transmitted up from the seabed, says acoustician Peter Dahl of the University of Washington. Dahl and his colleagues are analyzing the nature of this sound to find ways of suppressing it as well.

—Charles Q. Choi

COURTESY OF JAMES PIPER *University of Texas at Austin*

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MEDICINE

Cocaine's Newest Risks

A new drug contaminant is causing frightening outbreaks of blackened skin and low white blood cell counts

To the list of cocaine's many dangers, health officials have added at least one more: purpura, a rash caused by internal bleeding from small blood vessels. Two recent papers in major medical journals have documented cases of cocaine users showing up in emergency rooms with patches of blackened, dying skin on the ears, face, trunk or extremities. The condition causes scarring and sometimes requires reconstructive surgery. Noah Craft, a dermatologist at the Harbor-UCLA Medical Center who co-authored a paper on the condition published online by the *Journal of the American Academy of Dermatology* in June, says he now sees about one case per month: "It's become almost routine."

Skin deep: A patient with a purpura rash

The cause of the outbreak is a veterinary deworming medication that has become the most common ingredient used to dilute, or cut, cocaine coming into the U.S. from South America. The drug, called levamisole, was once approved for cancer treatment but was later pulled because of its side effects. Three quarters of the cocaine bricks seized by the U.S. Drug Enforcement Administration now contain levamisole.

Equally worrying is another of its side effects: a sometimes fatal lowered count of white blood cells that are called neutrophils. Doctors suspect that both conditions are allergic reactions to the drug. In one disease, the body's immune system attacks the skin; in the other, it attacks the bone marrow.

Traffickers may add levamisole to cocaine because it is cheaper than pure cocaine and may contribute to the cocaine high. Papers between the 1970s and 1990s, when levamisole was being suggested and then approved for medical use in the U.S., found it improved mood and caused insomnia and hyperalertness, effects that are similar to cocaine's.

For now, the DEA will not change how it pursues traffickers, says Barbara Carreno, an agency spokesperson. But doctors are learning to spot the skin rash quicker. Craft has added photos of his patients to a computerized alert system used by 1,300 hospitals nationwide.

—Francie Diep

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JOHN P. SULLIVAN *Cornell University*

LAB NOTES

One Brainy Fish

An electric fish from the Congo may hold the key to how we move

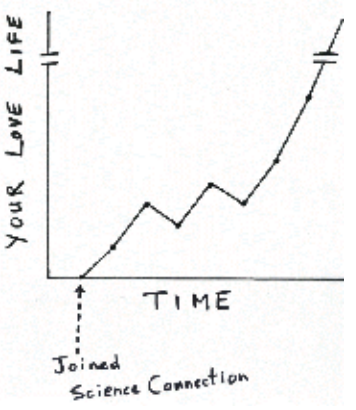
For decades neuroscientists have been building theories of brain function despite a near total lack of data on the most numerous neurons of all: cerebellar granule cells. Making up 70 billion of the nearly 86 billion neurons in the human brain, these relatively simple cells are tightly packed into the cerebellum, a broccoli-shaped structure tucked under the back of our brain. Cerebellar granule cells form part of a brain circuit with a strikingly regular, almost crystalline, structure.

Yet the purpose of this straightforward anatomical arrangement has baffled researchers. In the 1960s a team of neuroscientists, computer scientists and mathematicians theorized that these cells played an important role in the cerebellum's ability to learn motor skills. Several groups of researchers set out to put the theory to the test, imagining that, shortly, our understanding of the brain would take a giant leap forward. But gathering data on granule cells turned out to be not so easy. Their dense packing, small size and location deep in the brain make them difficult to reach with traditional experimental techniques. The theory has gone unresolved for 40 years, casting a shadow over the efforts of cerebellum researchers.

One possible road to discovery has recently come from an unusual source: the electric fish *Gnathonemus petersii,* which has long fascinated neuroscientists because it has a monstrously large cerebellum. By painstakingly recording the activity of individual granule cells with microelectrodes in a living electric fish, neuroscientist Nate Sawtell of Columbia University's Kavli Institute for Brain Science, where I am currently a Ph.D. candidate, has uncovered some of the first direct evidence in support of the 1960s theory that granule cells may enhance the cerebellum's ability to learn skills such as fine movements. Sawtell showed that neurons receiving input from these cells were able to predict the position of the fish's tail based on a combination of motor and sensory signals, a crucial step in the learning of motor skills. Sawtell is one of only a handful of neuroscientists working with this fish, but his results suggest the fish's potential in helping to solve this long-standing mystery.

Knowing the function of cerebellar granule cells could lead to further important discoveries. In humans, the cerebellum's extensive connectivity with the rest of the brain suggests it does far more than learn motor skills: it has been shown to have a part in both perception and cognition, with recent work linking cerebellar dysfunction to such complex diseases as schizophrenia and autism. It's time to start listening to the silent majority of 70 billion, which we are now starting to do thanks to a little electric fish with a huge cerebellum.

—Tim Requarth



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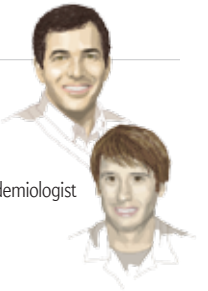

Matthew F. Daley is a pediatrician and researcher at Kaiser Permanente's Institute for Health Research in Denver.

Jason M. Glanz is an epidemiologist at the same institute.

Straight Talk about Vaccination

Parents need better information, ideally before a baby is born

Last year 10 children died in California in the worst whooping cough outbreak to sweep the state since 1947. In the first six months of 2011, the Centers for Disease Control and Prevention recorded 10 measles outbreaks—the largest of which (21 cases) occurred in a Minnesota county, where many children were unvaccinated because of parental concerns about the safety of the standard MMR vaccine against measles, mumps and rubella. At least seven infants in the county who were too young to receive the MMR vaccine were infected.

These troubling statistics show that the failure to vaccinate children endangers both the health of children themselves as well as others who would not be exposed to preventable illness if the community as a whole were better protected. Equally troubling, the number of deliberately unvaccinated children has grown large enough that it may be fueling more severe outbreaks. In a recent survey of more than 1,500 parents, one quarter held the mistaken belief that vaccines can cause autism in healthy children, and more than one in 10 had refused at least one recommended vaccine.

This sad state of affairs exists because parents have been persistently and insidiously misled by information in the press and on the Internet and because the health care system has not effectively communicated the counterarguments, which are powerful. Physicians and other health experts can no longer just assume that parents will readily agree to childhood inoculations and leave any discussion about the potential risks and benefits to the last minute. They need to be more proactive, provide better information and engage parents much earlier than is usually the case.

PERIL OF BUSINESS AS USUAL

Right now pediatricians typically bring up the need for vaccines during the well-baby checkup held about two months after birth. That visit has a jam-packed agenda. In the usual 20 minutes allotted for the appointment, the physician must learn the answers to many questions, of which the following are but a sample: How many times is the baby waking to feed at night? Is the child feeding well? Where do measurements of height, weight and head circumference fall on a standard growth chart? Do the parents know how and when to introduce solid food and how to safely lay the child down to sleep? Are various reflexes good? Can the sounds of a heart murmur be heard through the stethoscope? Are the hip joints fitting properly in their sockets, or are they dislocated?

Generally in the final seconds of the visit, assuming all has gone well to this point, the doctor mentions the required schedule for six recommended inoculations: the first DTaP shot (for diphtheria, tetanus and pertussis, also known as whooping cough), the polio shot, a second hepatitis B shot (the first having been given in the first few days after birth), the pneumococcal conjugate shot (for bacterial pneumonia and meningitis), the HiB shot (for another type of meningitis) and finally the rotavirus vaccine (to prevent a severe diarrheal infection). This is the point in the visit at which more and more pediatricians report a disheartening turn of events: although most parents agree to the inoculations without hesitation, a growing number say they would like to delay or even refuse some or all of the vaccinations for their infants.

A proper conversation that respects the reluctant parents' concerns, answers their questions and reassures them that the inoculations are indeed necessary—that countless studies by hundreds of researchers over many decades have shown that vaccinations save millions of lives—will likely take at least another 20 minutes. Meanwhile, though, other families sit in the waiting room, itching for their own well-baby checkups to start.

This all too common scene should never happen. Having this discussion at the two-month well-baby visit is too late. By then, parents may have read about any issues on the Web or chatted with other moms and dads in the park. Discussion with medical professionals should begin long before, usually during, or even

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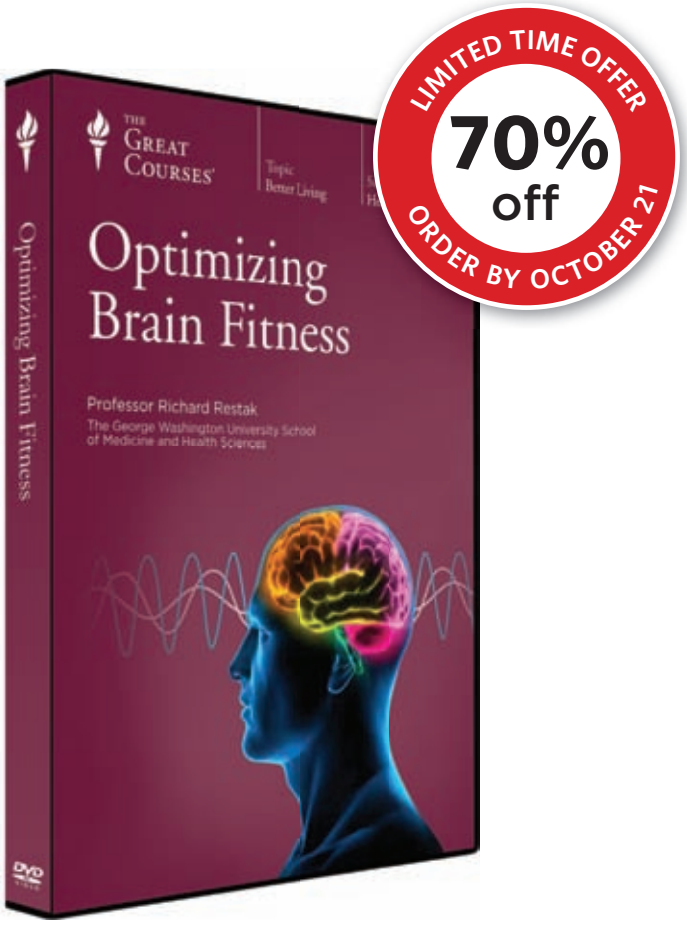

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prior to, the pregnancy. The evidence summarized below should form the basis for these exchanges.

FEARS AND FACTS

Although parents give many reasons for not wanting to vaccinate their children, we have noticed at least three recurring themes. Some do not believe their children are at risk for diseases such as polio, measles and tetanus, which are now rarely seen in the U.S. Others do not believe that certain vaccine-preventable diseases, such as chicken pox and measles, are particularly serious. And many worry about the safety of vaccines. The concerns may be about immediate, well-defined side effects such as fever or may take the form of anxiety that vaccines might harm the immune system or cause chronic diseases years later. Each of these concerns can be met with a careful review of the evidence.

Together we have conducted a series of studies to better quantify the risks of not vaccinating—information that speaks to the mistaken belief that today's children are unlikely to come down with whooping cough, measles or the like if they skip their inoculations. Our investigations looked at hundreds of thousands of children in Colorado and compared the risk of various vaccine-preventable diseases in children whose parents had refused or delayed vaccines, compared with children whose parents had had them vaccinated. We found that unvaccinated children were roughly 23 times more likely to develop whooping cough, nine times more likely to be infected with chicken pox, and 6.5 times more likely to be hospitalized with pneumonia or pneumococcal disease than vaccinated children from the same communities. Clearly, the parental decision to withhold vaccination places youngsters at greatly increased risk for potentially serious infectious diseases. These results also show the flaws in the "free rider" argument, which erroneously suggests that an unvaccinated child can avoid any real or perceived risks of inoculation because enough other children will have been vaccinated to protect the untreated child.

ONE IN 20 PREVIOUSLY HEALTHY children who get the measles will come down with pneumonia.

Depending on fate to soften the blow from an infection is also more dangerous than most people realize. One out of every 20 previously healthy children who get the measles will come down with pneumonia. One out of 1,000 will suffer an inflammation of the brain that can lead to convulsions and mental retardation, and one to two out of 1,000 will die. Similarly, chicken pox can lead to severe infections of the skin, swelling of the brain, and pneumonia. Even when no complications arise, chicken pox is painful and triggers high fevers and itchy rashes. Vaccinated children who develop chicken pox (no vaccine is perfectly effective all the time) usually suffer much milder symptoms.

Even when parents appreciate the peril of not vaccinating, they want to know that vaccines are safe. Because vaccines are given to huge numbers of people, including healthy infants, they are held to a much higher safety standard than medications used for people who are already sick. Nothing in medicine is 100 percent safe, however, and the absolute safety of vaccines cannot be proved. Safety can be inferred, though, by the relative absence of serious side effects in multiple studies.

COMMENT ON THIS ARTICLE ONLINE
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Studying the safety of vaccines is a complicated, labor-intensive process. Fortunately, the U.S. has a sophisticated system, a federally funded program that does not receive any money from vaccine manufacturers. This system can both test specific hypotheses and perform general monitoring of the safety of newly licensed vaccines. As a new theory arises, it can be rigorously tested.

Perhaps the biggest boost to the antivaccine movement came in 1998, when, in a paper in the *Lancet,* Andrew J. Wakefield and 12 colleagues proposed that the measles vaccine could cause autism in susceptible children. In the years since, more than a dozen studies have convincingly shown that vaccines do not cause autism. In fact, it is rare in science that published scientific findings have been so thoroughly, and publicly, disproved. The *Lancet* retracted the Wakefield article in early 2010. Most of the co-authors no longer vouch for the study findings. And Wakefield himself was accused of falsifying the data and lost his medical license.

Despite the complete dismantling of Wakefield's vaccines-cause-autism hypothesis, public skepticism about vaccination has only increased as new speculative theories have been put forward. Maybe, some contend, vaccine preservatives cause long-term problems. Or maybe the growing number of vaccines all assaulting the immature immune system at once causes complications. Or perhaps trouble can arise from a toxic combination of vaccines with air pollution, chemical and metal contamination of the environment, and the increasing stress of modern life.

That this cycle—debunked links followed by ever grander speculation—keeps repeating itself is a clear indication that the scientific community is more reactive than proactive when engaging the public about vaccine safety. Investigating narrow, specific theories about vaccines does not seem to provide adequate reassurance to parents with broad and vague worries about vaccines.

So where does this leave the conversation between health professionals and parents? A good place for talks to begin would be in a prenatal class devoted to vaccines or through Web chats with physicians and vaccine researchers. Web interactions, in particular, might encourage prospective parents to openly air their concerns and raise sensitive questions they may not feel comfortable asking in a face-to-face visit with their child's own pediatrician. Education campaigns should also be carried out. But many moms and dads will still need a forum where they can find accurate information, voice their worries, and engage in a full discussion about the benefits and risk of vaccines. And many will still want their infant's doctor to look them in the eyes and say, "This is one of the best things you can do for your child's health."

The key facts parents need to know, though, are that vaccines prevent potentially fatal diseases, that vaccines have a high degree of safety, and that their safety is constantly evaluated and reevaluated in a system operating independently from the pharmaceutical companies that make vaccines. Unless this message gets spread widely and well, too many doctors and parents are going to find themselves in emergency rooms and isolation wards, watching children suffer with the devastating effects of measles, whooping cough or some other readily preventable infectious disease. SA

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David Pogue is the personal-technology columnist for the *New York Times* and an Emmy Award–winning correspondent for *CBS News*.

Password Prevented

In a world drowning in absurd security requirements, it's nice to see a few islands of reason

Nobody seems to think much about passwords. After all, isn't their purpose obvious? You need one on your bank account so that nobody else can use your money. You need one on your e-mail account so that strangers can't find out your innermost thoughts.

But I was astonished when my daughter told me that her school has instituted a new security initiative. Student passwords must now be at least eight characters long, must contain letters, numbers and punctuation, and may not incorporate any recognizable English word. And the password must be changed every 30 days.

Can you guess what this password is meant to lock down? The fifth-grade homework-downloading Web page.

That's right. All of that inconvenience, memorization and hassle is intended to make sure some disturbed maniac doesn't read this week's spelling list.

Then there's the video production company I worked with recently, which hired a new tech guy. The first thing he did was to declare the company's network to be unsafe. He decided that workers could no longer choose their own passwords; he would supply them. They would be 12 characters long and consist of alphanumeric gibberish, and they would have to be changed every month. He also blocked chat programs, e-mail attachments and YouTube.

So is the production company more secure? That's hard to say. They haven't had any hacker break-ins—of course, they had never had any before, either. But there is a difference. Now the employees watch YouTube videos on their phones, use Gmail to

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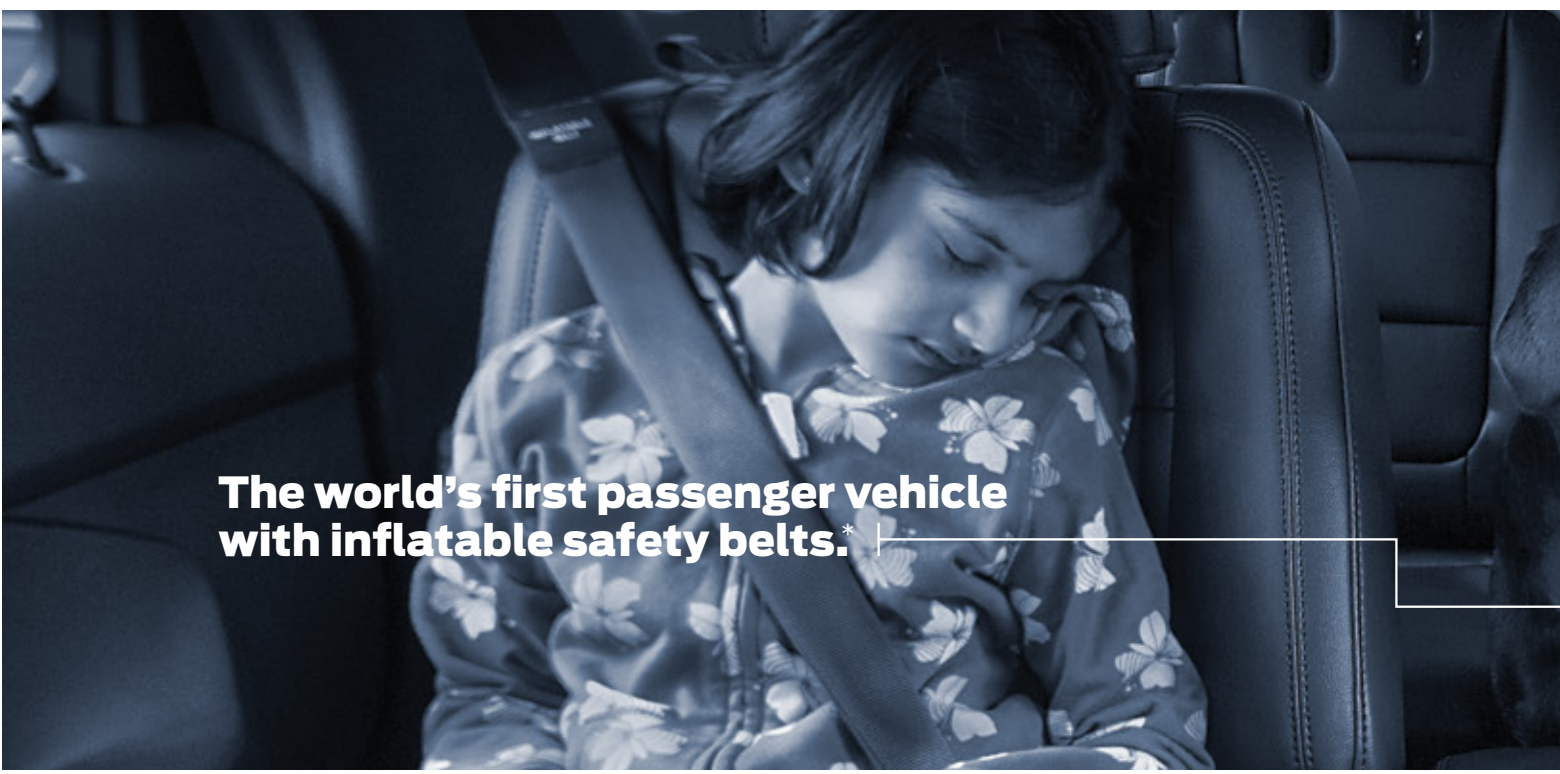

*Optional second-row inflatable safety belts for Explorer.

get file attachments and keep their unmemorizable passwords on Post-It notes taped to the monitor. Nice going, Mr. Security.

My point, of course, is that while it's important to be secure, it's equally important to ask why—and to consider the trade-off between security and convenience. Obscure and harmless entities sometimes get locked up like Fort Knox, punishing nobody but the legitimate users. (Don't even get me started on the Transportation Security Administration.) Other entities, such as Sony, Citibank and Lockheed Martin, are apparently not locked up enough. (Their computer systems were all hacked this past spring.)

It is actually possible to devise a system that ensures both security *and* convenience—if you're smart. For example, if you reserve a room as a member of Omni Hotels's Select Guest loyalty program, you can check in just by walking up to the counter and giving your name. They hand over your key and say, "Good evening, [your name here]. Have a great stay."

They don't ask for your ID. They don't say, "May I have your credit card for incidentals?" They don't tap on their keyboard for five minutes. They don't ask you any questions. No interrogation of any kind. They have your key waiting, and they just hand it over.

How can they get away with such lax security? Couldn't some ruffian pose as you, take your key and crawl into the bed in your hotel room?

It's never happened in the history of the Omni's Express check-in program. Why not? Because the ruffians don't know who you are or that you've booked a hotel room. And if you ever did arrive and find some evildoer in your bed, you would be able to clear up the confusion pretty quickly by showing your ID.

OBSCURE AND HARMLESS ENTITIES sometimes get locked up like Fort Knox, punishing nobody but the legitimate users.

Here's another example: When you buy a program from Apple's online Mac App Store, the program is downloaded and installed on your Mac automatically. You are not prompted for your system password, you don't click through any installer screens, there's no warning about software downloaded from the Internet. It's the height of convenience.

Shouldn't Apple be more worried about security? No, because it's done some thinking. It controls both ends of the transaction. It's not worried about viruses or malware, because it's providing the software itself. It doesn't have to ask you if you want to install the software—of course you want to (otherwise, why would you be buying it?).

Whether you're an administrator, designer or consumer, in other words, it's worth putting some thought into the security/convenience trade-off. Passwords have their place—but it's not every place. SA

THE SMART WAY TO PICK PASSWORDS
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CITIES

SMARTER GREENER BETTER

Street-Savvy

Meeting the biggest challenges starts with the city

By the Editors

IT'S HARD TO PIN DOWN THE PRECISE moment the world's center of gravity shifted. For thousands of years, people lived in the countryside. They worked on farms or in villages, knew little of the world beyond their immediate families and neighbors, and generally got by on their own. Slowly, they began to congregate. It happened in Mesopotamia and Egypt, later in Greece and Rome, and also in Europe and the Americas. More recently, we've seen fast growth in Africa and, most spectacularly, in Asia. And then, by 2008, according to the United Nations, the balance finally tipped: in the ebb and flow of daily births and deaths, the number of people who inhabit the world's cities ticked into the majority, for the first time ever.

The milestone itself isn't nearly as significant as the trend. In the 20th century cities grew more than 10-fold, from 250 million people to 2.8 billion. In the coming decades, the U.N. predicts, the number of people living in cities will continue to rise. By 2050 the world population is expected to surpass nine billion and urban dwellers to surpass six billion. Two in three people born in the next 30 years will live in cities.

Many otherwise lucid thinkers, from Thomas Jefferson to Frank Lloyd Wright to President Gerald Ford, tended to think of

VINCENT LAFORET *stockandmarketarchives.com*

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cities as centers of poverty, crime, pollution, congestion and poor health. In recent years, though, the thinking has shifted along with the demographics. Many experts have come to realize that people are better off when they live in a city. This is not to dismiss the problems of urban life; cities, particularly fast-growing ones in the poorer parts of Asia and Africa, can be places of great human suffering. But even a city slum has benefits that you won't find on the farm or in the village. The move from the country leads, for instance, to dramatic changes for many women. As Kavita N. Ramdas of the Global Fund for Women notes in Stewart Brand's *Whole Earth Discipline* (Penguin, 2010), "In the village, all there is for a woman is to obey her husband and relatives, pound millet, and sing. If she moves to town, she can get a job, start a business, and get education for her children."

Indeed, the city has come to look less like a source of problems than as an opportunity to fix them. Investments in sanitation and water have turned many cities in the developed world from places of disease and pestilence into bastions of health. City folk are at lower risk of death from motor vehicle accidents and suicide by firearms (although they are overstressed). From the standpoint of the metropolis, climate change also seems less intractable. Because city residents rely less on cars and live in more compact dwellings than suburbanites, they tend to leave smaller carbon footprints. The challenge is to extend the efficiency of the urban center to the wider conurbation, embracing the city center, suburbs and satellite towns. Although climate is bigger than any one fix, how we build our cities, and how efficiently we live in them, is going to factor large in our response.

The most hopeful impact of city life may be its effect on the mind. Humans are social animals; we draw stimulation from other minds close at hand. Plato and Socrates both lived in fifth-century B.C. Athens, a city-state. Galileo and Michelangelo lived in Renaissance Florence. Steve Jobs and Steve Wozniak grew up in a western U.S. conurbation that includes Silicon Valley. The young, agile minds at work on the next Big Thing are probably tweeting—they live, as author William Gibson points out on page 88, in a kind of digital meta city. Chances are, they are living in a physical city, too. Technology is reshaping city life and making it more intellectually productive, but it will not soon replace the easy interchange of ideas that comes from casual proximity, the cornerstone of city life.

This issue of *Scientific American* celebrates the city as a solution to the problems of our age. We have tried to present it in the true urban spirit: best ideas forward. SA

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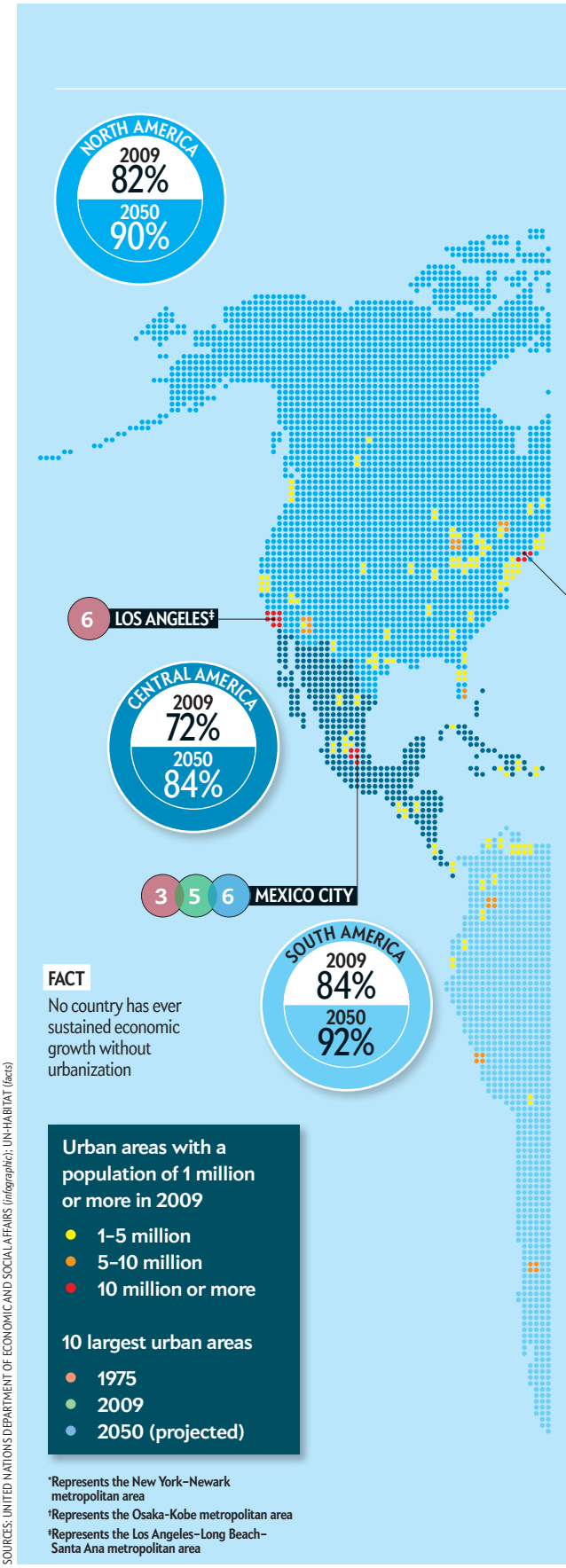
MILLION

The total number of people who have moved out of slums since 2000, according to the United Nations

SOURCE: UN-HABITAT



SOURCES: UNITED NATIONS DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS (*infographic*); UN-HABITAT (*facts*)

Illustration by Aiden Banyon-Mrak

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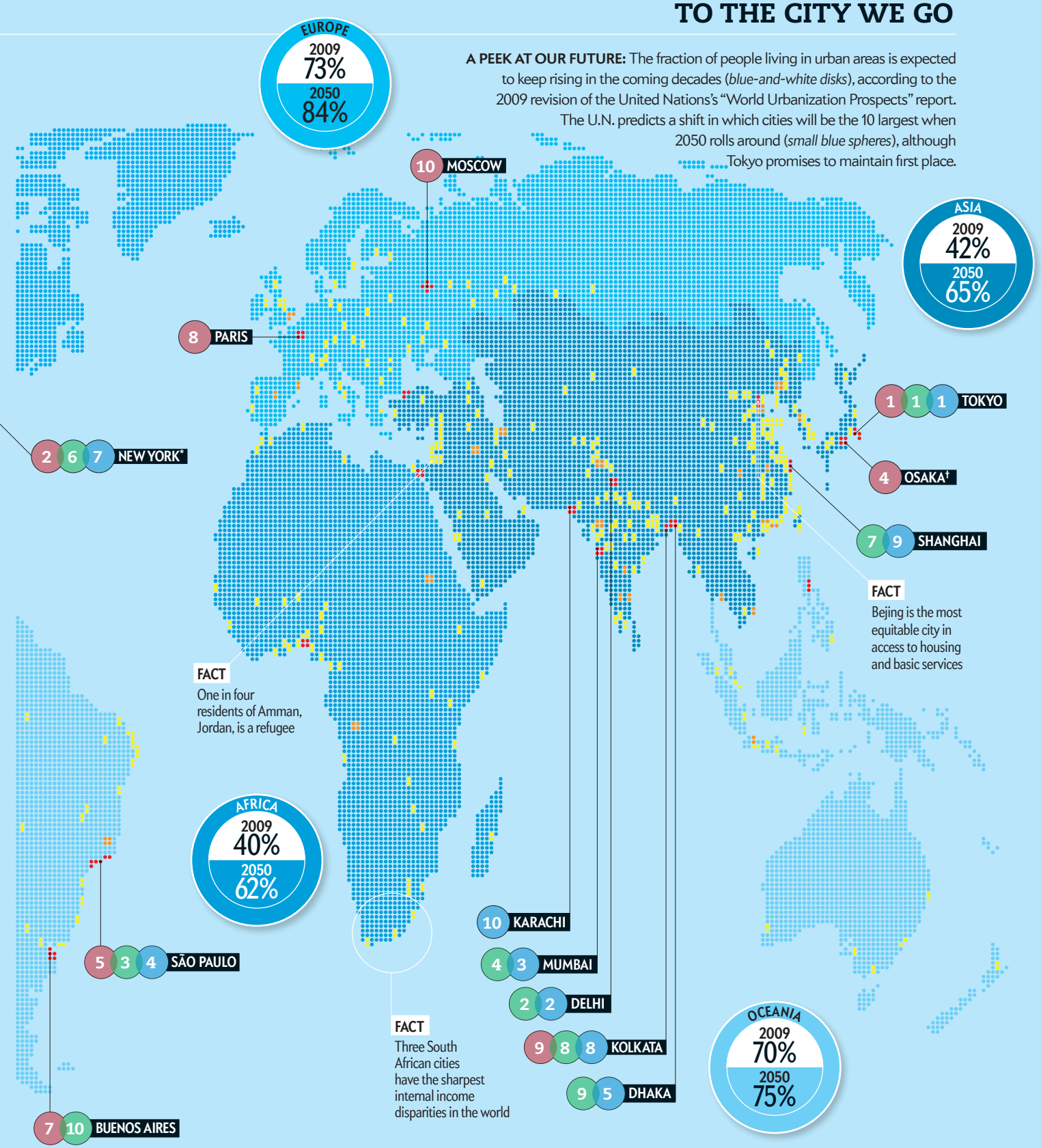
TO THE CITY WE GO

A PEEK AT OUR FUTURE: The fraction of people living in urban areas is expected to keep rising in the coming decades (*blue-and-white disks*), according to the 2009 revision of the United Nations's "World Urbanization Prospects" report. The U.N. predicts a shift in which cities will be the 10 largest when 2050 rolls around (*small blue spheres*), although Tokyo promises to maintain first place.



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The Social Nexus

The best way to harness a city's potential for creativity and innovation is to jack people into the network and get out of the way

By Carlo Ratti and Anthony Townsend

IN BRIEF

Truly smart cities will emerge as inhabitants and their many electronic devices are recruited as real-time sensors of daily life.

Networking the ubiquitous sensors and linking them to government databases can enhance a city's inventiveness, efficiency and services.

On January 25 the streets of Cairo erupted in protest against then president Hosni Mubarak's repressive Egyptian regime. Over the next 72 hours the government shut down the country's Internet service and mobile-phone system in an attempt to squelch the rebellion—to no avail: a rich ecosystem of Facebook conversations, Twitter outbursts and chat-room plans had already unified millions of Cairo's people, who continued the relentless uprising. The government backed down and restored communications to keep the country's economy on life support, but the masses kept up the pressure until Mubarak resigned 14 days later.

Just weeks before, during Tunisia's "Jasmine Revolution," dissident blogger and protest organizer Slim Amamou used the mobile social app Foursquare to alert his friends of his January 6 arrest. By "checking in" to Foursquare's virtual depiction of the jail in Tunis where he was being held, Amamou revealed his location to a global web of supporters and immediately grabbed the international spotlight. The news stories sparked further uprisings, and longtime president Zine El Abidine Ben Ali was soon ousted.

Across the archipelago of places where the "Arab Spring" revolts played out, citizens used new Internet applications and ubiquitous mobile phones to wage a battle over the soul of their cities, shifting resources back and forth from cyberspace to "city-space." Contrast those transformations with a handful of large urban development projects that have been vying to be crowned the model "smart city" of the future. Furthest along is Masdar in the United Arab Emirates, a walled community intended for 50,000 residents in the desert outside of Abu Dhabi, in which every building, streetlight and personal electric "pod" vehicle has been preplanned and preloaded with high-tech gear, largely to maximize energy efficiency. At Masdar, as well as New Songdo City in South Korea and PlanIT Valley in Portugal, real estate developers, global information-technology companies and governments are attempting to build urban centers from scratch that are filled with technologically enhanced infrastructure and services. The designers say their grand conceptions will determine how future cities will be built.

But as models, these top-down projects pale in comparison to the emergent form of intelligence that is bubbling up from millions of newly cyber-connected residents. Truly smart—and real—cities are not like an army regiment marching in lockstep to the commander's orders; they are more like a shifting flock of birds or school of fish, in which individuals respond to subtle social and behavioral cues from their neighbors about which way to move forward. Although the mobs in Cairo and Tunis appeared unruly, their actions resulted from digital coordination of human activity on an unprecedented scale. Hundreds of thousands of people appeared in Tahrir Square in Cairo because

Illustration by Oliver Munday

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Anthony Townsend is research director at the Institute for the Future, a Palo Alto, Calif., think tank that develops strategic forecasts and scenarios. He is writing a book about the future of urbanization and computing for W. W. Norton.

36.7

MILLION

The number of people who live in the Tokyo-Yokohama urban area, the most populated in the world

SOURCE: Demographia

text messages and tweets summoned them—reflecting an immensely powerful, democratic and organic alternative vision of the smart city.

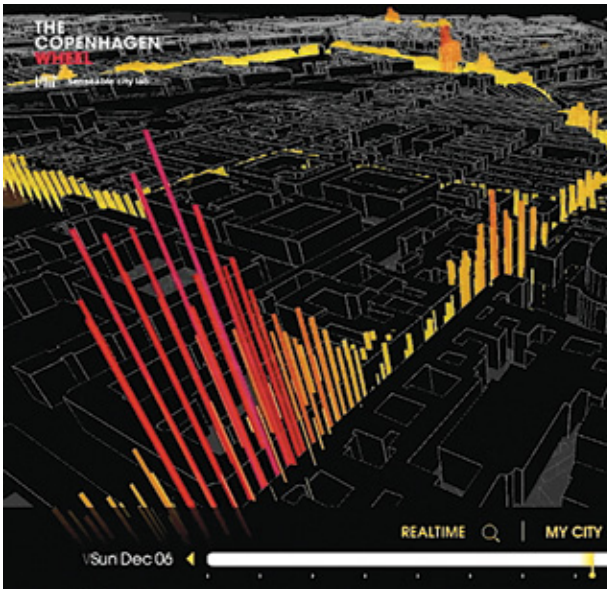
Rather than focusing on the installation and control of network hardware, city governments, technology companies and their urban-planning advisers can exploit a more ground-up approach to creating even smarter cities in which people become the agents of change. With proper technical-support structures, the populace can tackle problems such as energy use, traffic congestion, health care and education more effectively than centralized dictates. And residents of wired cities can use their distributed intelligence to fashion new community activities, as well as a new kind of citizen activism.

GOING BEYOND URBAN EFFICIENCY

WHY ARE COUNTRIES racing haphazardly to implement smart cities? Why is IBM forecasting a $10 billion market in this arena by 2015? What is happening at an urban scale today is similar to what happened two decades ago in Formula One auto racing. Up to that point, success on the circuit was primarily credited to a car's mechanics and the driver's capabilities. But then telemetry technology blossomed. The car was transformed into a computer that was monitored in real time by thousands of sensors, becoming "intelligent" and better able to respond to the conditions of the race.

In a similar way, over the past decade digital technologies have begun to blanket our cities, forming the backbone of a large, intelligent infrastructure. Broadband fiber-optic and wireless telecommunications grids are supporting mobile phones, smartphones and tablets that are increasingly affordable. At the same time, open databases—especially from the government—that people can read and add to are revealing all kinds of information, and public kiosks and displays are helping literate and illiterate people access it. Add to this foundation a relentlessly growing network of sensors and digital-control technologies, all tied together by cheap, powerful computers, and our cities are quickly becoming like "computers in open air."

The vast amount of data that is emerging is the starting point for making efficient infrastructure programmable so that people can optimize a city's daily processes. Extracting information about real-time road conditions, for example, can reduce traffic and improve air quality. In Stockholm's road-pricing scheme, cameras automatically identify license plates of vehicles entering the city center and charge drivers' accounts up to 60 kronor ($9.50) a day, depending on where the cars go. The system has reduced the waiting time for vehicles traversing the central district by up to 50 percent and has reduced pollutant emissions by up to 15 percent. Similar technologies can help lessen water use (one example is being used by the Sonoma County Water Agency in California) and provide better services to citizens.



Two recent projects devised by the Senseable City Laboratory at the Massachusetts Institute of Technology illustrate the intelligence that is possible. Trash Track reveals how garbage flows through a city's waste-management system, indicating how to create a more efficient "removal chain" (as opposed to the supply chain). Electronic tags that transmit information over cellular networks are attached to pieces of trash to see where the items go. In one Seattle test the lab tracked more than 2,000 items, including recyclable materials such as glass, metal and plastic; household hazardous waste such as rechargeable batteries; and electronics such as monitors. Some items traveled across the U.S. (one printer cartridge went 6,152 kilometers!). Some ended up in legally compliant destinations, and some did not. The results reveal ways to minimize carbon dioxide emissions by transporting waste more efficiently. And Seattle could use the information to promote behavioral changes among its citizens, encouraging them to recycle more or to properly dispose of hazardous materials.

The second project, LIVE Singapore, uses real-time data recorded by the myriad communications devices, microcontrollers and sensors found in our urban environment to analyze the pulse of the city, moment to moment. The results suggest new ways to understand and optimize the city, ultimately to help people experience it like never before. LIVE Singapore's open-platform software allows people to develop different applications in a collaborative way. Work has begun on apps that tell commuters how they can reach their homes fastest, how residents can reduce their neighborhood's energy consumption and how inhabitants can get hold of a taxi when a rainstorm is crossing the island and the vehicles all seem to have disappeared.

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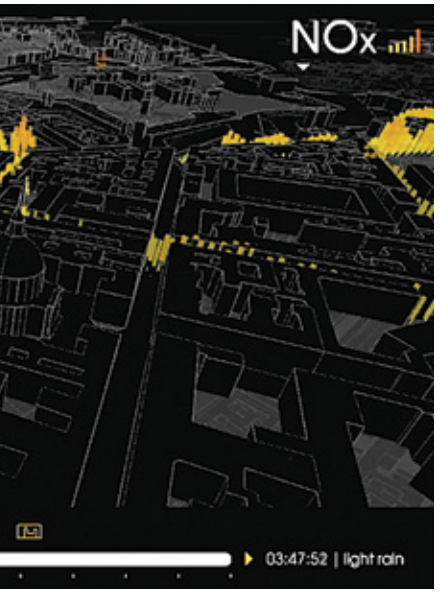

The potential for developing more of this kind of efficient infrastructure is vast—and a good fraction can be unleashed through smart systems. It is thus no surprise that many large corporations, such as IBM, Cisco Systems, Siemens, Accenture, Ferrovial and ABB, are setting their sights on the urban space.

LESSONS FROM THE NETWORKED PAST

IT IS FITTING that Cairo has become a modern model of urban transformation because the ancient world holds the key to understanding what makes cities thrive. The invention of agriculture 10,000 years ago begot the first fixed settlements. As farming produced more food than was needed for survival, towns and villages developed specialized labor forces and institutions. Markets, temples and palaces created social networks organized for commerce, worship and government. Over time the interactions within these networks became more layered and complex. It turns out that sociability, not efficiency, is the true killer app for cities.

Furthermore, although landmark buildings shape our historical understanding of many metropolises, in reality most of the physical stuff in cities was built by everyday people. City building was highly democratized, decentralized, free-flowing and adaptive, just like its social and economic life—a rich tapestry of communal architecture whose design achievements were the result of collective effort rather than celebrity "starchitects."

This organic growth of classical cities holds several lessons for future smart cities. First, by imposing a preordained design, centralized planners often fail to create a city that is tailored to inhabitants' needs, that reflects their culture or that creates the rich mix of activities that distinguishes great places. Centralized plans also make many assumptions about what people want, causing such plans to be brittle in the face of change. So many "smart home" projects have failed over the past few decades precisely because designers made the wrong assumptions about how people would want to integrate technologies into their daily lives and did not build in the capacity to adapt to unforeseen situations.

Second, top-down visions ignore the enormous innovative potential of grass-roots efforts. We have all witnessed how the decentralization of design transformed the World Wide Web into a fascinating milieu for social interaction. By providing finished solutions rather than new raw materials for building the physical and social fabric of smarter cities, top-down designs rob themselves of any capability to invent new ideas for how to make cities better. If we compare the bounty of ideas that have come from city-sponsored app contests such as New York City's BigApps challenges with the vague promises for how high-definition videoconferencing will be used in New Songdo City, it is clear that the biggest innovations will come from the bottom.

Finally, a focus solely on efficiency ignores fundamental civic goals such as social cohesion, quality of life, democracy and the rule of law. Improving sociability through technology, however, does target these needs, while also unlocking new approaches to efficiency. For example, the app Dopplr allows users to calculate and share the carbon footprint of their travel, which may inspire more sustainable behavior.

BUILDING FROM THE BOTTOM-UP

IF WE FOCUS on sociability as the starting point for design and tapping citizens as the source of innovation, how do we go about crafting a smarter city?

An ideal beginning is to leverage the growing array of smart personal devices we all wield and re-

Roll out: Controlled by a smartphone, the Copenhagen Wheel (*red disk*) provides pedal assistance but also sends temperature, humidity, noise and pollution data to a real-time environmental database. Nitrogen oxide levels in Copenhagen are displayed at the left.

COURTESY OF MIT'S SENSEABLE CITY LAB/MAX TOMASINELLI (*bike*); CHRISTINE OUTRAM AND XIAOJI CHEN (*visualization and Web interface*)

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cruit people as the sensors of a city rather than relying only on formal systems embedded into infrastructure. The traffic function on Google Maps is a good example. Instead of building a costly network of dedicated vehicle sensors along roadways, Google constantly polls a large network of anonymous volunteers whose mobile devices report their up-to-the-minute status, which reveals where traffic is flowing, slowed or stopped. The information is delivered to drivers via mobile mapping applications in various ways—as colored overlays indicating traffic speeds, as estimated driving times that account for delays or as a factor in determining alternative routes. These handy data allow users to see the circulatory network of the city in real time and to understand the constantly changing cost in time of getting from point A to point B. Although Google is certainly not a grassroots platform, this example shows how peer-to-peer sharing of sensory data can have a huge impact in helping to manage urban infrastructure. This scenario also shows how smart cities can be both sociable and more efficient without imposing order from above; you choose the best route based on your peers' observations instead of being directed by traffic engineers.

Google's traffic app leverages a large base of existing consumer devices. But bottom-up approaches to sensing can also provide rapid, cheap deployment of new kinds of sensors that measure and record data about people's activities, movements, surroundings and health. As recently as 2009, Paris had fewer than a dozen ozone-monitoring stations. To greatly expand this official data stream, the Green Watch project, overseen by Internet think tank Fing, distributed 200 smart devices to Parisians. The devices sensed ozone and noise levels as their wearers went about their daily lives, and the ongoing measurements were shared publicly through the Citypulse mapping engine. In the first trial more than 130,000 measurements were taken in a single city district. The experiment showed how a grassroots sensing network could be deployed almost in an instant—at dramatically lower cost than expanding the city's archaic fixed stations. The project also showed that citizens could become deeply engaged in environmental monitoring and regulation. Ultimately, sensors for grassroots networks will be built into everyday objects: phones, vehicles and clothing.

Bottom-up approaches are also leveraging the sociability of cities to change patterns of activity. As the booming popularity of local shopping networks such as Groupon and LivingSocial shows, connecting local businesses and city dwellers through mobile social networks is a powerful catalyst for action. These new ways of scripting the city can create more lasting kinds of social touch points, too. The Foursquare mobile social network that Amamou used in Tunis can also turn going out on the town into a kind of mobile game. It crowns the most frequent visitor to every café, bar and restaurant as the "mayor"—a reference to the "self-appointed public characters" described in 1961 by urbanist Jane Jacobs in *The Death and Life of Great American Cities*. Like the corner gossips that Jacobs argued were so critical to neighborhood cohesion and safe streets, Foursquare's mayors remind us that even the most intelligent of digital cities are vital because they are filled with interesting and accessible people.

Another way to put citizens in the driver's seat is to instrument buildings, plazas and even sculptures with embedded sensors and actuators. These devices will create capabilities for passersby to alter how the built city behaves. For example, the Digital Water Pavilion in Zaragoza, Spain, is a public sculpture whose walls are created by jets of water that can display patterns and react to people. As individuals walk through the space, the jets turn on and off, allowing pedestrians to proceed without getting wet.

This programmable world will extend beyond the physical city. Today many municipalities offer telephone hotlines reached by dialing 311 that give citizens rapid access to city government information and services, as well as the ability to file reports about everyday issues. These systems will evolve into wiki-like information repositories that allow citizens to team up and help themselves. For instance, one resident, using Boston's mobile 311 app

Dry passage: Sensors and actuators in Zaragoza, Spain, turn off select water jets as a pedestrian approaches—one example of responsive architecture.

COURTESY OF DIGITAL WATER PAVILION/RAMAK FAZEL

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LET'S GO.

(dubbed Citizen's Connect), responded to a plea for help in removing an errant possum from another Bostonian's garbage can in less than half an hour—well before the city's own Animal Control unit could mobilize to respond. On successfully evicting the critter, the Good Samaritan left a comment on the 311 system that the matter was resolved. As government information systems that enable citizens to add and edit information become more widespread, they will support innovation in how services are delivered and funded in caregiving, education and other nonemergency functions. Successes in online social gaming can provide lessons in how to motivate and reward volunteers. Citizens will have to make sure, however, that city government does not view "crowdsourcing" work from the masses as a convenient way to offload its obligations.

More natural computer interfaces will let nontechies, disabled persons and the illiterate participate more fully in civic life, making it smarter still. Although gestural interfaces that recognize individual faces are new, the Institute for Creative Technologies at the University of Southern California has developed a gestural controller for Gmail that, if combined with speech synthesis and recognition, could allow the illiterate poor, the elderly and the disabled to use e-mail and explore the Web. As these technologies spread to cybercafés throughout poor urban communities, such as the national network of more than 600 *Pontos de Cultura* (culture hotspots) in Brazil's favelas, we will see an urban movement emerge for more inclusive smart services.

Part of what makes cities smart is a system of checks and balances, and networked cities are changing the way citizens monitor city hall. Hyperlocal news sites such as EveryBlock aggregate Web content and public data about individual streets, cover local issues and monitor local government more thoroughly than traditional newspapers or television. Web sites such as Oakland Crimespotting in California enable residents to analyze and create interactive maps of detailed crime data by using information mined from ubiquitous, real-time social media streams and government databases. Crime information systems akin to New York City's CompStat have long allowed police departments to create detailed maps of criminal activity, but better access to crime data will empower citizens to analyze policing and public safety, perhaps leading to different kinds of community policing.

A PLANET OF CIVIC LABORATORIES

IF THE RISK of visions like Masdar is their elitism and singular focus on efficiency, their advantage is clarity of purpose. The bottom-up smart city is a continual work in progress; its organic flexibility is also its biggest flaw. But as civic laboratories for urban innovation, these seemingly chaotic places are becoming part of a global movement. To make rapid progress, we need to build mechanisms for scanning, evaluating and cross-fertilizing good ideas—ways to spread the best methods for crowdsourcing public services or using citizens as sensors, just as we have in the past spread the best ideas for bus rapid transit or bike sharing.

Here is where mayors, architects, planners and technologists might play their most effective role in shaping truly smart cities—by marshaling and integrating the great engineering resources of top-down approaches with the innovation of grassroots initiatives. Governments in cities as diverse as New York City, London, Singapore and Paris are taking tentative first steps by making formerly private government data warehouses public. These resources are empowering entrepreneurs to come up with mobile software applications that meet citizen needs. But it is not clear how the entrepreneurs will sustain these efforts. The grassroots developers bring engagement and creativity to the table, but corporations and politicians are needed to scale and sustain the large systems that the innovations run on. After all, the revolutions of Cairo and Tunis played out on a mobile infrastructure built by Vodafone and other global companies.

It is also up to civic leaders to listen to citizens and together frame their own smart city vision. Every community faces a unique set of circumstances, as well as resources to address them. Some local experiments will morph into "best practices," data sets, computer models and visualizations that can be repurposed elsewhere, but many of the best smart city solutions will be like the best urban experiences: unique, local and unreplicable—as they should be!

SMART CITIES FOR ALL TIME

IS MASDAR REALLY a glimpse into how we will live tomorrow? Or will it suffer the same fate as the machine universe of Fritz Lang's 1927 film *Metropolis*—another vision that will inspire designers but will ultimately fail to materialize? Masdar is perhaps a bit of both. It is providing an effective template for how to use pervasive computing to optimize urban systems, from transport to energy. Yet after five years and more than $1 billion, Masdar is also showing shortcomings of the centralized approach; a large replanning exercise will effectively turn it into a more conventional real estate development. More than smart systems that improve efficiency are needed to make the city "smart."

Taking a more bottom-up view of how cities actually develop gives us an opportunity to radically rethink what intelligent, connected communities of the future could look like and how they can be designed, built and lived in. By empowering people to devise ways to run their daily lives as smartly as possible, we can make their extended community—the actual embodiment of a city—smarter, too. SA

MORE TO EXPLORE

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Planet of Civic Laboratories: The Future of Cities, Information, and Inclusion. Anthony Townsend et al. Institute for the Future, 2010. www.iftf.org/inclusion

Building a Smarter Favela: IBM Signs Up Rio. Greg Lindsay in *Fast Company;* December 27, 2010. www.fastcompany.com

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Animations of smart city apps can be viewed at ScientificAmerican.com/sep2011/ratti

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CITIES

Edward Glaeser is Fred and Eleanor Glimp Professor of Economics at Harvard University, where he also serves as director of the Taubman Center for State and Local Government.

Engines of Innovation

Most of humanity now lives in a metropolis. That simple fact helps to fuel our continued success as a species

By Edward Glaeser

CRIME, CONGESTION AND POLLUTION mar all cities, from Los Angeles to Mumbai. But another force trumps the drawbacks of urban living: cities bring opportunities for wealth and for the creative inspiration that can result only from face-to-face contact with others. In fact, the crush of people living in close quarters fosters the kind of collaborative creativity that has produced some of humanity's best ideas, including the industrial revolution and the digital age. In the years ahead such collaborations can be

CONTINUED ON PAGE 54

Golden Prosperity Building, or the Jin Mao Tower, lords it over Shanghai's 23 million residents.

JOSEF HOFLEHNER *Gallery Stock*

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IN BRIEF

Teleconferencing and virtual meetings of all stripes were supposed to spell the death of distance. Yet the city (home of more than half the human species) continues to flourish.

Things seem to go better with closeness: a deal or relationship is often best sealed only with a handshake or a kiss.

Interchange of ideas that occur in the gargantuan urban swells of the developing world may help forge a pathway out of poverty.

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Bigger Cities Do More with Less

New science reveals why cities become more productive and efficient as they grow

By Luís M. A. Bettencourt and Geoffrey B. West

For centuries, people have painted cities as unnatural human conglomerations, blighted by pathologies such as public health crises, aggression and exorbitant costs of living. Why, then, do people throughout the world keep leaving the countryside for the town? Recent research that is forming a multidisciplinary science of cities is beginning to reveal the answer: cities concentrate, accelerate, and diversify social and economic activity.

The numbers show that urban dwellers produce more inventions and create more opportunities for economic growth. Often large cities are also the greenest places on the planet because people living in denser habitats typically have smaller energy footprints, require less infrastructure and consume less of the world's resources per capita. Compared with suburban or rural areas, cities do more with less. And the bigger cities get, the more productive and efficient they tend to become.

THE POWER OF POPULATION

This new, more quantitative science of cities is becoming possible because of the increasing availability of information—official statistics as well as novel measures of human and social activity—on cities and metropolitan areas worldwide.

By sifting through this flood of data, covering thousands of cities around the world, we have unveiled several mathematical "laws" that explain how concentrating people in one place affects economic activity, return on infrastructure investment and social vitality. Despite the rich diversity of metropolitan regions across the U.S., China, Brazil and other nations, we found a remarkable universality in the way that socioeconomic characteristics increase with a city's population. For example, if the population of a city is doubled, whether from 40,000 to 80,000 or from four million to eight million, we systematically see an average increase of around 15 percent in measures such as wages and patents produced per capita. If eight million people all live in one city, their economic output will typically be about 15 percent greater than if the same eight million people lived in two cities of half the size. We call this effect "superlinear scaling": the socioeconomic properties of cities increase faster than a direct (or linear) relation to their population would predict [*see illustration on opposite page*].

The data also reveal that cities' use of resources follows a similar, though inverted, law. When the size of a city doubles, its material infrastructure—anything from the number of gas stations to the total length of its pipes, roads or electrical wires—does not. Instead these quantities rise more slowly than population size: a city of eight million typically needs 15 percent less of the same infrastructure than do two cities of four million each. This pattern is referred to as sublinear scaling. On average, the bigger the city, the more efficient its use of infrastructure, leading to important savings in materials, energy and emissions.

Our findings also show that these patterns of increased productivity and decreased costs hold true across nations with very different levels of development, technology and wealth. Although we have much more information for cities in richer parts of the world, we are beginning to obtain good data from rapidly developing countries as well, and they seem to fit the same mold. The gross domestic product for cities in Brazil and China, for instance, closely follows the same superlinear curve that western European and North American cities exhibit, though starting from a lower baseline. We believe that the pattern holds true because the same basic social and economic processes are at work, whether in São Paulo's favelas, under Beijing's smog-filled skies or along Copenhagen's tidy streets.

Although urban superlinear scaling, which represents the average, idealized behavior of a city of a given size, prevails around the globe, actual cities deviate to varying degrees from the roughly 15 percent enhancements that come with size. Detailed data covering 40 years show, for example, that San Francisco and Boston are richer than their size would indicate, whereas Phoenix or Riverside, Calif., are somewhat poorer. Curiously, these deviations persist for decades: cities tend to stay remarkably close to their overperforming or underperforming histories. For example, cities that have attempted to improve their lot by creating conditions for the "next Silicon Valley" have often had disappointing results. Our research suggests that certain intangible qualities of social dynamics—more than the development of material infrastructure—hold the key to generating virtuous cycles of innovation and creation of wealth. These processes, such as the development of a spirit of local entrepreneurship, a reputation for cutting-edge novelty, and a culture of excellence and competitiveness, are difficult to design through policy because they rely on the dynamics of a city's social fabric across many dimensions. We expect the results of this exciting area of research will lead to better "recipes" for sustainable socioeconomic development.

What we can say with certainty, however, is that increased population promotes more intense and frequent social interactions, occurrences that correlate with higher rates of productivity and innovation, as well as economic pressures that weed out inefficiencies. In a city with high rents, only activities that add substantial value can be profitable. These economic pressures push urbanites to come up with new forms of organizations, products and services that carry more value added. In turn, higher profitability, excellence and choice tend to attract more talent to the city, pushing rents higher still, fueling the need to find yet more productive activities. This feedback mechanism, in a nutshell, is the principal reason cities accelerate innovation, while diversifying and intensifying social and economic activity.

DENSER BUT GREENER

Although cities create economic opportunities in rich and poor countries alike, people living in wealthier areas find it difficult to imagine why so many inhabitants of poor countries are attracted to places such as Nairobi, Lagos or Mumbai, where newcomers often end up in slums marked by pollution, crime and disease. These appalling conditions, however, should remind residents in developed nations of their own urban past. When Charles Dickens wrote about life in mid-1800s London or when Jacob Riis photographed the Bowery district of New York City's Lower East Side in the late 1800s, each was reporting simi-

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lar circumstances. These cities grew explosively during the 19th century—sevenfold for London and almost 60-fold for New York. Well-run modern cities have demonstrated that pervasive ills are not inescapable. The problems result primarily from nonexistent or poor planning and a lack of good governance. The development of these organizational traits may, in fact, be the most important and long-lasting effect of urbanization because it paves the way for socioeconomic development at the national level.

Some benefits besides wealth and innovation come about even when not legislated. One notable example is the impact of cities on the environment. Quality data are only now beginning to emerge, but we can already see that the largest U.S. cities have the lowest carbon dioxide emissions *per capita*. This gain is mostly an unplanned by-product of people living at greater densities because the bulk of the savings comes from energy-efficient public transportation and simple walking instead of driving, which is almost 10 times more energy-intensive.

Environmental efficiency becomes more challenging for developing nations such as India or China, where much urban infrastructure still needs to be built, although the trade-offs between a need for rapid growth versus the steps to achieve clean growth remain poorly understood. Still, urbanization may ultimately remain the most sustainable solution to our planet's environmental challenges.

Unbridled growth can nonetheless create crises that, in the extreme, could cause a city to collapse unless major innovations are found to stimulate new cycles of growth. In this sense, cities are never in a state of stable equilibrium. They exist in a dynamic balance—a kind of tug-of-war—between the forces that bind them together and those that can potentially tear them apart. That tension is another reason cities drive innovation: many of civilization's greatest inventions have come from dire necessities. Just think of plumbing, electricity and even democracy—not to mention coffee shops.

The ongoing challenge for urban growth is whether human creativity can keep innovating sufficiently fast to sustain ever expanding urban populations while decreasing our per capita consumption of resources and impact on the planet. As long as this trend can continue, cities will grow ever larger and will be the inevitable future of a more creative and prosperous humanity. SA

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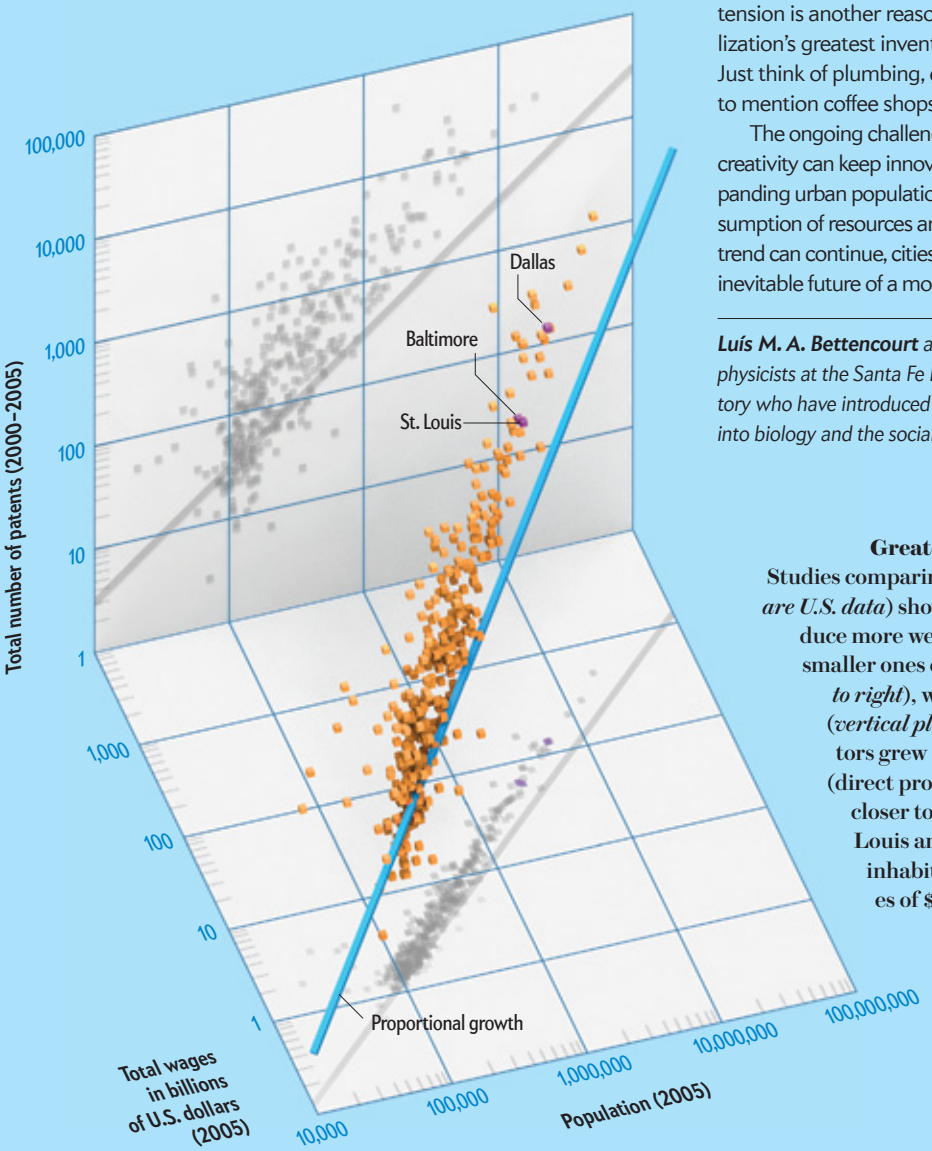

Greater Population, Greater Dividends
Studies comparing metropolitan areas (*orange cubes are U.S. data*) show that, on average, larger cities produce more wealth and innovation per capita than smaller ones do. As city population increases (*left to right*), wages (*horizontal plane*) and patents (*vertical plane*) rise even faster. If these indicators grew only at the same pace as population (direct proportionality), the cubes would align closer to the blue line. A typical example: St. Louis and Baltimore, with about 2.5 million inhabitants each, generate combined wages of $118 billion, yet Dallas, at five million people, has $130 billion in wages.

SOURCES: U.S. BUREAU OF ECONOMIC ANALYSIS (*wages of U.S. metropolitan areas*); U.S. PATENT AND TRADEMARK OFFICE (*data on patents filed between 2000–2005 for U.S. metropolitan areas*); COURTESY OF DEBORAH STRUMSKY AND JOSÉ LOBO

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Graphic by Bryan Christie

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DHAKA
in Bangladesh is the world's most densely populated urban area (35,000 people per square kilometer)
SOURCE: Demographia

HANOI
Vietnamese city predicted to experience the greatest GDP growth between now and 2025
SOURCE: Pricewaterhouse Coopers

CONTINUED FROM PAGE 50

expected to help solve the world's most pressing problems—poverty, energy shortages, climate change—and to promote the type of fundamental political transitions seen in Cairo that recently astonished the world.

Why do cities bring out the best in us? Technology lets us hold virtual meetings, and the Internet keeps us in touch 24/7, but neither can be a substitute for the types of social cues (a facial expression that signals comprehension or confusion) when people meet in an office, bar or gym. Cities deliver the random exchanges of insight that generate new ideas for solving the most intransigent problems [for more on this mechanism, see "Bigger Cities Do More with Less," by Luís M. A. Bettencourt and Geoffrey B. West, on the preceding two pages]. Young workers, whether they are on Wall Street or in Google's New York City offices, succeed by picking up unexpected bits of knowledge from the successes and failures of those around them. It has always been so.

Think of the chain of brilliance that spread throughout the towns of 18th-century England and brought us the industrial revolution. The crucial technology for spinning with rollers started with Lewis Paul and John Wyatt in Birmingham, passed to John Kay and Thomas Highs, and then ended in the hands of Richard Arkwright, thanks to a discussion over a few drinks outside of Manchester. By supercharging the flow of ideas, cities foster economic prosperity, innovation, better health—and even new ways to govern ourselves.

A SUPERHIGHWAY OF IDEAS

THE CONSTANT INTERCHANGE of ideas has helped cities throughout the developing world find a pathway out of poverty and into prosperity. Average incomes reach a level more than five times higher in countries that are mostly urbanized compared with those in which most of the population stays in the countryside. Across districts in India, mean individual earnings increase by about 20 percent as density doubles, even when individual age and education are constant.

As hubs of global commerce, cities also facilitate integration with the world economy. People in developing nations can become prosperous if they can sell their time—transformed into goods and services—to wealthy markets. In essence, cities connect poor countries with rich markets.

One example is telling. N. R. Narayana Murthy, one of the billionaire founders of Indian software giant Infosys, graduated in the 1960s from the University of Mysore and the Indian Institute of Technology Kanpur, but in those years an Indian engineering degree could not guarantee a high income. Murthy started working at Patni Computer Systems (now iGATE Patni), whose founders had lived in the U.S. and understood how to work with the American appetite for software. The founders took their knowledge back to India and, joined by Murthy, set up a back-office operation in Pune to serve U.S. companies, thereby linking Indian talent and American markets.

In 1981 they started their own software company and netted their first U.S. client in 1982. A year later they moved to Bangalore to work with a German spark-plug producer that wanted Infosys nearby. Almost 30 years on, Infosys is a flat-world phenomenon that has made billions of dollars for its founders and has trained thousands of Indians in Bangalore, helping them to become more prosperous by selling their engineering talents worldwide. That success has also rippled through the food chain in Bangalore to the service providers in local restaurants and taxis, which translates into jobs for thousands of other Indians.

Another small-world sensation emerged not far from Hong Kong. Shenzhen had little industry in 1980, during the then rigidly controlled People's Republic of China, when it became a special economic zone intended as a magnet for foreign investment in manufacturing. Tax breaks and exemptions from trade regulations encouraged such investment. Manufacturers were drawn by the obvious opportunity to make goods with inexpensive Chinese labor; workers came because factory jobs offered far more economic opportunity than life in rural China. Pepsi was the first American company to move into Shenzhen in 1982, bottling soda for Hong Kong consumers at a fraction of Hong Kong wages. Other international companies followed, making toys, handbags, sneakers and, ultimately, more sophisticated products. Today the area has nine million people and the McKinsey Global Institute, McKinsey & Company's economic and research arm, predicts that it will be the world's 10th-largest urban economy by 2025.

HEALTHY IDEAS

CITIES CAN BREED health as well as economic productivity. Today life expectancy in New York is more than a year higher than the national average. It isn't entirely clear why older New Yorkers are healthier. Some people credit walking; others talk about social connections made possible by density. But among younger people, the reasons are no mystery. Motor vehicle accidents and suicides are two primary killers of people younger than 35 years, and both are far less common in cities. In New York City the death rate from motor vehicle accidents is more than 70 percent lower than in the country as a whole. Taking the subway after a few drinks is just a lot safer than driving drunk. Cities can also make humankind healthier by producing knowledge. John Snow, a founder of epidemiology, had his great breakthrough in 19th-century London when the city itself provided the in-

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formation he needed to understand cholera. By studying the urban map of a cholera outbreak, he was able to connect the disease to a water pump and grasp the connection between polluted water and infection. More recently, early breakthroughs in AIDS occurred when Parisian researchers perceived the pattern of infection within that city. The knowledge that cities can provide is often the best weapon against disease.

The cities of the developing world are not yet healthy, in part because their governments have been unable to provide the basic infrastructure that cities need. Still, cities themselves may supply their own solutions. Often they are where the seeds of revolution against bad government sprout, and living contiguously facilitates the coordination that enables citizens to create reform movements that rise up and oust dictators. Urban uprisings do not always end in stable democracies, but most stable democracies benefited at some time from an urban uprising.

Europe's first modern republic—the Netherlands—had its roots in centuries of popular rebellions in the wool-making towns of Flanders, such as Brugge. In the central square of Brugge stands a statue of a weaver and a butcher, urban artisans, who are celebrated not for their crafts but because they helped to organize their fellow guild members in the fight against French royal rule. On May 18, 1302, they organized an urban insurrection, now called the Brugge Matins, and massacred the French knights occupying their town. Almost two months later Brugge's disciplined artisans and their allies demolished the flower of French chivalry at the Battle of the Golden Spurs.

These victories did not produce a republican government for centuries, until the fire of the Reformation, which had spread across the cities of northern Europe, added an extra religious reason to rebel. In 1556 the Low Countries had passed into the hands of the Spanish Hapsburgs, who attempted to tax and regulate these urbanites. Cities once again managed to coordinate action: first, an orgy of iconoclasm and then full-fledged revolt. The uprising took decades, and Flanders itself remained part of Spain, but the end result was an urban republic—the Netherlands—that became the center of a global empire of trade and conquest and a model for many republics to come.

The U.S.'s own uprising had its start in the dense corridors of 18th-century Boston, which connected revolutionaries-to-be such as Samuel Adams and John Hancock. Hancock had a commercial interest in getting crowds to agitate against British mercantilist policies; Adams knew how to conjure a crowd. Together they and their Bostonian allies—John Adams, Paul Revere and many others—became the nucleus of a fight for popular sovereignty.

JOSEF HOFLEHNER *Gallery Stock*

THE FACEBOOK REVOLUTION

THE ABILITY OF CITIES to spread ideas of freedom and to coordinate mass action has led to countless revolts since then, from Paris in 1789 to St. Petersburg, Russia, in 1917 to Cairo in 2011. The recent toppling of former Egyptian president Hosni Mubarak has been called a Facebook revolution, but he would not have left if people had just blocked him from their Facebook pages. They needed to take to Tahrir Square.

Humankind continues to confront enormous challenges, from endemic poverty to global warming, but the track record of our urban species makes me optimistic. I have enormous confidence in the ability of *Homo sapiens* to work miracles when people cooperate. Our greatest gift is our ability to learn from one another, to work together, to solve problems by leveraging our collective intelligence.

The new electronic media can facilitate that collaborative process, but so does the face-to-face contact that is made possible by the physical proximity afforded by cities. Cities have been solving our species' principal challenges for millennia, and they are likely to keep on doing so for centuries to come. SA

Urban centers worldwide attract elite workforces whose collaborative creativity generates some of our best ideas.

MORE TO EXPLORE

The Rise of the Skilled City. Edward L. Glaeser and Albert Saiz in *Federal Reserve Bank of Philadelphia Working Papers*, 2003. http://ideas.repec.org/p/fip/fedpwp/04-2.html

Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier and Happier. Edward Glaeser. Penguin Press, 2011.

A collection of papers by Glaeser on his Harvard Web site: www.economics.harvard.edu/faculty/glaeser/papers_glaeser

SCIENTIFIC AMERICAN ONLINE

Read a chapter from Glaeser's book, *Triumph of the City*, at ScientificAmerican.com/sep2011/glaeser

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Global Bazaar

Shantytowns, favelas and *jhopadpattis* turn out to be places of surprising innovation

By Robert Neuwirth

IN BRIEF

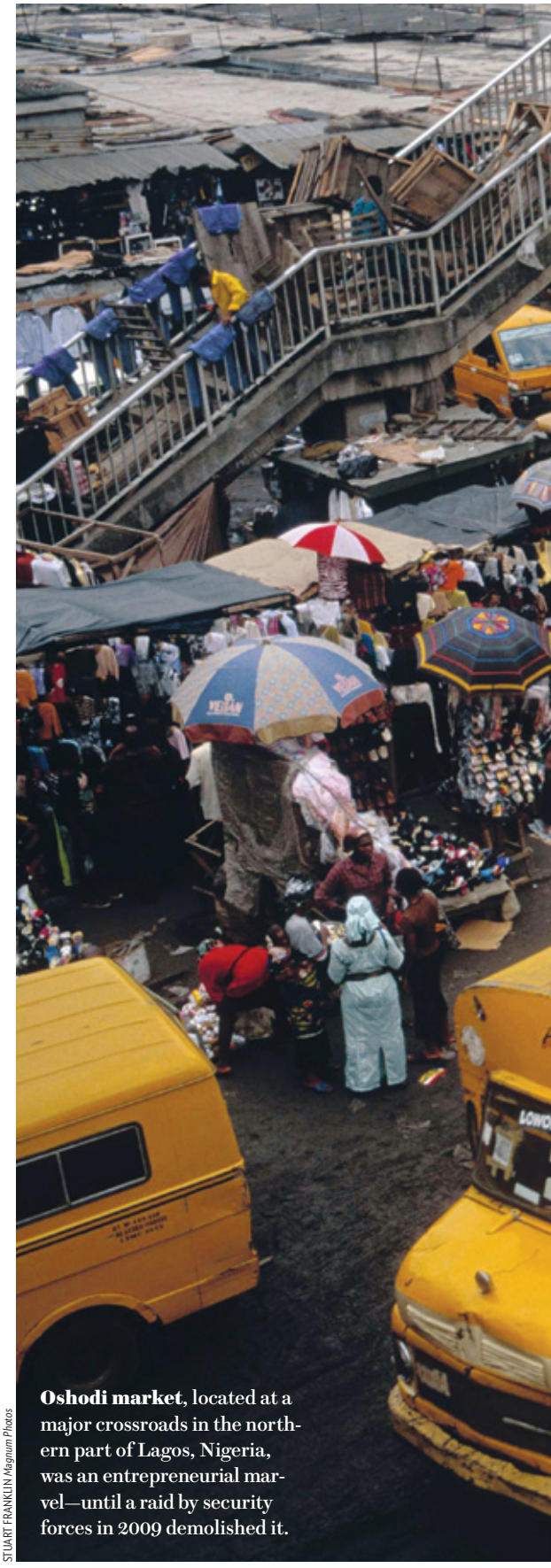
One in seven people on the planet live in squatter communities or in shantytowns. More than half the workers of the world earn their living off the books.

These markets and neighborhoods provide housing and jobs that governments and the formal private sector fail to.

Governments need to work with these communities rather than neglect or suppress them.

THE WOMEN MANEUVERED THEIR CRUDE canoes down narrow alleys of brackish water. They dipped their paddles lightly, gliding slowly past scrap-built houses elevated on spindly sticks that held the structures just beyond the reach of the tide. Here and there a head popped out of one of the homes to check who or what was passing. In the small harbor where the women beached their boats, the shoreline was a work in progress. People were filling the shallows, tamping down layers of trash to reclaim solid ground from the murky brown. Nearby, under a thatched-roof pavilion on one of those pounded patches stolen from the sea, a woman lit a match and put it to a pile of wood chips and sawdust at her feet. A lazy haze of smoke rose into the dusty air.

Greetings from Makoko, one of the most notorious squatter communities in one of the most notorious cities of the world: Lagos, Nigeria—a metropolis caught in a vortex between modernity and misery. With hundreds of ATMs, scores of Internet centers and millions of mobile phones, this bustling, maddening, overjammed city of between eight million and 17 million (depending on where you draw the lines and who does the counting) is fully plugged into the global grid. A hyperentrepreneurial interna-



STUART FRANKLIN *Magnum Photos*

Oshodi market, located at a major crossroads in the northern part of Lagos, Nigeria, was an entrepreneurial marvel—until a raid by security forces in 2009 demolished it.

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Robert Neuwirth's new book, *Stealth of Nations: The Global Rise of the Informal Economy*, is scheduled to be published by Pantheon later this year. He is also author of *Shadow Cities: A Billion Squatters, a New Urban World* (Routledge, 2006).

TIPPING POINTS

Less citified regions of the world, Asia and Africa, will witness their populations become more urban than rural in 2023 and 2030, respectively

SOURCE: UN-HABITAT

tional trading center and the commercial capital of Africa's most populous country, Lagos lures an estimated 600,000 new arrivals every year. Yet most neighborhoods, even some of the very best, have no water, no sewers and no electricity. Makoko—part on land, part hovering above the local lagoon—is one of the mega city's most deprived communities.

Neighborhoods like it—squatter communities—exist all over the world. Rio de Janeiro's 600 favelas dip down to Guanabara Bay and gallop up the steep hillsides from the famous beaches of Copacabana and Ipanema. Favelas are home to 20 percent of the city's residents. Mumbai's countless *jhopadpattis* line the banks of foul-smelling Mahim Creek, sit on the sidewalks of Reay Road and push against the tracks of the city's commuter rail lines. Half of all Mumbaikars are squatters, living on land they do not legally own. Kibera in Kenya—home to perhaps one million, making it one of the largest mud-hut neighborhoods in sub-Saharan Africa—is a short jaunt from downtown Nairobi, but it has no electricity, no sewers and no sanitation, and people who live there pay as much as 20 times what people in legal neighborhoods pay for drinking water.

Although 800 million to 900 million people—one in seven on the planet—live in such places, governments the world over have long looked down at these communities. When they have not been bulldozing or demolishing them, they have acted as if such places do not exist. One example: for decades, the official land-use map of the Nairobi city council showed Kibera, which is perhaps 100 years old and home to as many as one fifth of the city's residents, as a forest, not a neighborhood. With no city services and governments stuck in denial, these places have, of necessity, become hives of inventiveness, industry and self-made enterprise. Despite the hardship and deprivation, such illegal communities are the crucibles of our global future. Governments need to embrace them, not disown them.

FLOATING MARKETS

WHEN YOUR NEIGHBORHOOD sprawls over the water like Makoko, you cannot just open your door and walk to the store. Instead the products have to come to you, and the women sliding by on the listless Lagos Lagoon are the waterfront equivalent of a street market. Some carry staples such as *garri* (toasted, fermented cassava), *fufu* (another starch most often made from ground yam), bread and rice. Others sell soda and beer. Still others bring brooms and household supplies across the water.

Their canoes are manufactured by local artisans who sculpt the rough boards by hand to ensure that they can withstand the corrosive seawater. The houses, too, are a cottage industry, built by specialists who know just how far to pound the stilts and just how much weight those flimsy supports can hold. Filling in the shoreline is also an organized operation: just ask the young men who arrive several times a day in boats piled high with silt, which they spread over the compacted garbage.

And that smoky fire—which, if untended, could engulf the entire community—is a business, too. Here operating three large grills without a government license on land that until recently did not exist, Ogun Dairo smokes fish. She does not catch the fish herself but buys them from a cold-storage facility near her home. Nor does she sell the fish herself. She simply tucks the tail into the mouth, creating a compact, ring-shaped item that does not have to be flipped as it is smoked, exposes it to the smoldering chips for a few hours and then packs it in boxes. Those boxes—she typically fills between five and seven a day—go to a distributor who, in turn, sells them to women (the street sellers of smoked fish are always women) who peddle the catch all over the city. "The profit margin is not all that much," she said, using terms that a small businessperson anywhere in the world would understand. "The profit is made by the turnover."

I asked where the fish came from, figuring she would say that the lagoon, so polluted right there, was cleaner upstream or farther out to sea. Or perhaps the fish came from elsewhere in Africa, from other nations up or down the coast, or even from far inland. But I was not prepared for her answer: "Europe." The fish were caught in the North Sea, frozen and shipped to Lagos, where they were transported from the port to one of the most noxious neighborhoods to be smoked and then sold for a few naira of profit each (a few U.S. pennies) on the roadsides of the mega city.

These businesses are not registered, not licensed and not counted in official employment statistics. They lurk in the political and economic shadows. Yet they have become the global norm. Today more than half the workers of the world, or approximately 1.8 billion people, earn their living off the books. And their numbers are growing. By 2020 the informal economy will encompass two thirds of the global workforce, according to the Organization for Economic Co-operation and Development. What is more, estimates are that almost half the world's economic growth over the next 15 years will come from the top 400 cities in emerging economies. The urban center of gravity—indeed, the global center of gravity—is shifting to the developing world, and these massive do-it-yourself street markets and self-built neighborhoods are a vision of the urban future.

ON THEIR OWN INITIATIVE

TO PLANNERS and government officials, that sounds scary. They worry that ungovernable neighborhoods and off-the-books enterprises will become metastatic, spreading disorder, dysfunction and even outright criminality, dragging entire cities over to the dark side. And as residents themselves

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RADHIKA CHALASANI *Redux Pictures (woman in yellow scarf)*; JONAS BENDIKSEN *Magnum Photos (praying, school and sleeping)*; ERIC BOUVET *VII Network (workers)*

Dharavi is one of Mumbai's most famous shantytowns, familiar to moviegoers from *Slumdog Millionaire*. As many as one million people live in an area about the size of Prospect Park in Brooklyn or Jackson Park in Chicago. Residents reclaimed the land from a mangrove swamp and earn their living from recycling and light manufacturing. Two fifths are Muslim; the rest are Hindu. Some communal lodgings sleep 35 to a room. The area is the target of controversial redevelopment plans.

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will openly admit, living over a polluted estuary or without running water is not the 21st-century ideal. "It is not our wish to be here," Erastus Kioko told me as darkness enveloped his one-room dwelling in Kibera. "If we had money, we would not stay here." He stared at the misshapen mud walls of his home, then added, "I cannot say I have a future."

Still, despite the difficulties, his prospects are actually better in Kibera than if he lived elsewhere in Nairobi. That is because the cheapest single-room apartment in a legal neighborhood of the Kenyan capital generally costs four times more than the average mud hut in Kibera. Sadly, no government or private developer is prepared to build housing that Kioko or almost anyone else in Kibera (or, indeed, in all shantytowns the world over) can afford. Only squatters, building for themselves, have the ingenuity and desire to make these communities work.

In the developed world, people leverage their wealth to get mortgages that enable them to buy materials, hire contractors and build their homes all at once. Squatters do not have that luxury. Their mortgage is the time they are willing to put into building and rebuilding their homes. In Mumbai, hut residents sometimes spend years making and remaking their homes one wall at a time—and scavenged billboards, rusty fence posts, salvaged bricks and half-worn tiles are all valuable resources.

When governments deny these communities the right to exist, people are slow to improve their homes. For instance, when authorities in Rio de Janeiro waged war on the favelas back in the late 1960s, people feared that they would be evicted or burned out of their homes and were slow to invest. Most of the favelas remained primitive—scarcely different from the mud and wood huts of Mumbai and Nairobi. But as the politicians dialed down the hostilities and began engaging with the communities, the favelas rose into the open.

With acceptance, residents rapidly ripped down the old shacks and replaced them with multistory homes made from reinforced concrete and brick. Fly-by-night installers—called *gatos,* or cats—offered favela residents the opportunity to steal electricity from municipal lines (and you can still see their handiwork on utility poles topped with teased-out tresses of wires). Starting in 1997, however, the local power company recognized that squatters do not want the diminished service and short circuits inherent in pirated hookups. Today the utility has struck a bargain with many communities, offering to wire favelas as long as residents accept meters and pay for the electricity used. The program has been a huge success. Having stable electrical service has also worked wonders for public health, because squatters in Rio use plastic pipes and electric pumps to pilfer water from municipal mains. That may also be theft, but it has provided more than a million people in the city with access to safe drinking water.

UNDER THE UMBRELLAS

JUST AS SQUATTERS have been building the neighborhoods of the future, street vendors and other unlicensed operators are creating the jobs of the future. No government, no global nonprofit, no multinational enterprise can seriously claim to be able to replace the 1.8 billion jobs created by the economic underground. In truth, the best hope for growth in most emerging economies lies in the shadows. In Lagos, for instance, street markets have scaled up into huge roadside enterprises. Alaba International Market, Ikeja Computer Village, Ladipo, and the Auto Spare Parts and Machinery Dealers Association Market have established sophisticated networks for international trade. Merchants voyage to far-flung places (these days most trade is with China) in search of products and profit. They import most of the mobile phones, consumer electronics and car parts sold in the country—and their businesses have burst the boundaries usually associated with street operations. Remi Onyibo and Sunday Eze, two of the leaders of the merchants association in Alaba, told me that the market does more than $3 billion in business every year.

Given that kind of economic power, many major corporations have recognized that they, too, can harness the might of unlicensed entrepreneurship. The mobile phone industry is a good example. In Nigeria the mobile market is led by multinationals such as MTN (based in South Africa), Zain (based in Kuwait) and Globacom (based in Lagos but offering service through much of West Africa). These multibillion-dollar outfits make most of their money by selling phone-recharge cards through a huge, haphazard force of street vendors in impromptu booths under umbrellas at the side of the road. "The umbrella market is a very, very important market now," said Akinwale Goodluck, now corporate services executive for MTN's Nigerian operations. "No serious operator can afford to ignore the umbrella people."

Indeed, one umbrella stand operator told me that there was good money in the trade. She started with just $34 in recharge cards and within six months had increased her business 60-fold, netting a profit of $270 a month, five times the minimum wage then established by the government. But successful and responsible vendor though she is, the multinationals whose cards she sells keep their distance. They sell the cards to distributors who resell them to the umbrella stand operators and claim that this potent street force is actually an army of independent contractors with whom they have no relationship and for whom they have

Favela Santa Marta, also known as Dona Marta, is one of the steepest—and, once, most dangerous—in Rio de Janeiro. It has mellowed out as the state has gradually extended public services there.

5

Most populated cities in …

1950

1. New York
2. Tokyo
3. London
4. Paris
5. Moscow

2010

1. Tokyo
2. Delhi
3. São Paulo
4. Mumbai
5. Mexico City

SOURCE: United Nations, Department of Economic and Social Affairs

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BRUNO DOMINGOS *Corbis*

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Better Health for the Uncounted Urban Masses

By Gordon McGranahan and David Satterthwaite

Most of the people who moved to London, New York City, Chicago, Berlin and other big cities during the 19th century traded away their health to make better wages. Crowding, unsafe drinking water, bad sanitation, harsh working conditions and industrial pollution made them sicker than their cousins back home in the countryside and shortened their life spans.

But starting in the middle decades of the 1800s, government reforms and urban leaders began turning the health of these cities around by investing in water, sanitation, waste removal, education and more. Today affluent cities are among the healthiest places to live. Even in many middle-income countries urban dwellers go about their lives largely unthreatened by the classic epidemics.

Yet the 800 million to 900 million people living in the informal settlements that make up modern-day slums still await such miracles. They suffer the effects of overcrowding, contaminated water and lack of affordable health care. In many of these places one in six children dies before the age of five, and life expectancies are less than half as long as those in the healthiest cities.

The situation will not get better until governments take greater responsibility for the wellness of the poorest residents. Governments are often a large part of the problem, however. Most of the poorest settlements are on land that is illegally occupied or subdivided, so urban bureaucracies may ignore their existence. In addition, formal laws and institutions tend to assume that people can afford to live in sanitary homes and therefore often do more to marginalize communities that are at the edge of subsistence than to help them. Governments may also shy away from engaging with activists who encourage impoverished residents to organize around demands for improvements, but these organizers must be engaged if government programs that are put in place can hope to succeed.

Bright spots exist, however. Some local governments are now acknowledging the informal settlements and are collaborating with the inhabitants to install the health infrastructure and services needed. One of the most effective initiatives is the secure housing program run by the government of Thailand's Community Organizations Development Institute, which has supported hundreds of community-driven upgrading schemes, including paying for better water and sewage infrastructure and lending money to shack dwellers to improve their homes. Federations of slum dwellers are working with local authorities to change conditions in more than 15 other nations.

As these programs show, poor people's health and their economic status both benefit most when governments, international agencies and slum dwellers work together to plan, implement and manage changes. More cities must see their "uncounted, unhealthy masses" as partners with resources and capacities if they want to complete a meaningful urban revolution.

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no responsibility. And sadly, the Lagos state government has embarked on a campaign to destroy many roadside markets. This campaign has made it much more difficult for umbrella people and vendors of all sorts to do business on the street. This policy seems punitive and counterproductive given that, according to the government's own estimates, 70 to 80 percent of the working people in the city are part of the informal economy.

Still, the firms of the shadows continue to grow. Mumbai's formerly largest squatter community, Dharavi, has its own links to global trade. Here well-established workshops stitch leather bags and sew shirts for sale throughout the world. In Kenya, although they may not have tapped global markets, Kibera residents own or run many successful small businesses. The community's mud roads are lined with stores, bars, beauty salons, bakeries, tea shops and churches (even houses of worship can function as businesses)—and there are Kibera residents who own successful downtown firms. These outfits are innovative socially as well as economically, and many of the most successful entrepreneurs are women, who traditionally have had no opportunity to establish a degree of independence and power.

OUT OF THE SHADOWS

THE STANDARD CONSENSUS regarding the informal sector—whether squatter communities or street markets—is that it is a zone of criminal enterprise and the enemy of civil society. Yet apart from occupying land that is technically not theirs, most residents of squatter communities are law-abiding citizens. Similarly, although they may be avoiding taxes, most people who work off the books are productive members of society.

Indeed, one of the largest misconceptions about the informal economy is that it does not exist in the developed world. In truth, throughout history, squatters have been involved in building many of the world's great cities. Most European capitals were once ringed with large shack settlements. A century and a half ago San Francisco made the leap from a sleepy fishing village to a bustling gold-rush city by legalizing thousands of squatters. And in New York City, the Upper East Side and Upper West Side started life as squatter communities, as did many neighborhoods of Brooklyn. In fact, the last major squatter community in Midtown Manhattan, Sunken Village on West 62nd Street—in between Central Park and where Lincoln Center now stands—was not pushed out until 1904. In the developed world, the public associates the economic underground with criminal enterprises such as drug dealing—but most of the people earning money off the books are involved in benign businesses, from cash-under-the-table construction jobs to street food vendors to fashion designers who ply their wares online.

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As a result of the misconceptions, policy makers have tended to create sharp divisions that lead to simplistic solutions: legal and illegal, productive and unproductive, good and bad. These binary oppositions endanger the livelihoods of more than a billion people and threaten to block an important stage in global development. There has to be a middle ground—one that does not endorse all quasi legality but allows multiple ways for economic markets to function.

Alfonso Morales, a professor of urban planning at the University of Wisconsin–Madison, offers one such proposal. Morales, who put himself through graduate school, in part, by working as a street vendor in Chicago, suggests that municipalities the world over should offer business licenses to street sellers—for a substantial fee—in exchange for not pursuing them for their taxes. In the current reality, unlicensed vendors run a risk every time they hit the streets. For them, a license would mean that the police can no longer harass them, and Morales suggests that they will be willing to pay dearly for that protection. The government would get a clear benefit, too—gaining some revenue from these subrosa street merchants who otherwise provide nothing to the public coffers. It would not be a perfect solution—and certain trades, such as food selling, would still have to comply with health regulations and other rules—but it would mark an important shift to engagement instead of criminalization. Morales says, "We need to go from a purely enforcement mentality to a mentality of 'Let's try to enlarge the pie and increase people's share of it.'"

Martha Chen, a lecturer at Harvard University's John F. Kennedy School of Government who works with informal enterprises through her position as coordinator at Women in Informal Employment: Globalizing and Organizing, puts it this way: "We need to come up with models that allow the street trader to coexist along with retail shops and along with large malls. The informal economy is not the problem. It's part of the solution. Street traders, waste pickers, market women: these people really do contribute to the economy and to their cities. How can we manage our cities in a way that has space for them? What we need to do with the informal economy is to figure out how to help it become more productive, more efficient and more effective."

To be sure, governments do not have a great track record in working with people whose survival depends on hiding their homes and earnings from official oversight. The Indian government, for instance, has a cabinet-level commission dedicated to the informal sector, but that has not prevented local governments from pushing punitive policies against squatters and street hawkers. Still, bottom-up initiatives offer hope. Squatter communities and street markets have developed their own cooperative institutions. In Mumbai women in the *jhopadpattis* and informal marketplaces are creating shared savings schemes and joint insurance plans. In the favelas bunches of families join to create *mutiroes*—mutual construction societies—that share labor and allow them to build their homes together. In Kibera women form "merry-go-rounds" to pool their money, and the stash goes to one member every week—an infusion of cash that has helped many women grow their businesses and develop financial independence. In Lagos every illegal market has a self-governing association and, often, a market court that handles disputes.

For enlightened governments, each of these homegrown institutions offers an opportunity. The *mutiroes* can evolve into cooperative construction firms that abide by building codes; the merry-go-rounds and savings schemes can morph into cooperative credit unions and microlending societies; and the market associations can move into infrastructure investments and provide their own public services, such as garbage pickup and street cleaning. These things may seem minor, but their cumulative impact would be significant. Even if these cooperative ventures stay small, the more institutionalized and permanent they can become, the easier it will be for them to forge fruitful links with government agencies. Conversely, only by working with local groups can governments bring a level of inclusive development to the most neglected and maligned parts of the urban world. Through a combination of bottom-up and top-down action, squatters and street marketeers can lead the fastest-growing cities into the future. SA

STUART FRANKLIN *Magnum Photos*

Industry amid misery: **Fishers build their houses above the foul waters of the Lagos Lagoon in the district of Ebute Metta, north of central Lagos.**

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Brains over Buildings

To rejuvenate urban centers, look to teachers and entrepreneurs

By Edward Glaeser

DETROIT ONCE HAD 1.85 MILLION inhabitants. Now it has fewer than 740,000. Cleveland and St. Louis, too, are half the size they were in 1950. Across the Atlantic, Liverpool and Leipzig are also dramatically smaller. When so many cities are booming, why are some trapped in decline?

Cities naturally rise and fall as technologies change. Detroit and the other cities of the Great Lakes established themselves as agricultural transport hubs before the Civil War. Afterward, they enjoyed a second growth spurt when American industry settled along waterways for easy access to raw materials such as iron ore. But their geographical advantages eroded over the course of the 20th century as the real cost of moving a ton a mile by rail dropped by more than 90 percent. Manufacturers relocated to lower-wage areas such as the South.

Every older city was hit by the deindustrialization tsunami. Garment production in New York City was hammered even more savagely. Forty years ago two wags put up the sign, "Will the last person leaving Seattle—turn out the lights," when Boeing's cutbacks seemed to imperil the city.

Economic decline was often accompanied by social unrest, including the 1967 Detroit riot that destroyed more than 2,000 buildings. Social fractures often came to dominate politics as well. Detroit mayors Roman Gribbs and Coleman Young were seen as representing particular groups rather than the city as a whole. Some leaders, such Boston's legendary Mayor James Michael Curley, may have actually welcomed the flight of population groups that opposed their leadership.

The surprising fact is not that cities decline but that they manage to reinvent themselves. Today Seattle is practically synonymous with information-age success. New York, Boston and Minneapolis have also come back. The main reasons appear to be education and entrepreneurship.

In the metropolitan areas of the Northeast or Midwest, where fewer than 7.5 percent of adults had college degrees in 1970, the population grew by 8 percent between 1970 and 2000. Where more than 15 percent had college degrees, the population grew by 53 percent. Before 1970 growth was correlated more with high school graduation rates than with college achievement; after 1970 college became the deciding factor. Boston is doing about as well as its education level would predict, and so is Buffalo.

Are educated cities more successful, or do successful cities simply attract educated people? Historical records provide one way to answer that question. They reveal that the educational level of a city's population does not change much with time. The percentage of adults with a college degree as of 1940 correlates strongly with education levels in 1970 and today—and also with high incomes and population growth in recent decades, especially in the Northeast and the Midwest. The presence of a land-grant college in a metropolitan area before 1940 is associated with higher earnings and faster growth today. Thus, education seems to beget success rather than the other way around.

A culture of entrepreneurship also helps. Proxies for entrepreneurial energy, such as the share of employment in start-ups and the average firm size, correlate with successful urban reinvention. As with education, entrepreneurship appears to precede success. Cities with comparatively low entrepreneurship in 1900, such as those dominated by big companies in mining or manufacturing, continue to have comparatively low entrepreneurship—they are still dominated by big companies in export-oriented services, which have lagged economically, even in growing areas of the South and West.

Sadly, it is only fairly recently that planners came to appreciate the importance of education. For much of the past half a century, the federal government pushed declining cities to undertake construction and transportation projects, which are not fixes for decline. I have looked for connections between urban-renewal policies and urban resurgence and found none. The futuristic Detroit People Mover glides over desolate streets. Skills, not structures, are the best antidote against urban failure. SA

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For case studies of urban reinvention, good and bad, see ScientificAmerican.com/sep2011/urban-makeover

Illustration by Oliver Munday

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How Green Is My City

Retrofitting is the best way to clean up urban living

By David Biello

IT WAS TO BE THE ULTIMATE URBAN PARADISE. Hundreds of pages of plans, maps and charts detailed the construction of a state-of-the-art eco-city called Dongtan on China's Chongming Island, at the mouth of the Yangtze River. Energy-efficient buildings would be clustered together to encourage residents to travel on foot; only battery- or hydrogen-powered cars would be permitted in the development. Surrounding organic farms would supply food; sea breezes and the burning of husks of China's staple crop, rice, would furnish power. Canals and ponds would incorporate the local wetlands, providing restful views for humans and continued respite for migrating birds.

Yet for all its grand goals, this island city-to-be remains unbuilt. Whether China has abandoned the project totally is unclear. It was originally slated for completion in 2010 but has failed to proceed beyond the construction in 2009 of a tunnel and bridge linking Chongming to the mainland. It is one of numerous planned eco-cities around the world that have fizzled, many because of cost. Even if every planned eco-city were successful, however, their effect on overall energy use and emissions would be minimal because the vast majority of urbanites would still live in existing cities. All these reasons suggest that we cannot rely on new construction to fully address the challenges of feeding, housing and transporting urban populations in ecologically sound ways. We need another solution.

The solution needs to take the future into account. Today's cities are by many measures greener than suburbs—among other things, urbanites use less energy and emit less carbon dioxide per household than their suburban counterparts do because they live in closer quarters and use public transportation. But it is not enough to be green. Cities need to be sustainable, too. That is, they must be able, as the United Nations's World Commission on Environment and Development stated in 1987, to meet "the needs of the present without compromising the ability of future generations to meet their own needs." Existing metropolises will not be able to sustain themselves if left to operate on a business-as-usual basis—demand for resources will outstrip supply as the number of people inhabiting cities swells from more than three billion today to more than six billion by 2050. The many traditional cities that are mushrooming in China and India and elsewhere are facing the same conundrum.

In theory, new cities could have sustainability built into their infrastructure from the start—as was planned for Dongtan. But a larger payoff would come from retrofitting existing cities for sustain-

IN BRIEF

The planning of new eco-cities generates buzz, but retrofitting existing metropolises to be environmentally friendly and sustainable would be more effective because they already house so many people.

Readying today's cities for the future will require both high-tech and low-tech changes.

IWAN BAAN

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New York City and other existing metropolises need to be updated to lessen their impact on the environment and boost their sustainability. Pictured here is the High Line, an elevated rail structure–turned-park on Manhattan's West Side.

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ability, given how many there already are. "We must work with existing cities; I have no doubt about it," asserts sociologist Saskia Sassen of Columbia University, who has spent her career studying cities. That approach would be less costly than rebuilding cities from scratch and could still conceivably save enormous amounts of energy and water, allowing today's cities to flourish for centuries to come. To meet these objectives, engineers, city planners and locals could take good ideas from planned eco-cities that have failed as cities but succeeded as incubators for innovation. Simple changes, such as training building superintendents in best practices, can also go a long way toward helping cities support us well into the future.

SAVING ENERGY

A KEY PRIORITY for cities adapting to a world transformed by global warming is increasing energy efficiency and reducing greenhouse gas emissions to stave off even more catastrophic climate change. "As the primary centers of economic activity globally, cities are significant consumers of energy and emit nearly three quarters of the world's carbon emissions," New York City mayor Michael Bloomberg told a recent conclave of mayors at a meeting of C40, a planning group for 59 major cities engaged in efforts to combat climate change.

A major focus of C40 is equipping old buildings with energy-efficient features. In the U.S., the average building—whether skyscraper, house or church—was built in the 1970s. Replacing their black-tar roofs with white roofs that reflect sunlight to keep buildings cooler in the summer or installing solar-thermal hot-water heaters, for example, can translate into major energy savings: heating hot water accounts for 17 percent of the energy used by buildings in the U.S., according to the Department of Energy. C40 has thus partnered with the World Bank to ensure funding for such retrofitting projects, among other climate action plans for cities.

Existing cities might also benefit from installing transportation systems originally conceived of for planned eco-cities. Tailpipes in the U.S. spew 1.7 billion metric tons of carbon dioxide a year, along with a host of noxious fumes. In contrast, the electric car system proposed for Fujisawa City in Japan would produce no tailpipe emissions. Electric car systems require infrastructure, though, particularly to ensure that people can charge the cars. In Tokyo a company called Better Place has had success in testing a system of electric vehicles powered by batteries that, when depleted, can be quickly and easily swapped out for recharged ones at battery switch stations. In the near term, simple changes, such as converting buses to run on compressed natural gas rather than diesel, can both clean up the air and improve efficiency. Already such efforts have helped Denver save more than 24 million gallons of gasoline between 2005 and 2009.

Cities must not only conserve energy and limit emissions but also diversify their energy supply. New York City recently mandated a switch from heavy heating oils to lighter, cleaner-burning fuels, such as natural gas, in a bid to improve air quality. Yet even such seemingly straightforward decisions can demand difficult trade-offs: David Bragdon, director of Bloomberg's Office of Long-Term Planning and Sustainability, notes that New York is struggling to reconcile this increase in the use of natural gas with its desire to prevent hydraulic fracturing, or fracking—a process for producing natural gas from deep rock—in its watershed because fracking can contaminate water supplies.

WATER AND WASTE

ENSURING THAT sustainable supplies of freshwater continue flowing to growing urban populations is another daunting task facing the international community. Large swathes of the world are already pushing the limits of water availability. Cities throughout the western U.S., from Denver to Phoenix, for instance, are using up more than the normal flow of the Colorado River. And the International Food Policy Research Institute estimates that about half of global grain production will be at risk because of limited water by 2050. To help cities conserve, C40 has developed a list of best practices based on case studies of strategies employed by cities ranging from Austin, Tex., to Tokyo. Austin, which launched its water-efficiency program in 1983 in response to a housing and commercial boom, offers a number of incentives to curb water use, including rebates for installing rainwater-harvesting systems and water-conserving toilets. Tokyo, meanwhile, is the world leader in detecting and controlling leaks in its waterworks. It has earned this distinction by systematically checking, repairing and replacing pipes and by fixing leaks on the same day that they are identified.

For its part, the planned city of Masdar in the United Arab Emirates (not a C40 city) takes a Big Brother–like approach to conserving water: showers shut off automatically after a few minutes, and each resident's water use, along with energy use, is monitored via a computerized smart grid that allows the provider to intervene if users get greedy.

Water must also be clean. For most cities, meeting this objective will mean not maintaining the status quo but vastly improving on it: according to the U.N., nearly a third of city dwellers live in slums, which typically lack access to safe drinking water and sanitation services, leaving them vulnerable to cholera and other waterborne diseases.

Poor waste management is not just a problem for water quality, however. New York City, for example, has closed its landfills in Brooklyn and Staten

A HIGHER PITCH

Urban great tits (*Parus major*) sing at higher frequencies to be heard over the relentless din of urban noise

SOURCE: "Ecology: Birds Sing at a Higher Pitch in Urban Noise," by Hans Slabbekoorn and Margriet Peet, in *Nature*, Vol. 424; July 17, 2003

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Eco-dreaming: Artist's conception of Dongtan, a sustainable city that China planned but has not built.

COURTESY OF ARUP

Island and now pays as much as $100 a ton to move waste hundreds of kilometers away. Even recycling is not a panacea—Dubuque, Iowa, halted its glass recycling program, according to Mayor Roy Buol, because trucking the material to far-flung processing plants added more to the city's greenhouse gas emissions than dumping it in a landfill. Even better than simply disposing of waste or recycling it, of course, would be making something useful from it. Just such a transformation is taking place in an industrial park outside the city of Rizhao in China, where Luxin Jinhe Biochemical Company makes citric acid for beverages from cassava, corn and sweet potatoes. The leftover waste flows into tanks called biodigesters, where microbes turn it into solids that can be converted into meal for animal feed and methane that can be burned for industrial purposes, such as generating electricity. In fact, capturing methane from landfills is one of the cheapest ways to cut down on greenhouse gas emissions while making a new "natural" resource.

EASY FIXES

WITHOUT A DOUBT, existing cities will need cutting-edge technology to help achieve their long-term sustainability goals. But policy tweaks and low-tech solutions can play an important role, too—for instance, changing building codes to require more energy efficiency, which could be achieved with better insulation. Indeed, the real battle to make an existing city such as New York more sustainable may be won in the minds of superintendents managing the metropolis's roughly one million buildings. Hence, the U.S. Department of Energy's Green Supers program, which trains building service workers in green operations and which recently graduated its first class. "I was under the impression that these techniques were very expensive. It's just time, it's just dedication and just applying it," said superintendent Victor Nazario during his address to his fellow classmates at commencement.

These concepts are spreading worldwide, thanks to organizations that bring leading cities together to share plans that work, such as C40 and ICLEI–Local Governments for Sustainability. And when cities act, national governments notice—taking its cue from the 259 cities in China that are striving to be low-carbon, the Chinese Ministry of Housing and Urban-Rural Development is now studying plans to encourage the use of more energy-efficient and long-lasting building materials, which could significantly enhance the sustainability of the country's boomtowns.

Cities are an expression of our collective will, a potent mix of economics and environment, private visions and public dreams. Boosting their ability to provide clean energy, transportation, food, water and waste disposal will be key strategies to ensuring a brighter future for humankind. But when it comes to eco-cities, those efforts too often prioritize aesthetics over the real-world needs of people. And it is the people who ultimately make a city sustainable or not. SA

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All Climate Is Local

Mayors are often better equipped than presidents to cut greenhouse gases

By Cynthia Rosenzweig

IN BRIEF

Cities are tackling climate change because they are suffering from floods, rising seas and heat waves. They are innovating ways to reduce carbon dioxide emissions, conserve water, protect transportation systems and help the public avoid heatstroke.

City leaders should share best practices to maximize progress and minimize costs.

FOR YEARS SCIENTISTS HAVE URGED national leaders to tackle climate change, based on the assumption that prevention efforts would require the coordinated actions of entire nations to be effective. But as anyone who has watched the past 15 years of international climate negotiations can attest, most countries are still reluctant to take meaningful steps to lower their production of greenhouse gases, much less address issues such as how to help developing countries protect themselves from the extreme effects of climate change. Frustrated by the ongoing diplomatic stalemate, a number of urban leaders have decided to take matters into their own hands, adopting solutions that already exist or inventing new ones for limiting greenhouse gas emissions and preparing for the effects of ongoing global warming.

Mayors and urban managers are taking over because they have a keener sense about how changing weather patterns will affect their cities' political and economic future. As Bärbel Dieckmann put it in 2007, when she was mayor of Bonn, Germany, "cities are already experiencing flooding, water shortages, heat waves, coastal erosion and ozone-related deaths." Since the mid-1990s, according to a 2009 report, the number of intense hurricanes has been increasing in the Atlantic Ocean, and the size of wildfires has been growing in the western U.S. As temperatures continue to rise, such extreme events may become even more frequent and severe. Most of the world's major metropolises were originally built on rivers or coastlines and are therefore subject to flooding from rising seas and instances of heavier rainfall.

Many civic leaders point to Hurricane Katrina and the devastation it visited on New Orleans in 2005 as their moment of awakening. They saw how the multiple failures of an aging and inadequate infrastructure, plus indifferent planning, sharply increased the death toll of a catastrophe that had long been predicted. Indeed, two major alliances of city mayors to combat climate change formed within months after Hurricane Katrina's landfall. The organization now known as the C40 Cities Climate Leadership Group launched in London in October 2005, and the World Mayors Council on Climate Change (WMCCC) got its start in Kyoto that December. As of June 2011, more than 190 mayors and other local authorities, representing some 300 million people from around the world, have also signed a voluntary pact sponsored by the WMCCC to reduce greenhouse gas emissions.

In some ways, cities may be in a better position than nations to do something about climate change. By conservative estimates, the cities of the world emit no less than 40 percent of such greenhouse gases as carbon dioxide, methane, nitrous oxide and fluorinated gases. According to a 2011 study by Daniel Hoornweg and his co-authors in the journal *Environment and Urbanization,* cities may actually be responsible for roughly 80 percent of emissions if one takes into account their consumption

STYLING BY LAURIE RAAB/HALLEY RESOURCES

Photograph by Dan Saelinger

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of electricity, food and other commodities that require the burning of fossil fuels. Indeed, the article found that if the C40 cities were a country, its population would be about 290 million people, and it would be the fourth-largest emitter of greenhouse gases, after the U.S., China and Russia.

Cities are already assessing the greatest climate risks they face and are beginning to try out solutions to the most obvious challenges. Scientists and engineers are helping the effort by sizing up existing programs and evaluating proposed initiatives, using the best available evidence. The people leading the charge still have much to learn—particularly with respect to integrating the efforts of multiple players in the public and private sectors. But it is already apparent that cities have the power to reduce the sources of climate change while softening the blow from whatever weather extremes have already become unavoidable.

86%

of urban residents in wealthy countries live on low coasts that risk flooding from rising sea levels—as do **56%** of urban residents in lower-middle-income countries and **41%** in low-income countries

SOURCE: "Looming Disaster and Endless Opportunity: Our World's Megacities," by Saskia Sassen in *Megacities*, No. 2; 2009

STEPPING UP

EACH URBAN CENTER faces its own unique constellation of climate-related problems. The risk of damage varies depending on its physical features (such as whether it is built on a delta or floodplain), its particular layout (a compact, high-density arrangement or urban sprawl), and its built environment (such as the amount and location of pavement that promotes runoff during storms). Urban planners need to know precisely which neighborhoods and what services are most vulnerable.

Nevertheless, cities are beginning to address four interconnected issues:

Reducing emissions. Commercial and residential buildings account for a significant portion of urban energy use. The combination of rising energy costs and concerns about climate change is pushing many cities to try to tame consumption by improving the energy efficiency of new buildings and by retrofitting old ones. For example, about 75 percent of New York City's carbon emissions stem from energy used in buildings. Mayor Michael Bloomberg has begun tackling this issue with a program that evaluates the energy use of the city's largest buildings and mandates improvements in cost-effective energy efficiency. To reduce emissions, water use and heat buildup, cities can adopt more renewable energy sources; Oakland, Calif., now meets 17 percent of its needs with electricity generated from wind, solar and geothermal plants. In cities in developing countries, lack of access to reliable energy is more often the key problem. In many cases, improved energy systems are needed to aid in development rather than to combat climate change. But the two may be linked if renewable sources are encouraged.

Some cities are further along than others in reducing the production of greenhouse gases. The Hoornweg study found that each person living in Denver emits the equivalent of 21.5 metric tons of carbon dioxide every year. Residents of New York City, in contrast, produce about 10.5 metric tons apiece. New York City's higher population density, milder winters and lesser use of cars for commuting allow its inhabitants to produce less than a third of the per capita average of greenhouse gases for the entire U.S. population. Lest New Yorkers starting patting themselves on the back, however, they should consider the citizens of Amsterdam, who are each responsible for only 6.7 metric tons of carbon dioxide a year—and other European cities are lower. As part of Amsterdam's plan to reduce its carbon footprint by 40 percent from 1990 levels by 2025, it is generating heating and electricity from waste and sewage and is placing additional wind turbines in its port and upgrading old ones.

Preserving water. Most climate change models predict a long-term decline in the availability of freshwater in southwestern regions of North America, southern Europe, the Middle East and southern Africa. With a water-conservation program that began in 1983, Austin, Tex., has pioneered the large-scale use of low-flush toilets, rebates to residents who replace turf grass with native plants that are better adapted to drought conditions, and progressive water rates for residential customers that become more expensive as more water is used. Cities can also use "gray water"—wastewater that has been cleaned enough by treatment plants to be dumped into rivers but not enough to drink again—to keep city parks green instead of using freshwater. Since 2002 Melbourne, Australia, has responded to a continuing drop in rainfall by enacting increasingly stringent water restrictions. Sanitation officials, however, anticipate that the sharp drop in water flow, combined with increasing temperatures, will make wastewater warmer and more concentrated, increasing the chance of corrosion in sewer pipes; they will have to change their inspection and maintenance programs to keep up.

Keeping transportation systems moving. Key transportation infrastructure is often located near waterways and is thus vulnerable to sea-level rise and inland flooding. When tunnels, ramps and vent shafts flood, pumps are needed to remove the water. Debris must be cleared, and essential elements of the system, such as motors, relays, resistors and transformers, must be repaired or replaced. Entrances to the Taipei subway in Taiwan have been raised to avoid inundation from flash floods and high tides. Sweltering temperatures can also disrupt equipment such as overhead electrical wire and steel rails, eventually causing them to sag or even to buckle. Installing transformers and wiring that are able to function efficiently at higher temperatures and keeping equipment dry are minimum first steps.

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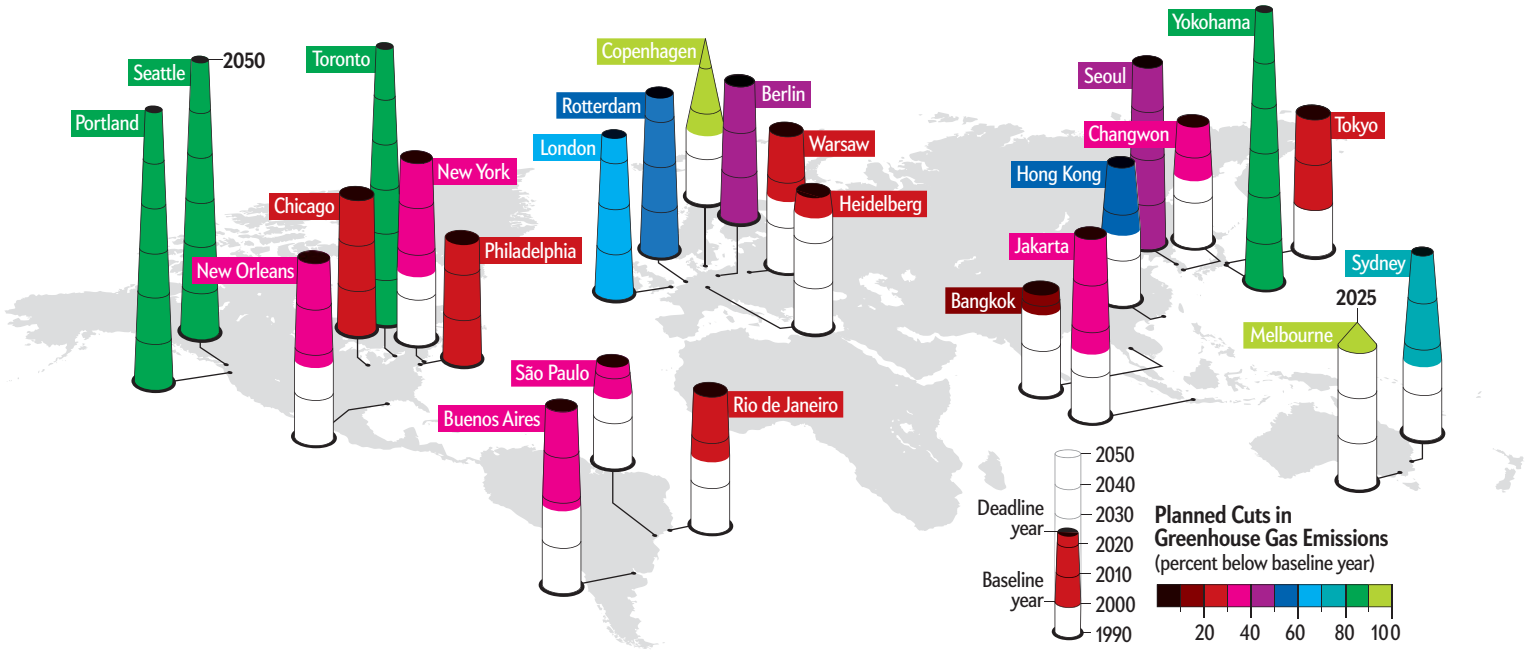

Protecting public health. The rise in average global temperatures will likely lead to a worsening of urban health problems such as respiratory ailments related to poor air quality and bring about new difficulties, such as a greater range for certain illnesses caused by rodents and other disease-carrying animals. Perhaps the most immediate effect, however, will be more frequent and severe heat waves, which are already the most deadly weather-related events in the U.S. Chicago and Paris are planning for the changes, but there has been little research to show public health authorities which interventions—such as opening cooling centers or identifying particularly vulnerable individuals ahead of time—actually save lives or reduce hospitalizations. Some adaptation strategies can pay off in multiple ways; for example, improving energy efficiency reduces power generation, which lessens the heat and pollution a city generates, thus lowering cases of heatstroke and asthma.

As soon as civic leaders have a clearer picture of their own city's individual risks, they need a strategy for prioritizing initiatives. My colleagues and I encourage cities to concentrate on efforts that result in multiple wins. For example, greenery planted on rooftops decreases water runoff from storms and acts as an insulator that reduces a building's energy consumption, thereby lessening carbon emissions.

HELPING ONE ANOTHER SUCCEED

MANY CITIES DO NOT HAVE the expertise within their own governments to accurately assess their risk from climate change and to develop a comprehensive response plan. Various groups of international researchers, including the Urban Climate Change Research Network, have come together to try to fill that gap by linking scholars with decision makers. The network's first in-depth assessment covering some 50 cities—including Buenos Aires, Delhi and Lagos—was released this year and found, among other things, that severe flooding is as bad as unrelenting drought when it comes to loss of power or the provision of clean water. The goal of such reports is twofold: to provide scientific analysis of the specific challenges cities face because of climate change and to evaluate potential adaptations that might limit the most deleterious effects.

Going forward, it makes sense to develop common sets of standards for reporting greenhouse gas emissions and reductions, the impacts of climate change on cities, and the efforts to lessen the toll in human lives and property. Such universal benchmarks would allow cities to measure their own progress, compare their results with those of other municipalities and share their innovations.

Just as important, cities have to engage larger groups of citizens—especially those from the poorest and most vulnerable neighborhoods because they are the people who are likely to suffer most from climate change and may need to make the biggest adjustments. The Ecuadorian city of Quito, for example, provides technical support to nearby impoverished farmers that helps them switch from growing potatoes and corn to native Andean crops such as quinoa, which require less water and better prevent soil erosion. Such changes improve the amount of water available as well as its quality in both rural and urban areas.

In the six years since Katrina, climate change initiatives by some of the world's largest cities have shown that progress is possible when motivated partners work together. Much must be done, and cities in many nations still need to get onboard. But the momentum is growing. Let us hope it is not too late to save lives and safeguard the future. SA

City leaders: To mitigate climate change, Seattle, by 2050, plans to cut greenhouse gas emissions to 80 percent below its 1990 level (*far left*). By 2025 Melbourne (*right*) plans to achieve 100 percent reductions—zero net emissions—which might require the purchase of carbon offsets.

MORE TO EXPLORE

Cities and Climate Change: Global Report on Human Settlements 2011. UN-HABITAT, 2011. www.unhabitat.org/pmss

Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network. Edited by Cynthia Rosenzweig, William D. Solecki, Stephen A. Hammer and Shagun Mehrotra. Cambridge University Press, 2011.

Urban Climate Change Research Network: www.uccrn.org

Urbanization and Global Environmental Change: www.ugec.org

SCIENTIFIC AMERICAN ONLINE

For a slide show about flood threats to cities, see ScientificAmerican.com/sep2011/urban-floods

SOURCE: CARBON DISCLOSURE PROJECT, KPMG ADVISORY N.V.

Graphic by Jen Christiansen

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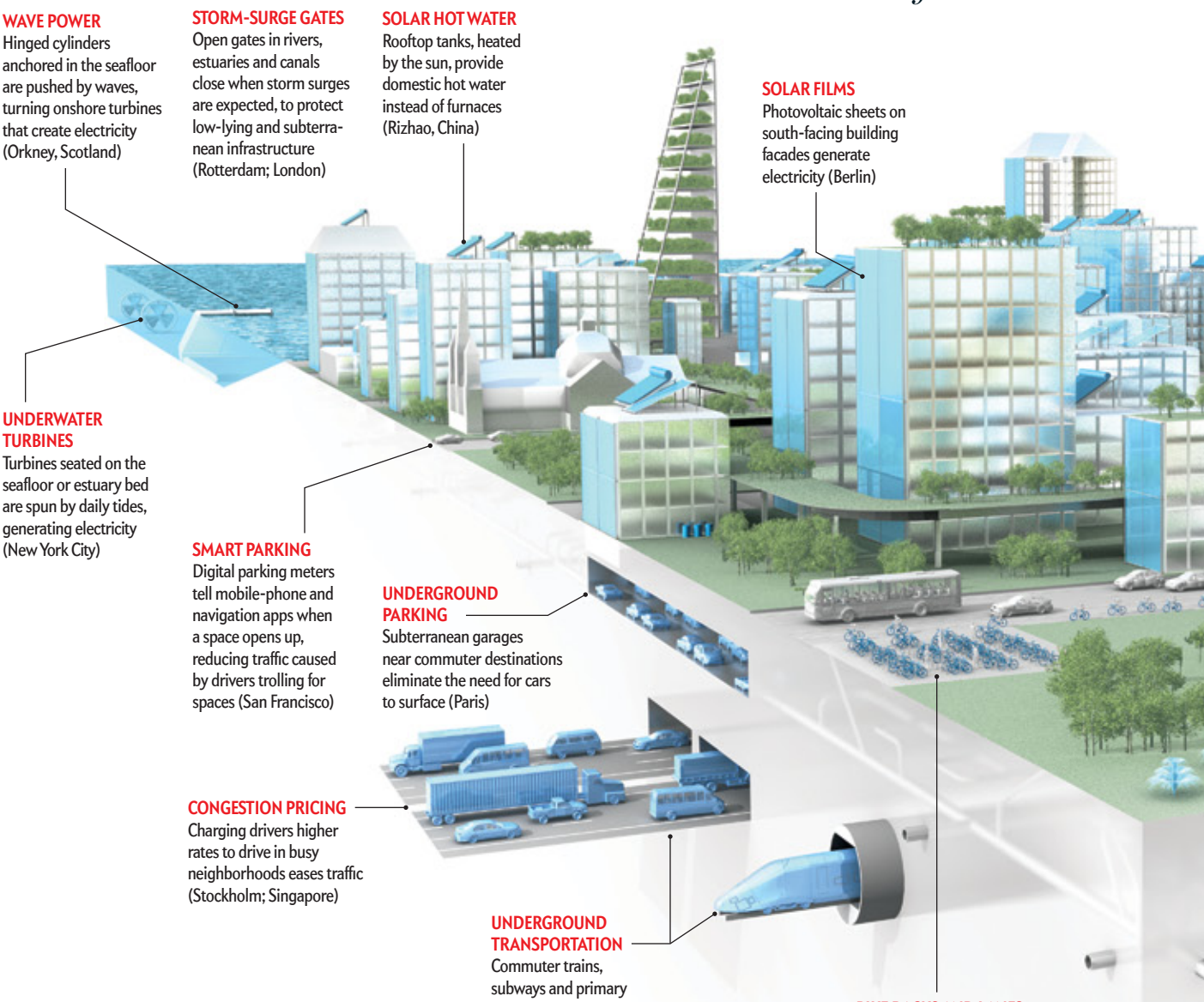
The Efficient City

Municipalities worldwide are exploiting a host of creative solutions to reduce energy consumption, water use, waste and emissions, while also making it easier for people to get around

By Mark Fischetti



WAVE POWER
Hinged cylinders anchored in the seafloor are pushed by waves, turning onshore turbines that create electricity (Orkney, Scotland)

STORM-SURGE GATES
Open gates in rivers, estuaries and canals close when storm surges are expected, to protect low-lying and subterranean infrastructure (Rotterdam; London)

SOLAR HOT WATER
Rooftop tanks, heated by the sun, provide domestic hot water instead of furnaces (Rizhao, China)

SOLAR FILMS
Photovoltaic sheets on south-facing building facades generate electricity (Berlin)

UNDERWATER TURBINES
Turbines seated on the seafloor or estuary bed are spun by daily tides, generating electricity (New York City)

SMART PARKING
Digital parking meters tell mobile-phone and navigation apps when a space opens up, reducing traffic caused by drivers trolling for spaces (San Francisco)

UNDERGROUND PARKING
Subterranean garages near commuter destinations eliminate the need for cars to surface (Paris)

CONGESTION PRICING
Charging drivers higher rates to drive in busy neighborhoods eases traffic (Stockholm; Singapore)

UNDERGROUND TRANSPORTATION
Commuter trains, subways and primary roads run underground in massive tunnels, freeing the ground level for easy, clean bike and pedestrian traffic (Portland, Ore.)

BIKE RACKS AND LANES
Ample bike lanes and racks encourage more people to ride instead of drive; they also promote fitness (Minneapolis)

SCIENTIFIC AMERICAN ONLINE
For details about projects in selected cities, see ScientificAmerican.com/sep2011/infrastructure

NOTE: EXEMPLARY CITIES APPEAR IN PARENTHESES

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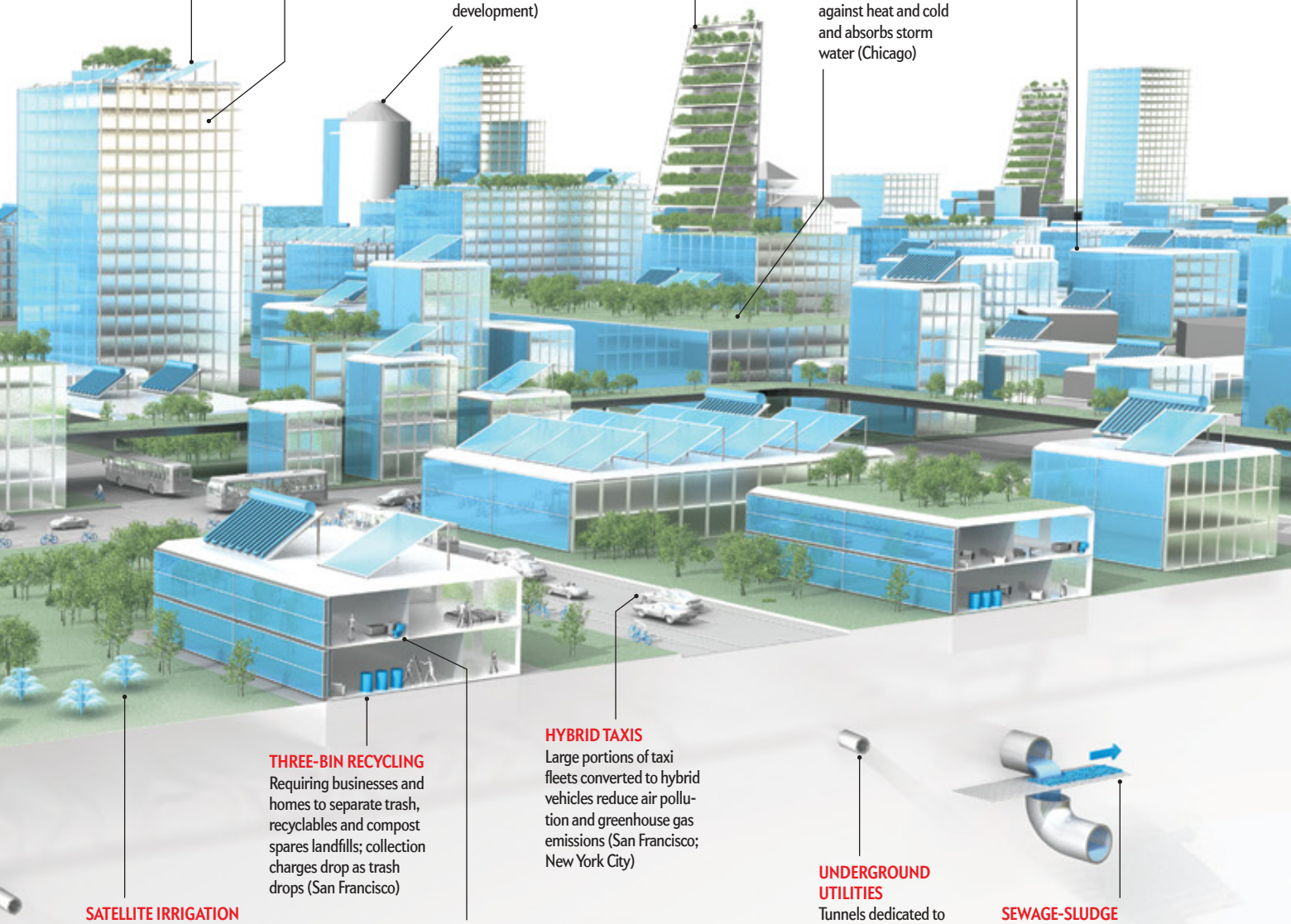

SOLAR POWER
Panels generate electricity instead of power plants and also shade rooftops to lower a building's cooling needs (Redlands, Calif.)

HIGH-EFFICIENCY WINDOWS
Superinsulated windows quadruple the thermal performance of double panes and can be made from the glass in existing windows (Empire State Building, New York City)

CARBON-SEQUESTERING CONCRETE
Construction material made locally with carbon dioxide that is exhaled by power plants could reduce greenhouse gas emissions (Under development)

VERTICAL FARMS
Food grown indoors could reduce fertilizer and freshwater use, shorten transport and recycle gray water otherwise dumped by treatment plants (Under development)

STORM-WATER PRICING
Taxing property owners on the volume of storm water that runs off their property promotes retrofits that reduce wastewater volume at treatment plants (Philadelphia)

LEED NEIGHBORHOOD
Residential and commercial construction done across a city region to the highest green, or Leadership in Energy and Environmental Design (LEED), standards saves energy, materials and emissions (Rockville, Md.)

WHITE ROOFTOPS
Rooftops painted white reflect heat, lowering a building's cooling cost and a city's heat buildup (Washington, D.C.)

GREEN ROOFS
Rooftop vegetation insulates buildings against heat and cold and absorbs storm water (Chicago)

THREE-BIN RECYCLING
Requiring businesses and homes to separate trash, recyclables and compost spares landfills; collection charges drop as trash drops (San Francisco)

HYBRID TAXIS
Large portions of taxi fleets converted to hybrid vehicles reduce air pollution and greenhouse gas emissions (San Francisco; New York City)

SATELLITE IRRIGATION
Satellite control of park and lawn irrigation systems cuts water consumption and pumping power (Los Angeles)

LOW-FLOW APPLIANCES
Water-saving toilets and showerheads installed in buildings save millions of gallons annually (Austin, Tex.)

UNDERGROUND UTILITIES
Tunnels dedicated to carrying electricity, water, cable television and broadband Internet minimize damage from storms and make repairs easier (London)

SEWAGE-SLUDGE INCINERATION
Solid waste extracted from sewage at treatment plants is burned to make electricity (Nashville, Tenn.; Buffalo, N.Y.)

Illustration by Bryan Christie

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Castles in the Air

The attacks of 9/11 supposedly ended the age of the skyscraper. A decade on we're building more than ever

By Mark Lamster

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IN BRIEF

The greatest boom in skyscraper construction in history is under way, led largely by rapidly urbanizing societies in Asia.

Engineering advances have made skyscrapers safer than ever.

Skyscrapers offer solutions to the next century's most pressing large-scale problems—overpopulation and global warming.

Twin peak: Dubai's Burj Khalifa is nearly the same height as the destroyed Twin Towers stacked on top of each other.

Mark Lamster is an architectural historian and associate American editor of the *Architectural Review*. He is working on a biography of the late architect Philip Johnson.

690,000

Number of trips taken in the first 10 months of Washington, D.C.'s bike-sharing program, which allows users to rent a bicycle in one part of town and drop it off at their destination

SOURCE: District Department of Transportation

ON THAT COOL BLUE MORNING 10 YEARS ago when everything changed, Les Robertson was half a world away, hosting a dinner at a Hong Kong restaurant. The rattling of cell phones left on the table—"a detestable habit"—was the first indication that something had struck one of the Twin Towers. Robertson, the revered engineer responsible for their structural design, was at first unconcerned.

"I just assumed that a helicopter had run into the Trade Center," he said recently, speaking from his 47th-floor office, which looks out over Ground Zero. Such an event, unfortunate as it might have been, was well within the tolerances for which the towers were designed. A few minutes later, however, when those cell phones started buzzing once more with news of a second crash, he realized it was "quite another thing again" and excused himself to watch the unfolding events from a hotel room.

In the weeks that followed Robertson declined all requests to speak publicly about the tragedy, even as the innovative structural design of the towers became the subject of public contention. "I thought at that time that my career as a designer of structures was over," he says. For that matter, it seemed that his entire profession might have become obsolete, as fear spread that the attacks marked the very end of the age of the skyscraper.

Anxious stories began to fill America's newspapers. "Many workers fear that their lofty dwellings are more dangerous than glamorous," the *Wall Street Journal* reported on September 19. *USA Today,* on the same date, was less guarded in tone: "It wasn't just the World Trade Center that was obliterated last week. The future of the skyscraper as an American landmark may be teetering."

In the coming months the press would report on, and the U.S. Patent and Trademark Office would receive proposals for, any number of devices—parachutes, tethers, detachable vehicles—to facilitate escape from a burning building. The attacks precipitated a worldwide case of vertigo.

Beyond anxieties about safety, there was a pervading sense that in the digital age the city, and the skyscraper along with it, had become a relic of the past. Henry Petroski, a professor of engineering at Duke University and author of numerous books on the design of the everyday world, made this argument emphatically, just five days after 9/11, in an essay, "Onward but Perhaps Not Upward," in the *Washington Post.* The fast and easy telecommunications provided by the Internet, according to Petroski, translated into "a diminished need for compact contiguous space."

As it turns out, the various prognostications of the skyscraper's demise turned out to be very much mistaken, the moment of questioning an altogether brief interregnum. "There were a lot of foolish predictions or claims that skyscrapers killed people," says Carol Willis, founding director of New York City's Skyscraper Museum. "Terrorists killed people. It wasn't the buildings that were evil or dangerous."

Overseas, construction barely paused after 9/11. The furious urbanization taking place across the Pacific generated a huge demand for new skyscrapers there. "China, the Middle East, Asia? Nobody gave it a moment's notice," says T. J. Gottesdiener, managing partner of Skidmore, Owings & Merrill, an architectural firm synonymous with the design of corporate towers. "We had projects that were in the design stages, and they all continued."

Indeed, our very thinking about the skyscraper has changed dramatically since that day: we now understand that tall buildings can be something more than hubristic blots on our skylines. They just might be the most efficient and sustainable way of accommodating the flood of global urbanization.

GOING UP

THE PAST DECADE, in fact, has been the single greatest period of skyscraper construction in history. According to the Council on Tall Buildings and Urban Habitat (CTBUH), an organization that tracks skyscraper development, some 350 skyscrapers have been constructed since 2001, more than doubling their worldwide population. The number of "supertall" buildings (structures greater than 300 meters in height) has also doubled in that time.

This boom is accelerating. Last year marked the completion of the Burj Khalifa in Dubai, which at 828 meters is not only the world's tallest build-

Green space: Modern skyscrapers such as New York City's Bank of America Tower (*foreground*) are filled with energy-saving technology.

PRECEDING PAGES: IWAN BAAN; OPPOSITE PAGE: DAVID SUNDBERG Esto

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ing but also exceeds its closest competitor (Taipei 101, completed in 2004) by 320 meters, about the height of New York City's Chrysler Building. No building topped off this year or next will dethrone the Burj Khalifa, but 2011 will go down as the single greatest year for the construction of tall buildings in history, with more than 97 skyscrapers over 200 meters (including 22 supertalls) slated for completion.

"The term you hear over and over again is 'iconic,'" Willis says. "Clearly, clients are asking for iconic buildings, and they want them to be tall—taller than the most efficient way to get a return on their investment."

Most supertalls, in fact, cannot be justified on strictly economic terms. Once a building rises beyond roughly 70 stories (the exact figure varies depending on location), the added costs required to achieve structural stability and the added space necessary for elevators and other services generally preclude any direct financial profit.

The overwhelming majority of these aspirational supertalls are rising outside the borders of the U.S. "Cities are using skylines to brand themselves," says Antony Wood, executive director of the CTBUH. "The skyline is seen as an important symbol to portray that a country has arrived on the scene and is a First World country."

Of the 20 tallest buildings completed in 2010, only one, Chicago's Legacy tower, is on American soil (and at number 19, it barely cracks the list). One World Trade Center, formerly known as the Freedom Tower, is only the fourth-tallest building under construction worldwide. It will eventually top out at a symbolic 1,776 feet (541 meters).

China is leading the skyscraper boom. According to a 2009 report by the McKinsey Global Institute, China's cities will swell by 350 million people by 2025. By comparison, the transformational migration of African-Americans from the Jim Crow–era South to northern American cities between 1915 and 1970 entailed a population shift of just six million.

TOP 10

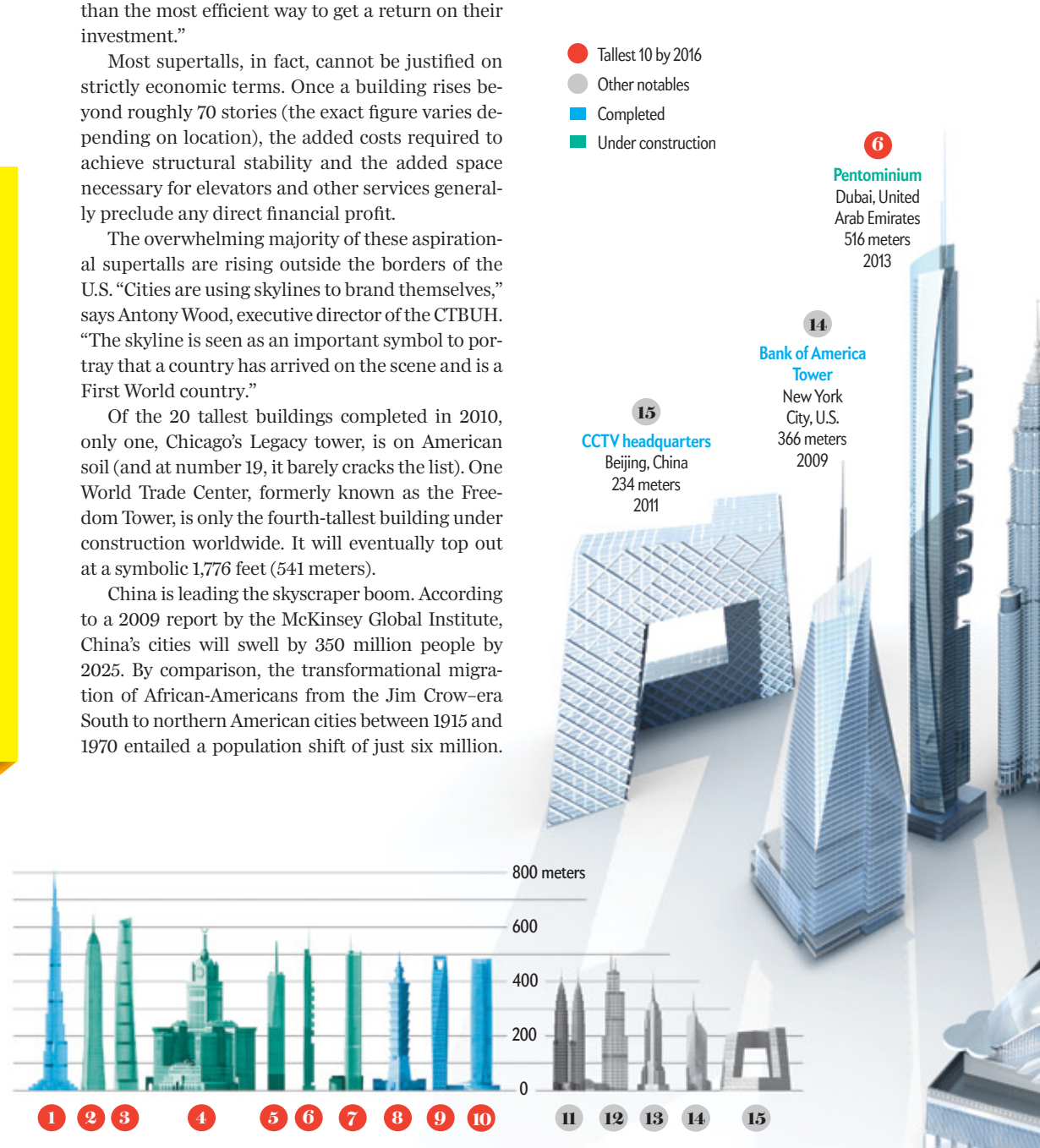
Richest cities of 2025 measured by projected per capita GDP:

1. Oslo, Norway
2. Doha, Qatar
3. Bergen, Norway
4. Macau, China
5. Trondheim, Norway
6. Bridgeport-Stamford, Conn.
7. Hwaseong, S. Korea
8. Asan, S. Korea
9. San Jose, Calif.
10. Yeosu, S. Korea

SOURCE: McKinsey Global Institute

The Skyline of 2016

In 2001 Malaysia's twin Petronas Towers tied each other for the honor of the tallest building in the world. By the middle of this decade they will no longer crack the top 10. Buildings currently under construction are expected to take spots two through seven on the world's tallest list (for the time being the Burj Khalifa remains in a class of its own), another indicator that the world's appetite for statement-making skyscrapers shows no sign of waning. Below, see the 10 that will be the tallest in 2016, along with some interesting outliers.



An Effective Point

Official building-height rankings take into account structural elements such as spires but not antennas or flagpoles. This distinction pushes a building such as 1 WTC 5 ahead of the Pentominium 6, despite the latter's higher roof.

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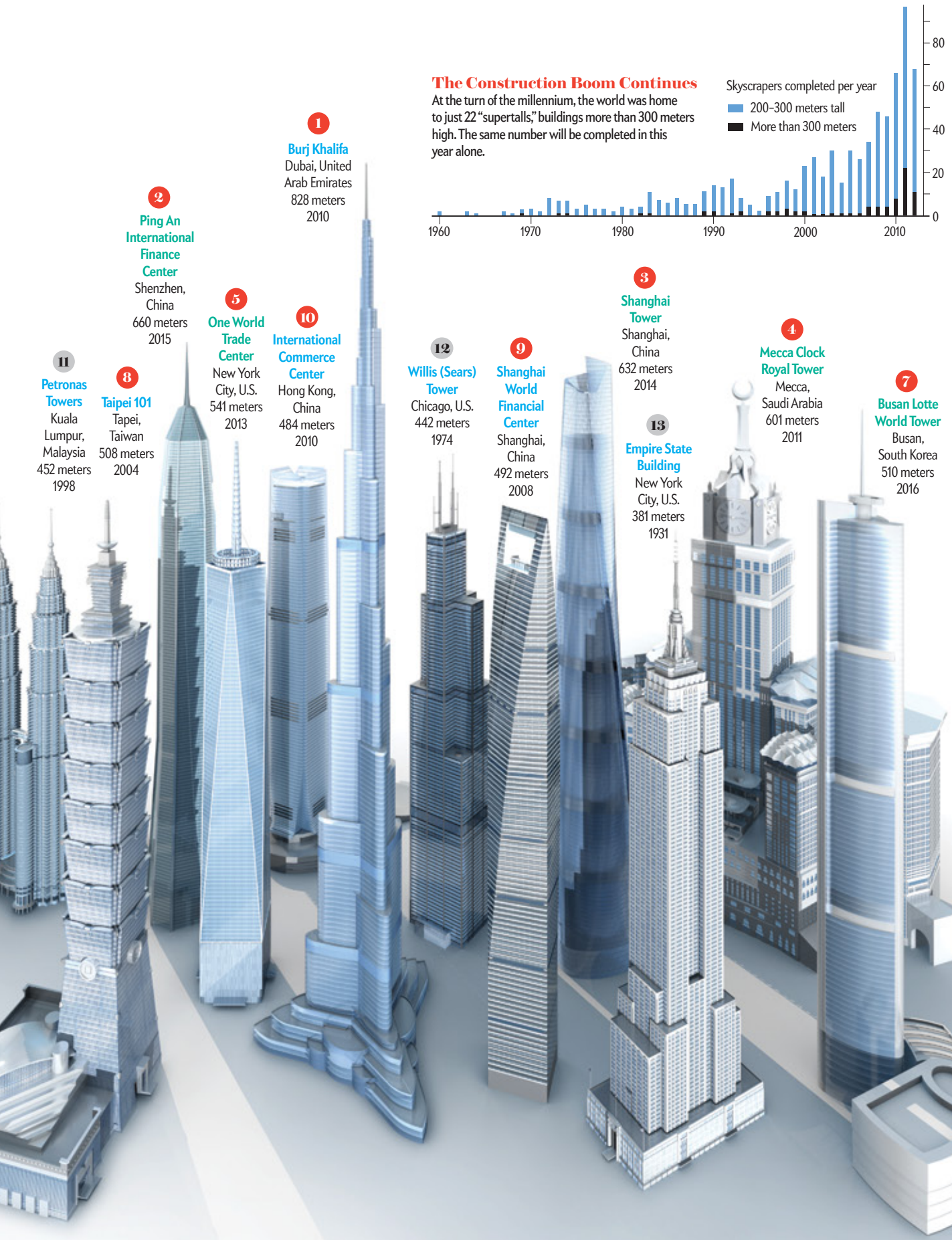

SOURCE: COUNCIL ON TALL BUILDINGS AND URBAN HABITAT (*graph*)

Illustration by Bryan Christie

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Yet even if they are not constructed in the U.S., supertall buildings remain very much a national idiom, their design dominated by American architectural and engineering firms. "If you're going to spend $3 billion on a building," Willis says, "you want to have someone who has done it before."

Given this essential conservatism, it should not be surprising that advances in the design and engineering of the basic structure of these buildings over the past decade have been more incremental than radical. "In terms of grand thought, there's very little that's really new in the design of structures," Robertson says. One of the world's most visually dramatic new skyscrapers is a shimmering 76-story, 265-meter residential tower in Lower Manhattan designed by architect Frank Gehry (who compared its rumpled steel facade to the sculpture of Bernini) that, from a structural standpoint, is quite standard.

Earthquakes still pose a serious challenge to structural engineers. Buildings located in earthquake zones must be stiff enough to carry all of the weight of a supertall yet supple enough to sway when the ground moves. Designs that have "high mass and high stiffness make things worse because a building's mass is what creates your earthquake forces," says Leonard Joseph, a structural engineer who specializes in supertall buildings for engineering firm Thornton Tomasetti.

The lighter and more flexible structures required in earthquake zones must also resist the push of the wind. Among the most inventive engineering solutions to this dilemma have been tuned mass dampers such as the one specified by Joseph and his team at Thornton Tomasetti for Taipei 101, which was until last year the world's tallest building. This 660-metric-ton steel ball is suspended from the 92nd floor to minimize uncomfortable motion. It sways in opposition to the building, pushing and pulling against giant shock absorbers that convert the edifice's motion to harmless heat.

Although the idea seems counterintuitive, today's tall buildings actually offer some advantages over low-rise structures during earthquakes. "When the ground moves suddenly, the skyscraper will 'roll with the punches,' absorbing the sudden movements by deforming," Joseph says. "Short buildings cannot absorb sudden ground movements that way because too much movement would need to be absorbed over too short a height."

Rise again: After years of red tape, finger-pointing and lawsuits, One World Trade Center is rising fast. As of mid-July, workers had reached the 74th (of 104) floors.

AP IMAGES

WORST-CASE DESIGN

OF COURSE, 9/11 taught us that tall buildings may have more to contend with than earthquakes and typhoons. There are limits, however, to the extent to which the design of tall buildings can provide protection against terror attacks, especially given the size and speed of contemporary aircraft. The World Trade Center was designed to withstand the impact of a Boeing 707, which weighs in around 20 percent of an Airbus A380, today's largest passenger jet.

Roughly a month after the attacks, Robertson found himself back in Hong Kong, forced to explain this reality to a nervous development corporation. The intervening weeks had allowed him a bit of perspective, and he was now prepared to make a case for tall buildings. "I espoused to the board that the responsibility was to keep airplanes away from the buildings and not to design the buildings for that circumstance," he says.

Architects and engineers, however, are not without recourse. Improving communications systems for firefighters has been a major priority, solved in part by placing radio repeaters throughout stair towers. "Unquestionably, as a result of 9/11, there has been greater consideration of life safety," Gottesdiener says.

On the other hand, few of the more outlandish emergency egress systems that found their way to the patent office have made much headway with designers. Structural engineers consider these measures extraneous at best. "The building has to give people the option of getting out in a conventional way," says Guy Nordenson, a professor of architecture at Princeton University. "You really want everyone to be able to get out safely."

One safety-enhancing design feature that is only beginning to be implemented is the use of sky bridges between buildings, a staple of futuristic renderings of the early 20th century. Several of the unreal-

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ized proposals for Ground Zero took advantage of these passages. The most prominent standing example is the Chinese Central Television (CCTV) headquarters, which is formed from two towers that rise and connect at a crooked angle in the sky.

The effect is not just visually striking, though it is certainly that. In the event of fire or other calamity, occupants have multiple routes to safety. "From any point in the building, you can go down and out or over and out," says Nordenson, who engineered an even more ambitious Beijing project, the Linked Hybrid complex, along similar lines. Conceived by New York City architect Steven Holl, the mixed-use development spreads 644 apartments, a hotel, a movie theater and even a Montessori school across eight towers, all connected by skywalks.

Today's eye-catching buildings are designed with software that is changing not just the way skyscrapers look but the way they operate. Computer-aided modeling technologies allow architects to adjust their designs on the fly. Just as transformational has been the introduction of building information modeling software, which allows architects to integrate the skyscraper's complex mechanical systems—the need to heat, cool, and move people and materials into and out of the building—into the earliest stages of the design process. The same technology will also allow building managers to test how occupants would react to unique situations such as fire alarms, thereby improving performance.

SCALE FACTOR

THE BIGGEST CHANGE in skyscrapers over the past decade, however, may not have anything to do with the design of the buildings themselves or with their size but with how we think about them. There was a time—and not long ago—when the skyscraper was understood to be the built equivalent of the SUV, an energy-and-resource-sucking drain on the environment.

"The notion that skyscrapers are green is so contrary to what was the standard position a decade ago," says Terence Riley, curator of a landmark 2004 exhibition on tall buildings at the Museum of Modern Art in New York City. "In a lot of people's minds, living green means living in the country." In fact, just the opposite is often true. Residents of cities with dense urban cores, such as New York or Chicago, use far less energy per capita than those who live in suburban or rural areas.

"There are clear environmental benefits in high density and in reducing urban sprawl by bringing spaces for living and working together within a single, compact footprint," says British architect Norman Foster, whose office is engaged in the design of numerous supertall buildings. His Commerzbank headquarters in Frankfurt, completed in 1997, is widely considered the world's first "green" skyscraper, notable for its natural-ventilation system, spiral of sky gardens and daylight-accessible workspaces.

"The higher the building, the more viable it becomes to take advantage of economies of scale," Foster says. "And by bringing together different functions, we can balance energy needs across these uses, generating even greater environmental benefits." Perhaps most important of all, the skyscraper, centrally located, encourages the development and use of public transportation systems.

The most environmentally sophisticated office building in the U.S. is the Bank of America Tower, an asymmetrically capped, 366-meter-tall white pylon just a block from Times Square. It is the first commercial high-rise to receive the Leadership in Energy and Environmental Design (LEED) "platinum" certification, the highest designation awarded by the U.S. Green Building Council.

The Bank of America Tower creates two thirds of its own energy (it has a natural gas generator), filters its incoming air for volatile compounds and recaptures its storm-water runoff. Its floor-to-ceiling, thermally insulated windows and internal glass partitions allow daylight to penetrate deeply into the building and ensure that a high percentage of occupants has a view out. Travel down to the lowest basement level, and you will find what amounts to the largest ice cube tray on earth. Every night chillers freeze the water in 44 enormous tubs, each three meters tall and two and a half meters in diameter. When these ice batteries melt during the day, they provide a significant portion of the building's air-conditioning, shifting its energy consumption to off-hours.

For all its high-tech systems, however, if you ask Robert F. Fox, Jr., a partner in Cook + Fox Architects, the building's designers, what feature is most crucial to the tower's sustainability, he will answer with the real estate agent's maxim: location, location, location. "We can no longer have one person in a car spending fossil fuel to get to work," he says. "A three-story building in the suburbs in the future won't allow for the necessary density, the access to public transportation, or the ability for lots of people to get together and collaborate."

That's right. In direct contrast to Petroski's dire forecast immediately following 9/11, it seems that even as we spend so much of our time on social media (or perhaps because we spend so much of our time on social media), a desire for the human contact afforded by cities—and the skyscrapers within them—are more powerful than ever. Indeed, Google, the standard-bearer of the digital economy, recently spent $1.8 billion on a new building in Manhattan (albeit one only 15 stories tall).

As it is, more and more people are seeking that kind of human contact—or at least the jobs that cities generate. According to the CTBUH, worldwide roughly one million people move to urban centers every week. "Cities have to go vertical," Wood says. They are doing just that. SA

MORE TO EXPLORE

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Council on Tall Buildings and Urban Habitat: **www.ctbuh.org**

The Skyscraper Museum: **www.skyscraper.org**

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Street Talk

What innovation—technological or otherwise—would make any city a substantially more livable place? We put this question to urban leaders and our own readers. Here's what they said

Compiled by Michael Easter and Gary Stix

Cell-Phone Paradise

Communication is at the heart of the future. A future city would need to respond to people on a personal level. Our cell phones can become devices that are able to open the door to our home, pay for our bus and subway charges, make purchases at any store with a tap and a password, and give us unfettered access to the Internet.

—CRAIG BRAQUET, Long Beach, Calif.

Solar-Panel Windows

It would make cities across the globe more livable if the window-panes of city buildings were replaced with transparent and semi-transparent solar panels, which have been (at least crudely) in existence for a number of years. The energy generated from this could then be directed around the city, reducing energy costs and the need to burn coal and thus carbon dioxide emissions.

The power could also be used for public transport, making such transport and the expansion of transport networks much cheaper. Cheap, accessible and expansive public transport would greatly reduce the need for motor vehicle traffic, while also reducing CO_2 emissions.

—HOLLY UBER, political activist and historian, Melbourne, Australia

Wires of Light

It's time for cities to bring fast, reliable fiber-optic broadband to every home and business. When people gave up the old phone modem for the cable modem, that spurred a revolution in our economy and even in the way we interact with one another. The much greater speeds enabled by fiber will do even more. They will create a platform for new innovations and allow urban residents to invent things we can't even imagine today. Fiber-optic broadband is a missing piece in creating a more livable and prosperous city in the 21st century.

—MIKE McGINN, mayor of Seattle

Lockdown for Gridlock

You could collect data from different kinds of sensors—cell-phone signals, surveillance signals, car-mounted [radio-frequency identification] tags, and so on and then create some algorithms to change traffic-light timing to prevent gridlock, help buses move more efficiently and let people know where to park their cars.

—CHARLES D. LINN, writer, editor and architect

A Game Plan

Where we place our infrastructure—the housing, roads, water systems, parks and other components that make up a city—has a huge impact on livability. By being more strategic about these important investments, we can deliver a cleaner, healthier environment, more walkable neighborhoods and other important benefits—all for less cost to taxpayers.

—LISA P. JACKSON, U.S. Environmental Protection Agency administrator

iCities in the Desert

The city should be designed and built with a specific maximum number of people in mind, large enough to accept expected population growth for 100 years. It would be difficult to retrofit current cities, so this should be applied to the concept cities eventually built in the desert by Apple, Microsoft or another large company.

—MIKE KURILKO, Ocala, Fla.

Front-Yard Farming

All landscaping in the front yard of homes and apartments should be limited to either the growing of edible crops or the growing of native species to the area.

—BLAINE M. OSBORNE, Salt Lake City

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More Toilets

In the developing world a billion people live in urban slums, with another billion expected in the coming decades. Their most urgent need is sanitation—water that is free of communicable diseases—and a clean, private place to urinate and defecate. Accordingly, the Bill & Melinda Gates Foundation invited 22 institutions (from Caltech to universities in Brazil and South Africa) to "reinvent the toilet."

—STEWART BRAND, founder of the *Whole Earth Catalog* and co-founder of the Long Now Foundation and Global Business Network

Water, Water Everywhere

The ancient metropolises like Persepolis [in what is now Iran], Athens and Mohenjo Daro [in what is now Pakistan] had superb water-distribution and sewage-removal systems. In my country, "urbanism" can be measured by the number of taps supplying clean water into the household, proper disposal of wastewater, and sewage treatment. So my vote goes to better water-distribution systems (both for drinking and sewage) as the one innovation that would make any city a substantially more livable place.

—PRADIPTO BANERJEE, graduate student, VIT University, India

A Place to Put Your Head

In Vancouver homelessness has eroded the city's "livability." I would like to see forms (emphasis on the plural) of housing that appeal to the homeless—forms that they will use. This undertaking will necessarily address the root causes of their issues. Those afflicted by mental health, poverty, substance abuse and joblessness and runaways make up this population, and we cannot subject them to a one-size-fits-all approach. A place to put your head in safety and comfort—if it isn't an inalienable right, it ought to be one. If our citizens are healthy and productive, the rest falls into place.

—JAY PELTON, Vancouver, B.C.

Smart Sensors

Sensors can serve many purposes, from making traffic patterns more efficient to measuring and reducing our emissions output to monitoring our health in our homes. The shrinking size and growing dispersal of sensor technologies in cities will make these improvements in urban life possible.

—PARAG KHANNA, senior research fellow at the New America Foundation and author of *How to Run the World: Charting a Course to the Next Renaissance* (Random House, 2011)

Urban Face-lifts

A total makeover. Cities are responsible for about 80 percent of carbon pollution. In Sydney we have decided to reduce our carbon emissions by 2030 by 70 percent from 2006 levels through decisive action taken now to retrofit our central business district using various technologies.

The innovation here is not the technology itself but its application at the scale of a city. A series of master plans will create low-carbon zones across the city, with co-located trigeneration energy systems (combining power, cooling and heating), recycled water treatment, and automated waste collection/utilization. And although individually these ideas and technologies are not new, bundling "green infrastructure" together in this way—and at city scale—is an Australian first.

In Sydney our energy comes from coal-fired power stations located more than 200 kilometers away. Our ultimate goal is to take the city off the national electricity network. We are looking at 70 percent of our electricity coming from local, decentralized energy and the remaining 30 percent from renewable-energy technologies. Interim reports suggest the trigeneration network alone could cut greenhouse gas emissions in city buildings by 40 to 60 percent, avoiding some of the high costs of transporting electricity from the country to the city, as well as reducing the need to upgrade the grid to cope with future demand.

—CLOVER MOORE, lord mayor of Sydney, Australia

Personalized Subways

Transportation innovation is one of the keys to creating a more livable city. And one innovation that has the potential to greatly impact life through transportation is personal rapid transit. Personal rapid transit is essentially a personalized subway system for a city. These systems use pods that can hold a handful of people, carrying them directly from point to point, with no stops and no waiting at stations. Creating an easier way to navigate a city promotes interactions among its inhabitants and, in turn, a more livable, and potentially more productive, city.

—SAMUEL ARBESMAN, senior scholar at the Ewing Marion Kauffman Foundation and creator of Mesofacts, an initiative designed to promote awareness of the slowly changing facts in our everyday life

Conga-Line Commuting

My solution is to totally integrate public and private transportation. Individuals would own or lease their own small electric vehicles. They would use them to commute to a station where they would join to form a "train" driven by the electricity network. This would travel at speed along the major arteries, charging batteries as it went. At their destination station the individual cars would decouple and be driven to their final point. Stations could be well spaced because commuters would have their own vehicle to travel the last few kilometers.

—LAURIE McGINNESS, New South Wales, Australia

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Sustainability Lessons

Public transportation has to be a priority and include, for daily commuting, small, nonpolluting cars integrated into a "public transportation system," as Paris did with the Vélib' bicycle-sharing scheme. Second, people need to get involved with sustainability by using fewer cars, separating recyclable garbage at home, living close to work or working close to home, and teaching children about sustainability. Children are phenomenal agents of change.

—JAIME LERNER, former mayor of Curitiba, Brazil, which implemented, during Lerner's first tenure in the early 1970s, an innovative transportation system that has been imitated worldwide

Power, Power Anywhere

People in poor countries crowd the urban centers because of the lack of infrastructure in rural areas. Micro CHP generators, which can use fuels ranging from solar-thermal to biogas, make rural areas more livable by providing electrical infrastructure, affording the powerful potential to decrease overcrowding in urban areas and leading to long-term improvements in urban quality of life.

—IQBAL Z. QUADIR, director of the Legatum Center for Development and Entrepreneurship at the Massachusetts Institute of Technology and developer of the concept of providing universal access to phone service for the poor in Bangladesh

Scooping Up the Fallen Fruit

Long before I learned about the risks of climate change, I was fanatical about energy efficiency. Whenever my wife and I move into a new home, I check the attic for adequate insulation. I look for leaks around doors and windows and install a programmable thermostat if needed. When our hot-water heater needed replacement, we installed a tankless water heater that decreased our summertime gas use by 50 percent.

Taking these steps is called weatherization. I would rather call it "saving money by saving energy." For the next few decades energy efficiency will be one of the lowest-cost options for reducing carbon emissions while promoting economic growth. The quickest and easiest way to reduce our carbon emissions is to make our appliances, cars, homes and other buildings more efficient. In fact, energy efficiency is not just low-hanging fruit; it is fruit that is lying on the ground. Over the next several years I want to help millions of American families seize the same opportunity to cut their utility bills by making their homes and appliances more energy-efficient while increasing comfort.

—STEVEN CHU, U.S. secretary of energy

Better Information on the Internet, Please

Better urban planning, public policy and education could be solutions, but in the current Chinese system those changes could be costly and hard to actualize. Shanghai is not so "compact" compared with other world metropolitan areas, as we have about 20 million people in a very spread-out urban area. We already have some severe urban problems such as intense traffic congestion, overcrowding in public areas, housing supply shortage, environmental pollution, fast-increasing amounts of greenhouse gas emissions and the public overreacting to rumors.

When I turn to science for solutions, the Internet and other public media seem to have much more potential to readily spread helpful information to the public and enable them to make efficient and beneficial decisions, making things easier for everyone. That should be the main goal desperately sought after by the urban-management practitioners.

—PAN HAOZHI, student, Tongji University, Shanghai

Car-Free Zones

Abolish the private automobile from the urban core (or significantly built-up areas) and redirect the current investment in private capital that automobiles represent to investment in public transportation and redevelopment of former streets, parking lots, and the like into housing, parks and urban agriculture.

Completely rethink our definition of "the city" and begin to plan accordingly. We need to see cities as complete human ecosystems and recognize that the complementary (and arguably more important) productive component of the urban human ecosystem is its resource hinterland, an area typically hundreds of times larger than the city itself and increasingly scattered all over the planet. In short, the city's true "ecological footprint" dwarfs the tiny, consumptive urban center. The big footprint is essential for the survival of the urban core and yet is typically ignored or taken for granted.

—WILLIAM REES, professor at the University of British Columbia and originator of the "ecological footprint" concept, which measures human demand on ecosystems

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Smart Growth

The policies and planning practices of "smart growth" would create and encourage sustainable places. This approach to combating sprawl is about encouraging new development of housing and jobs to locate in and around the urban core. For example, in Maryland former governor Parris Glendening spearheaded the state's landmark smart-growth legislation in 1997. The state law creates "priority-funding areas" that dictate where public funding of new infrastructure (that is, roads, sewers, social services) will be allocated. These areas are located near big cities, which encourages new development—and even redevelopment—near our urban centers and saves green fields and farms on the urban fringe from development.

—THOMAS VICINO, professor at Northeastern University and co-author of *Cities and Suburbs: New Metropolitan Realities in the US* (Routledge, 2010)

Intermetropolises

I envision an interconnecting grid of futuristic cities strategically placed around the continent. The main purpose and design of these cities is such that they utilize their natural surroundings, wind, hydro, solar, geothermal and bio, to power themselves and provide a neighboring city with excess power or necessary power.

—CHRISTIAN CARR, Kristiansand, Norway

Ixnay on the Oalcay

Cities need to stop burning fossils.

—BRUCE STERLING, science-fiction author who helped to establish the cyberpunk genre

Clusters

Cities should be built near the resources they need, such as agricultural and industrial land. Within cities there should be clusters of tall buildings, designed to leave most of the ground free to be renaturalized or left in its natural state and providing an urban park with easy access to the building dwellers. Each building or building cluster would have basic services such as commerce, administration, sports, and such. The high-density model would greatly simplify transportation and utility networks, while at the same time providing easy access to the natural world, which would be literally an elevator ride away.

—VÍTOR PEREIRA, Porto, Portugal

Social Cohesion

For as long as we have had cities, we have had inequity in access to social and environmental resources among urban citizens. Cities cannot be more livable nor support sustainability without policies that work on both unsustainable overconsumption in the city and unlivable social divides among groups. This is not an impossible innovation—just a difficult one and one we have never tried.

—CAROLYN STEPHENS, London School of Hygiene & Tropical Medicine and National University of Tucumán, Argentina

Populist Purse-Strings Control

"Participatory budgeting" changes the standard operating procedures of government by involving the citizens directly in municipal budgetary decisions. The process decentralizes decision making to the subcity level by breaking down the budget along neighborhood lines, involving residents in setting priorities for local government expenditures and electing a council of delegates that is held accountable. Experience shows that the results can be more efficient use of public funds, consensus building around investments in underserved neighborhoods and a dramatic drop in corruption. This changes the rules of the game, bringing heretofore disenfranchised individuals and groups to the bargaining table and provides an alternative incentive structure for collaboration.

Porto Alegre, a city in the south of Brazil, started experimenting with this process in 1989. Since then, it has been improved and adapted in various forms by more than 1,200 municipalities elsewhere in Brazil and Latin America, as well as in Africa, Asia, Europe and North America.

—JANICE PERLMAN, president of the Mega-Cities Project, a nonprofit organization that identifies and shares successful urban innovations across cities worldwide

The Internet of Things

We need more smarts. Cities, in their next generation, will become more highly embedded with intelligence via computing and thus with information, responsive capability and, ultimately, agency. Some of this transformation is already visible—"the Internet of things" will make it possible to query our surroundings the way we search the Web; citizen sensing through smartphones creates geo-coded, real-time, cheap and useful data. Beyond the near term, the possibility of a city that is significantly smarter could help us manage many aspects of daily life and could be customized to our preferences and routines. The key will be to design this new urban intelligence to create a better city and with enough transparency so that our privacy is protected and opting out is easy.

—DANA CUFF, director of cityLAB and professor of architecture and urban design at the University of California, Los Angeles, and author of *The Provisional City: Los Angeles Stories of Architecture and Urbanism* (MIT Press, 2002)

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Gary Stix *is senior writer at* Scientific American.

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For more responses from pundits and readers, go to ScientificAmerican.com/sep2011/survey

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William Gibson, after a boyhood in small-town Appalachia, has made elaborately imagined urban settings into the centerpiece for his intricate fictional worlds.

Life in the Meta City

We walk a line between the anarchy of choice and Disney-fication, says the author of *Neuromancer*

By William Gibson

MY FIRST CITY WAS CONAN DOYLE'S LONdon, in the company of Holmes and Watson. My mother gave me a two-volume omnibus edition when I was 10. London was a vast, cozy, populous mechanism, a comforting clockwork. Foreigners and criminals served as spices, highlighting the assumed orderliness and safety of the Empire's capital (assuming one were sufficiently comfortably placed in society, and in Doyle one tended to be).

I lived in rural southwestern Virginia, the nearest cities several hours away and those were smallish cities. Relatively little of what I saw on television conveyed much sense of urban reality, perhaps because it was still inherently difficult to film in large cities. Except for Los Angeles, and I saw a lot of that, and Los Angeles never did become much a part of my imagination's map of cities.

I reverse-engineered a concept of urban life from Doyle's rich and intriguing (and cozy) construct. I walked through my hometown, imagining it a city. What I was imagining, I now see, was an increase not in size but in number of choices.

Cities afforded more choices than small towns, and constantly, by increasing the number and randomization of potential human and cultural contacts. Cities were vast, multilayered engines of choice, peopled primarily with strangers.

You never know whom you might meet in the city. In a small town, you're less likely to encounter people or things or situations you haven't encountered previously. These people or things or situations may be wonderful or horrible, in either city or town, but cities have the numbers, the turnover. To a writer of fiction, this is extremely handy, a city being able, more or less believably, to mask excessive coincidence, producing, as Doyle taught me, whatever the narrative might require.

Should the populous mechanism of the fictive city fail to produce phenomena of sufficient weirdness, our literature of the fantastic often turns, quite reflexively, to dead cities, our most profoundly and mysteriously haunted artifacts.

Many deserted cities probably never were engines of choice. To stand in the vast plaza of the pre-Columbian Monte Albán, for instance, is to know that Monte Albán was about decreasing choice, narrowing it. Monte Albán was a control machine, an acoustically perfect environment with magnificent lines of sight: a theater of power. We don't know why Monte Albán was as abruptly deserted as it may have been. Perhaps the show failed, finally, to come off, and no other was available, or possible, within that inflexible, uni-purposed structure.

That's the danger of choice reduction, of top-down control. And the curse of gated attractions, the ultimate fate of every Disneyland: you can't repurpose a theme park. Cities, to survive, must be capable of extended fugues of retrofitting. Only the most pubescent of cities have never witnessed, to whatever extent, their own ruins. Berlin has, Rome has, Lon-

Illustration by Donato Giancola

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don has, Tokyo has, New York has. Relative ruin, relative desertion, is a common stage of complex and necessary urban growth. Successful (which is to say, ongoing) cities are built up in a lacquering of countless layers: of lives, of choices encountered and made.

The most crucial layers are those of various essential technologies, all of which must in some sense be present and functional for a city to endure. We didn't begin to build cities until we could secure adequate supplies of food, which generally meant growing and storing it. Growth beyond a certain size requires mastery of sewage-disposal technologies. The city evolves as a pyramid of technologies, some essential, others incidental.

Cities can be at their experientially richest during periods of relative disjunction. Cities that are somewhat dysfunctional in one sense can be brilliantly functional in others. The city you want, as a young creative person, is partially ruined, marked by areas semimoribund in real estate values. Low rents, minimal policing, casual welding allowed on sidewalks. Manhattan in the 1970s, a place and time people my age now regard with mixed nostalgia, was fraught with ruins, with buildings abandoned, nights lit by insurance fires. On first observing this, in 1979, I suggested, half-seriously, that the Japanese be allowed to sort the place out, given their way with urban real estate. New Yorkers smirked at my bumpkin naïveté, knowing the Bowery would always be the Bowery.

Today the Bowery is nothing like the Bowery.

Cities can do that, reversing out of disjunction, throwing themselves into a different gear. Although in doing so, they run the risk of Disneylanding themselves, of building themselves too permanently into a given day's vision of what they should be. Paris feels that way to me, lovely as it is, with New York and London hurrying to catch up.

Meanwhile, though, some of the world's largest human settlements are now not only places where one can weld on the sidewalk but places that have bypassed many of the ways in which Europeans and North Americans have assumed cities necessarily need to grow: Rio, Mumbai, Nairobi, Istanbul, Mexico City.... Vast squatter conurbs, semi-neo-Medieval in their structure and conditions. The future will emerge from such cities as surely as it will emerge from the Disneylanded capitals of an Old World that now includes North America.

The future of cities will consist of two different modalities combined within the ageographical and largely unrecognized meta city that is the Internet.

As a boy, I took myself away to cities as quickly as I could and have lived in them ever since. When I travel now, I travel mainly to cities, and I tend to return to those I know, taking a deepening pleasure in the serial experience. The idea of visiting a fascinating city only once saddens me, and I seldom leave a city I've come to know without wondering if I'll see it again. But in our ageographical existence, I am never entirely not in London, entirely not in Tokyo.

We all inhabit the meta city now, regardless of physical address. SA

MORE TO EXPLORE

Gibson's latest book: **Zero History.** Berkley, 2011
The author's Web site: www.williamgibsonbooks.com
His Twitter handle: @GreatDismal

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Read an interview with Gibson on cities at ScientificAmerican.com/sep2011/gibson

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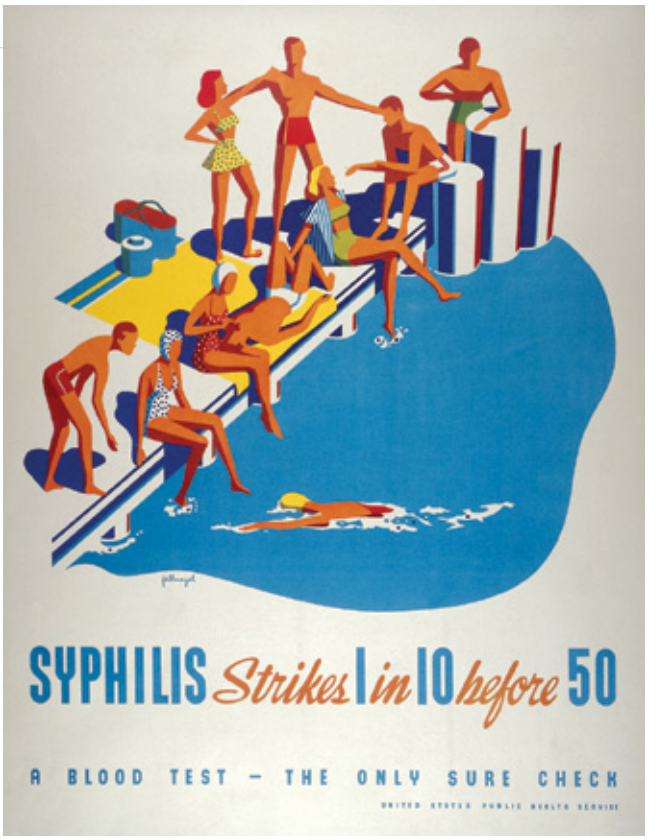
The Art of Medicine: Over 2,000 Years of Images and Imagination

by Julie Anderson, Emm Barnes and Emma Shackleton. University of Chicago Press, 2011 ($50)

For millennia, artists have chronicled human health and the quest to preserve it. Behold the evolution of medicine through the ages, as encapsulated in this compendium of artifacts, drawings, paintings and biomedical images from the holdings of London's Wellcome Collection.



U.S. Public Health Service poster, 1940

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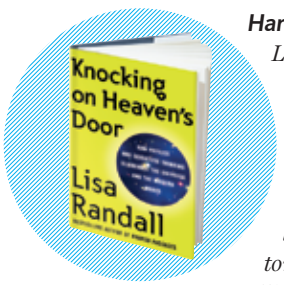
EXCERPT

Knocking on Heaven's Door: How Physics and Scientific Thinking Illuminate the Universe and the Modern World

by Lisa Randall. HarperCollins, 2011 ($29.99)



***Harvard University physicist** Lisa Randall discusses the nature of science and the latest ideas in physics and cosmology. Below she recounts touring the world's largest particle accelerator, CERN's Large Hadron Collider (LHC) near Geneva.*

"The first time I visited the LHC, I was surprised at the sense of awe it inspired—this in spite of my having visited particle colliders and detectors many times before.... Although the scientist in me recoils at first in thinking of this incredibly precise technological miracle as an art project—even a major one—I couldn't help taking out my camera and snapping away. The complexity, coherence, and magnitude, as well as the criss-crossing lines and colors, are hard to convey in words....

"People from the art world have had similar reactions. When the art collector Francesca von Habsburg toured the site, she took along a professional photographer whose pictures were so beautiful they were published in the magazine *Vanity Fair*.... The actor and science enthusiast Alan Alda, when moderating a panel about the LHC, likened it to one of the wonders of the ancient world....

"I've heard such statements from people in all walks of life. The Internet, fast cars, green energy, and space travel are among the most exciting and active areas of applied research today. But going out and trying to understand the fundamental laws of the universe is in a category by itself that astounds and impresses. Art lovers and scientists alike want to understand the world and decipher its origins. You might debate the nature of humanity's greatest achievement, but I don't think anyone would question that one of the most remarkable things we do is to contemplate and investigate what lies beyond the easily accessible. Humans alone take on this challenge."

ALSO NOTABLE

BOOKS

The Quest: Energy, Security, and the Remaking of the Modern World, by Daniel Yergin. Penguin Press, 2011 ($37.95)

Columbus and the Quest for Jerusalem, by Carol Delaney. Free Press, 2011 ($29.99)

Welcome to Your Child's Brain: How the Mind Grows from Conception to College, by Sandra Aamodt and Sam Wang. Bloomsbury, 2011 ($25)

Feynman, by Jim Ottaviani. Illustrated by Leland Myrick. A graphic biography. First Second, 2011 ($29.99)

Empire of the Beetle: How Human Folly and a Tiny Bug Are Killing North America's Great Forests, by Andrew Nikiforuk. Greystone Books, 2011 ($17.95)

Cosmic Numbers: The Numbers That Define Our Universe, by James D. Stein. Basic Books, 2011 ($25.99)

Making Sense of People: Decoding the Mysteries of Personality, by Samuel Barondes. FT Press, 2011 ($25.99)

EXHIBITS

Dinosaur Hall. New addition at the Natural History Museum of Los Angeles County.

Picturing Science: Museum Scientists and Imaging Technologies. On view through June 24, 2012, at the American Museum of Natural History in New York City.

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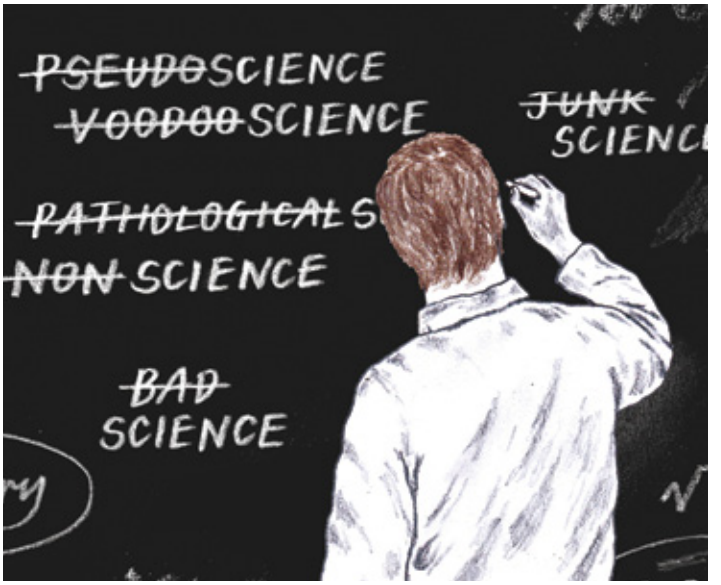
Michael Shermer is publisher of *Skeptic* magazine (www.skeptic.com). His new book is *The Believing Brain*. Follow him on Twitter @michaelshermer

What Is Pseudoscience?

Distinguishing between science and pseudoscience is problematic



Climate deniers are accused of practicing pseudoscience, as are intelligent design creationists, astrologers, UFOlogists, parapsychologists, practitioners of alternative medicine, and often anyone who strays far from the scientific mainstream. The boundary problem between science and pseudoscience, in fact, is notoriously fraught with definitional disagreements because the categories are too broad and fuzzy on the edges, and the term "pseudoscience" is subject to adjectival abuse against any claim one happens to dislike for any reason. In his 2010 book *Nonsense on Stilts* (University of Chicago Press), philosopher of science Massimo Pigliucci concedes that there is "no litmus test," because "the boundaries separating science, nonscience, and pseudoscience are much fuzzier and more permeable than Popper (or, for that matter, most scientists) would have us believe."

It was Karl Popper who first identified what he called "the demarcation problem" of finding a criterion to distinguish between empirical science, such as the successful 1919 test of Einstein's general theory of relativity, and pseudoscience, such as Freud's theories, whose adherents sought only confirming evidence while ignoring disconfirming cases. Einstein's theory might have been falsified had solar-eclipse data not shown the requisite deflection of starlight bent by the sun's gravitational field. Freud's theories, however, could never be disproved, because there was no testable hypothesis open to refutability. Thus, Popper famously declared "falsifiability" as the ultimate criterion of demarcation.

The problem is that many sciences are nonfalsifiable, such as string theory, the neuroscience surrounding consciousness, grand economic models and the extraterrestrial hypothesis. On the last, short of searching every planet around every star in every galaxy in the cosmos, can we ever say with certainty that E.T.s do not exist?

Princeton University historian of science Michael D. Gordin adds in his forthcoming book *The Pseudoscience Wars* (University of Chicago Press, 2012), "No one in the history of the world has ever self-identified as a pseudoscientist. There is no person who wakes up in the morning and thinks to himself, 'I'll just head into my pseudolaboratory and perform some pseudoexperiments to try to confirm my pseudotheories with pseudofacts.'" As Gordin documents with detailed examples, "individual scientists (as distinct from the monolithic 'scientific community') designate a doctrine a 'pseudoscience' only when they perceive themselves to be threatened—not necessarily by the new ideas themselves, but by what those ideas represent about the authority of science, science's access to resources, or some other broader social trend. If one is not threatened, there is no need to lash out at the perceived pseudoscience; instead, one continues with one's work and happily ignores the cranks."

I call creationism "pseudoscience" not because its proponents are doing bad science—they are not doing science at all—but because they threaten science education in America, they breach the wall separating church and state, and they confuse the public about the nature of evolutionary theory and how science is conducted.

Here, perhaps, is a practical criterion for resolving the demarcation problem: the conduct of scientists as reflected in the pragmatic usefulness of an idea. That is, does the revolutionary new idea generate any interest on the part of working scientists for adoption in their research programs, produce any new lines of research, lead to any new discoveries, or influence any existing hypotheses, models, paradigms or worldviews? If not, chances are it is pseudoscience.

We can demarcate science from pseudoscience less by what science is and more by what scientists do. Science is a set of methods aimed at testing hypotheses and building theories. If a community of scientists actively adopts a new idea and if that idea then spreads through the field and is incorporated into research that produces useful knowledge reflected in presentations, publications, and especially new lines of inquiry and research, chances are it is science.

This demarcation criterion of usefulness has the advantage of being bottom-up instead of top-down, egalitarian instead of elitist, nondiscriminatory instead of prejudicial. Let science consumers in the marketplace of ideas determine what constitutes good science, starting with the scientists themselves and filtering through the editors, educators and readers. As for potential consumers of pseudoscience, that's what skeptics are for, but as always, caveat emptor. SA

COMMENT ON THIS ARTICLE ONLINE
ScientificAmerican.com/sep2011

Illustration by Alex Robbins

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People customarily believe they have control of their thinking and thus their behavior—a belief that is a proven fantasy, causing untold damage in the lives of all members of the human race.

That might seem to be a shocking statement until it is checked for correctness by reference to the reality of life itself. What follows briefly explains.

For example, on this planet when people drop things, do they always fall *downward*? Do they ever rise *upward*? Perhaps only young children fail to know that it is nature's law of gravitation that controls what happens when people drop things—*not people*.

Careful attention to every aspect of life on planet Earth reveals that laws of nature determine the results of the physical activity of people everywhere. Such laws are referred to as nature's laws of physics.

The reason for the mistaken *belief* that personal behavior is controlled by each individual is that most people have not been introduced to ***nature's behavioral law of absolute right***.

Knowledge of that law destroys the fantasy that people have control of their chosen destiny. Nobody ever did; nobody ever will; and the following text explains why.

After an earnest appeal to the creator as to why people everywhere behaved so irresponsibly and destructively, Richard W. Wetherill in 1929 was given insight into a natural law, controlling the results caused by people's reactions to life's every situation.

It states: ***Right thoughts and behavior get right results at all times, for everybody, in all places; contradictory wrong thoughts and behavior do not***. This natural law requires right thinking and behavior to be ***rational*** and ***honest*** in people's relationships with one another, their environment, and when dealing with whatever happens in their lives.

Consider two serious problems prevalent in society today: killings and numerous kinds of corruption in high places and low. Those are people-activities that perpetrators usually try to conceal to avoid getting caught by the authorities.

People's irrational, dishonest thoughts and behavior, however, can never be concealed from ***nature's self-enforcing law of absolute right***. All deviations from its right action are causing penalties for people. And that is the reason why people have not realized that they, themselves, are causing those results.

Ordinarily people regard a white lie as harmless and permissible. Not so! People's thoughts that are not rational and honest cause wrong results. Further, they get lodged in memory where they continue causing future difficulties usually blamed on other people.

Do people question the irrational or dishonest thoughts that arise in their minds? They should. Those thoughts arise from past efforts to control their behavior. If not released, they cause recurring wrong results.

The answer? Self-enforcing natural laws rule this planet and its people; always did; still do. Rational and honest behavior that conforms to nature's law of absolute right is the only solution that releases past wrong thoughts from the mind.

What could be simpler?

Let a natural law serve its function, and it will peacefully control the attitudes and behavior of people of every age, race, and creed.

Learn how to free yourself from the past fantasy of self-control of behavior. Let nature's-control have its way in your life, as routinely as you do with all the self-enforcing laws of physics.

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This public-service message is from a self-financed, nonprofit group of former students of Mr. Wetherill.

The ongoing search for fundamental farces

Steve Mirsky has been writing the Anti Gravity column since the 20th century. He is not working on a screenplay, but he does host the *Scientific American* podcast Science Talk.

Noble Nobel Faces

A week in Lindau, where scientists are celebrities

As the ship pulled out of port, a young man near me started humming the theme from *Gilligan's Island*. I mentioned to him that the show would have been very different had the SS *Minnow* been carrying not a lone professor but—as our vessel was—a contingent of Nobel laureates. "Yeah," he replied, "with everybody who's here, we'd probably get off the island pretty quick."

This boat ride on Lake Constance, or the Bodensee as it is locally known, was part of the last day's activities of the 61st annual Lindau Nobel Laureate Meeting in Germany. It was tough to swing Nobel Prize winner Erwin Schrödinger's possibly dead cat in the tiny seaside resort town all week and not hit one of the 23 Nobelists who had come to deliver lectures and advice to some 600 young researchers from all over the world.

A collection of biographies of the science greats in attendance is awe-inspiring (and available online at www.lindau-nobel.org). But what I'll remember is their faces. For one thing, a traffic circle near the Inselhalle conference center featured a display of 10-foot-high head shots of all the visiting academic dignitaries. But face-to-face, their animated faces made a deeper impression.

Take Oliver Smithies, who shared the 2007 Nobel Prize in Physiology or Medicine for the development of gene targeting in mice, which allows researchers to study the function of virtually any mammalian gene by taking it out of the equation. In his spare time, he invented gel electrophoresis, one of the workhorse analytical tools of molecular biology. Smithies could be called a wizard—and he looks like the kindly Harry Potter version: twinkling eyes on the top floor, a perpetual whimsical smile downstairs. He showed the audience a photograph of his jerry-built PCR machine, cobbled together years before such devices could be bought online from Amazon.com. (I checked: a new one is available for $7,250.) Smithies's creation looked like it followed a strict Rube Goldberg design and bore the label "NBGBOKFO," which, he explained, stood for "no bloody good but OK for Oliver."

Thomas Steitz looks like he should be piloting a whaling ship, by virtue of his old-timey New England seafarer's beard-with-no-mustache. Make it a whale-watching ship, seeing as how the Yale University researcher's 21st-century New Haven face lacks the grimness of those 19th-century New Bedforders'. Steitz shared the 2009 chemistry Nobel for his elegant elucidation of the three-dimensional structure and detailed function of the ribosome, the cellular organelle charged with the actual production of proteins as per the instructions of the genetic code. So, naturally, we talked baseball.

Steitz and his wife, Joan, a renowned molecular biologist herself, are the parents of Jon Steitz, who was a good enough pitcher at Yale to be a 2001 third-round draft pick of the Milwaukee Brewers. The senior Steitz disclosed a little gem of baseball trivia: "Jon's signing bonus with the Brewers was bigger than my share of the Nobel Prize."

The conference's senior face belonged to 93-year-old Christian de Duve, who now bears a strong resemblance to one of those wise and benevolent tortoises found in various feature-length cartoons. With the gross architecture of the cell now well known, most living laureates who have studied biological systems, such as Steitz, worked at the molecular level. But de Duve's 1974 Nobel was for his six-decade-old discoveries of theretofore entirely unknown cell organelles, the lysosome and the peroxisome. If he's a tortoise, he's one of those Galápagos versions that both greeted Darwin and thrived into the 21st century. When the slide projector failed during his talk, he calmly told the AV tech frantically trying to fix the problem, "Don't worry, I know what's on them." Genius. SA

SCIENTIFIC AMERICAN ONLINE To listen to interviews with some of the Nobel Prize–winning scientists in attendance at the Lindau meeting, visit the Science Talk section at **ScientificAmerican.com/podcast**

Illustration by Matt Collins

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September 1961

Nerve Cells Talking

"So far we have said nothing about inhibition, even though it occurs throughout the nervous system and is one of the most curious modes of nervous activity. Inhibition takes place when a nerve impulse acts as a brake on the next cell, preventing it from becoming activated by excitatory messages that may be arriving along other channels at the same time. The impulse that travels along an inhibitory axon cannot be distinguished electrically from an impulse traveling in an excitatory axon. But the physicochemical effect that it induces at a synapse must be different in kind. —Bernhard Katz"

Katz shared the 1970 Nobel Prize for medicine.

September 1911

Tesla Turbine

"It will interest the readers of the SCIENTIFIC AMERICAN to know that Nikola Tesla, whose reputation must, naturally, stand upon the contributions he made to electrical engineering when the art was yet in its comparative infancy, is by training and choice a mechanical engineer. For several years past he has devoted much of his attention to improvements in thermo-dynamic conversion, and the result of his theories and practical experiments is to be found in an entirely new form of prime movers. Briefly stated, Tesla's steam motor consists of a set of flat steel disks mounted on a shaft and rotating within a casing, the steam entering with high velocity at the periphery of the disks, flowing between them in free spiral paths, and finally escaping through an exhaust port at their center. Tesla depends upon the fluid properties of adhesion and viscosity—the attraction of the steam to the faces of the disks—in transmitting the velocity energy of the motive fluid to the plates and the shaft."

NOTE: The thin steel plates could not withstand higher temperatures and speeds. Newer materials such as carbon fiber or ceramics may renew interest in this compact design.

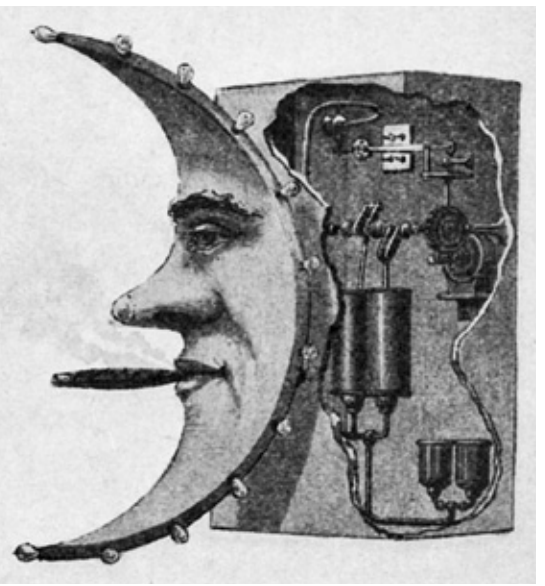
Modern Tobacco Ads

"Most people imagine that the wooden Indian has a monopoly of the tobacco sign business, but he has a competitor in the dummy which ostensibly smokes a cigar. The cigar, however, is likewise a dummy, and the smoke comes from a concealed pot of burning tobacco and is intermittently expelled from the lips of the dummy by concealed bellows. One of the most elaborate of these signs is a hollow crescent figure [*see illustration*], whose convex face is studded with incandescent lights, and bulbs are also at the outer end of the cigar."

More mechanical advertising devices are at www.ScientificAmerican.com/sep2011/novelties

Horses and Heat

"The health department of New York city, which has the task of removing dead horses, reported that during the six working days of the hot period of July, 171 horses died each day—a total of 1,026. These horses represented over half a million dollars cash value, which was entirely wiped out in a single week. It is estimated that the money would pay for a sufficient number of electric vehicles to do all of the work done by the horses, and do it more efficiently and economically."



Smoking Moon: mechanical novelty to promote cigar sales, 1911

September 1861

Cocaine Isolated

"The German chemist, Dr. Niemann, has recently been making experiments with coca leaves, and has obtained from them an alkaloid which he proposes to call *cocaina*. Pure cocaina is colorless; the crystals are large prisms. It has an alkaline reaction, a bitter taste, and when placed upon the tongue it promotes the flow of saliva and induces a sensation of cold. Several German chemists and physicians have recommended coca leaves as a substitute for coffee in European armies, on account of the well known qualities of coca, to preserve life and strength for a considerable time without common food."

Nautical Discipline

"The British merchant ship *Star of the East,* while on her passage from Bombay for Liverpool, was lost while beating through the Mozambique channel. At the official inquiry into her loss, the first witness was the sailmaker of the ship, who stated that when she struck she was about a mile off the shore. Whereupon Mr. Tyndall, the attorney for the government Board of Trade, says to him, 'Didn't you think it strange that the ship should be so close in shore?' Witness—'We're not allowed to think; there's only the cook and the captain allowed to think on board a ship.' The answer was a sockdologer, and the representative of their lordships, after this brief exposition of sea law, made no more interruptions."

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The Human Cost of Energy

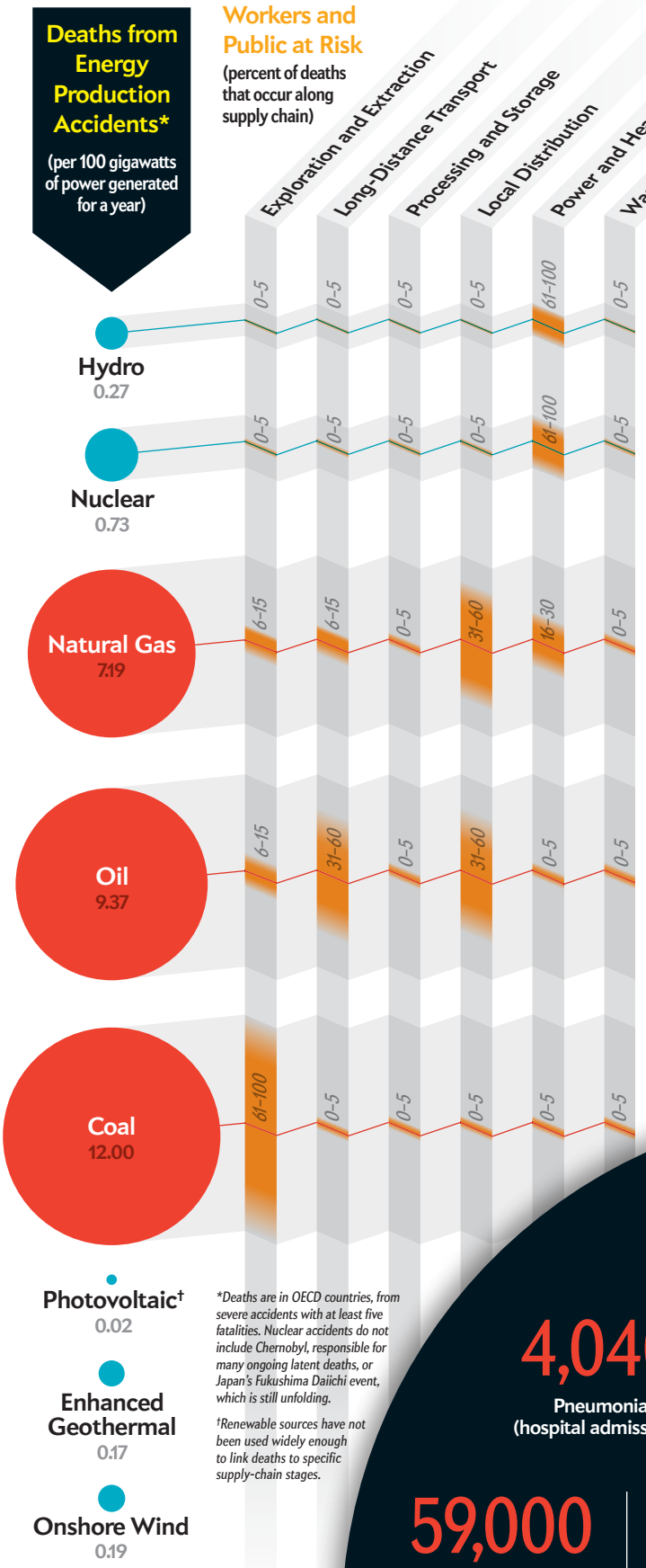
Fossil fuels exact the biggest toll in terms of lives lost

Deadly accidents involving nuclear reactors, oil rigs and coal mines in recent months remind us that all forms of energy generation carry risks. In developed countries, coal is the most hazardous (*bottom left*), according to the Paul Scherrer Institute in Switzerland, which studied more than 1,800 accidents worldwide over nearly 30 years. For coal, mining tends to be the most dangerous step; for oil and gas, most accidents occur during distribution; and for nuclear, generating plants are on the hot seat (*orange bars*).

Developing nations tend to have higher fatality rates, experts say (although reporting is less comprehensive, so no numbers are shown). "Regulations may be less strict," explains Peter Burgherr, head of technology assessment at the energy systems analysis laboratory at the institute. "Working conditions are also poorer," and less mechanization means more people are doing manual labor in harm's way.

The lion's share of human costs, however, comes not from accidents but from pollution, which makes fossil fuels the most dangerous form of energy generation (*below*). As Burgherr notes, "People are often not aware of what is happening to them in daily life." —*Mark Fischetti*

SCIENTIFIC AMERICAN ONLINE
More data at ScientificAmerican.com/sep2011/graphic-science



SOURCES: PAUL SCHERRER INSTITUTE (*deaths*); ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (*health burden*)

U.S. Health Burden Caused by Particulate Pollution from Fossil-Fueled Power Plants

(mean number of cases per year)

4,040 Pneumonia (hospital admissions)	9,720 Cardiovascular ills (hospital admissions)	30,100 Premature deaths
59,000 Acute bronchitis cases	603,000 Asthma attacks	5,130,000 Lost workdays

Graphic by Jen Christiansen

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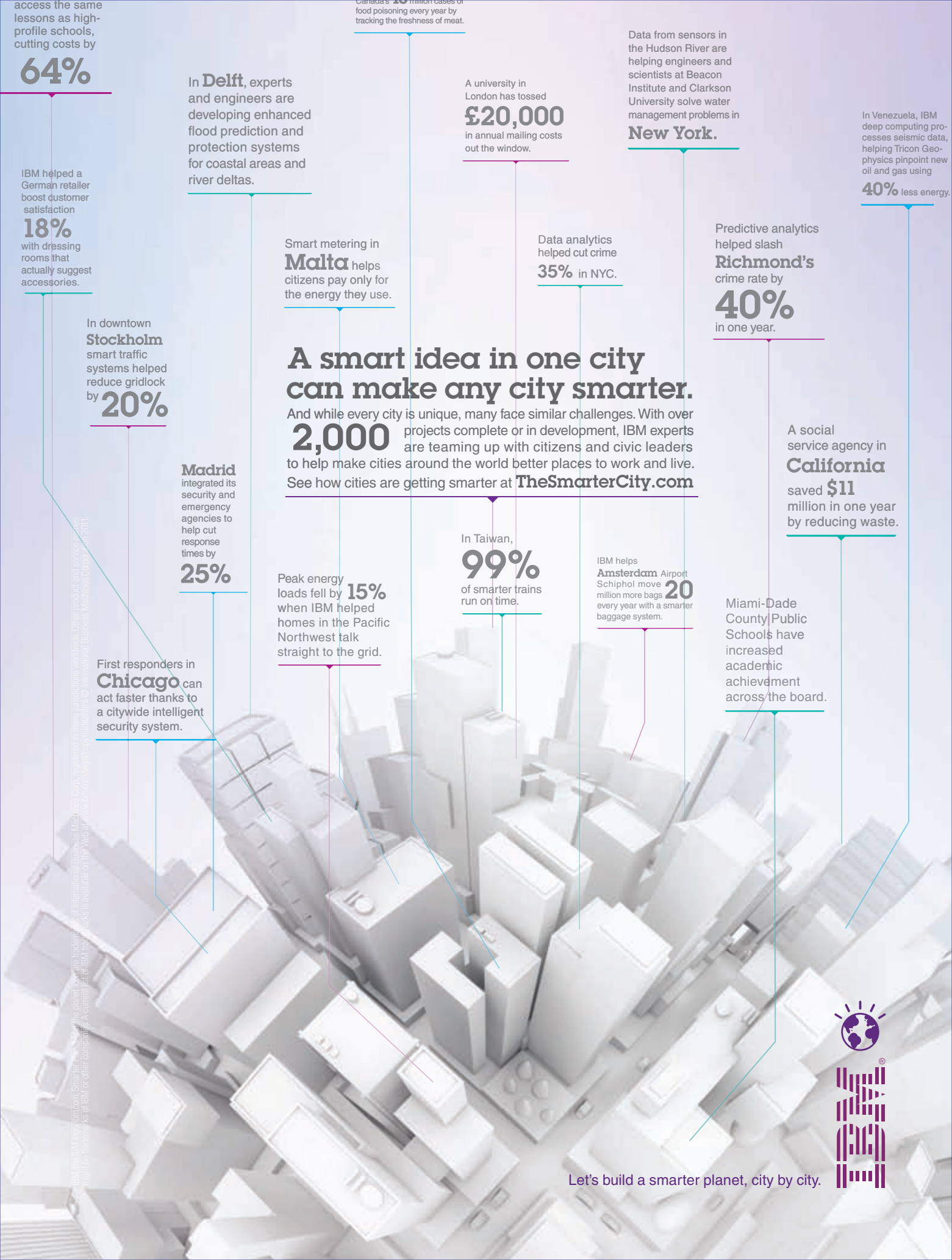

Let's build a smarter planet, city by city.

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