WASHER: 153 | ELECTRIC DRYER: 1,521 | HAIR DRYER: 57 | TELEVISION: 548 | STEREO: 167 | DESKTOP PC: 321 | MICROWAVE: 179 | DISHWASHER: 599 | REFRIGERATOR: 1,191 | CENTRAL AC: 4,067 | TOASTER: 53

Pounds of CO_2 emitted per item each year in the U.S.

SAVING ENERGY

IT STARTS AT HOME

We already know the fastest, least expensive way to slow climate change: Use less energy. With a little effort, and not much money, most of us could reduce our energy diets by 25 percent or more—doing the Earth a favor while also helping our pocketbooks. So what's holding us back?

Thermographic photography offers clues to where energy is being wasted in this older house in Connecticut. Red and yellow patches indicate escaping heat, while new double-pane windows appear cool blue. By sealing in warmth, the windows cut heating costs, which can account for up to half a family's energy bill.

BY PETER MILLER PHOTOGRAPHS BY TYRONE TURNER

THE MISSING POWER PLANT
Instead of building a new 730-megawatt facility like the Decker Power Plant, the Austin, Texas, electric utility reduced demand by the same amount through rebates on energy-saving appliances and other programs. "Go into any store in Austin, and you can't buy an inefficient air conditioner," says general manager Roger Duncan (above). "They just stopped stocking them."

could we come to a lifestyle the planet could handle? If it turned out we couldn't do it, perhaps we could at least identify places where the diet pinched and figure out ways to adjust. So we agreed to shoot for 80 percent less than the U.S. average, which equated to a daily diet of only 30 pounds of CO_2. Then we set out to find a few neighbors to join us.

John and Kyoko Bauer were logical candidates. Dedicated greenies, they were already committed to a low-impact lifestyle. One car, one TV, no meat except fish. As parents of three-year-old twins, they were also worried about the future. "Absolutely, sign us up," John said.

Susan and Mitch Freedman, meanwhile, had two teenagers. Susan wasn't sure how eager they would be to cut back during their summer vacation, but she was game to give the diet a try. As an architect, Mitch was working on an office building designed to be energy efficient, so he was curious how much they could save at home. So the Freedmans were in too.

WE STARTED ON A SUNDAY in July, an unseasonably mild day in Northern Virginia, where we live. A front had blown through the night before, and I'd opened our bedroom windows to let in the breeze. We'd gotten so used to keeping our air-conditioning going around the clock, I'd almost forgotten the windows even opened. The birds woke us at five with a pleasant racket in the trees, the sun came up, and our experiment began.

Our first challenge was to find ways to convert our daily activities into pounds of CO_2. We wanted to track our progress as we went, to change our habits if necessary.

PJ volunteered to read our electric meter each morning and to check the odometer on our Mazda Miata. While she was doing that, I wrote down the mileage from our Honda CR-V and pushed my way through the shrubs to read the natural gas meter. We diligently recorded

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Peter Miller is a senior editor at National Geographic. *Photographer Tyrone Turner's last feature for the magazine was on New Orleans after Katrina.*

A Grander K What is a kilogram? It's 2.2 pounds, of course. Or is it? The kilo is the only basic international standard pegged to a physical object—a 120-year-old platinum-iridium cylinder kept in a vault outside Paris and known as Le Grand K. In recent years scientists noticed slight variations in the cylinder's weight. They've gone into high gear to redefine the kilo as a universal constant based on nature instead of an object vulnerable to distortion.

Physicists in some countries are analyzing near-perfect spheres of pure silicon crystal that will allow them to count the number of atoms in a kilo for the first time. Other scientists are measuring the kilo in terms of gravity and magnetism. Once results are confirmed, an international committee will make the final decision on redefinition, perhaps as soon as 2011. "It'll be a grand thing," says physicist Richard Steiner, who leads the American effort. Then Le Grand K can gain or lose as much weight as it wants. *—Hannah Bloch*

STANDARD SOLUTIONS
Unlike the kilogram, the other six basic international units—meter, second, ampere, kelvin, mole, and candela—are defined by universal measures. The meter is defined by the length light travels in 3.3 nanoseconds.

German physicist Arnold Nicolaus wants to count the atoms in this silicon sphere to set a standard for the kilogram.

PHOTO: MARC STEINMETZ

Fold Everything

Anything can be made with origami—from birds and bugs to stents and space telescopes. It's just a matter of math.

One sheet, no cuts: Even in its simplest form, origami, the art of paper folding, generates enchantment. Since the earliest known manual, *A Thousand Cranes,* was published in Japan in 1797, flocks of paper birds have alighted on countless windowsills. But these days, the ancient art is being revitalized by another form of expression: math. By describing their work mathematically and modeling it with computers, origamists have jumped from paper to metal and plastic and from toy to technology. Folded creations have flown in space; someday one may lodge in your artery.

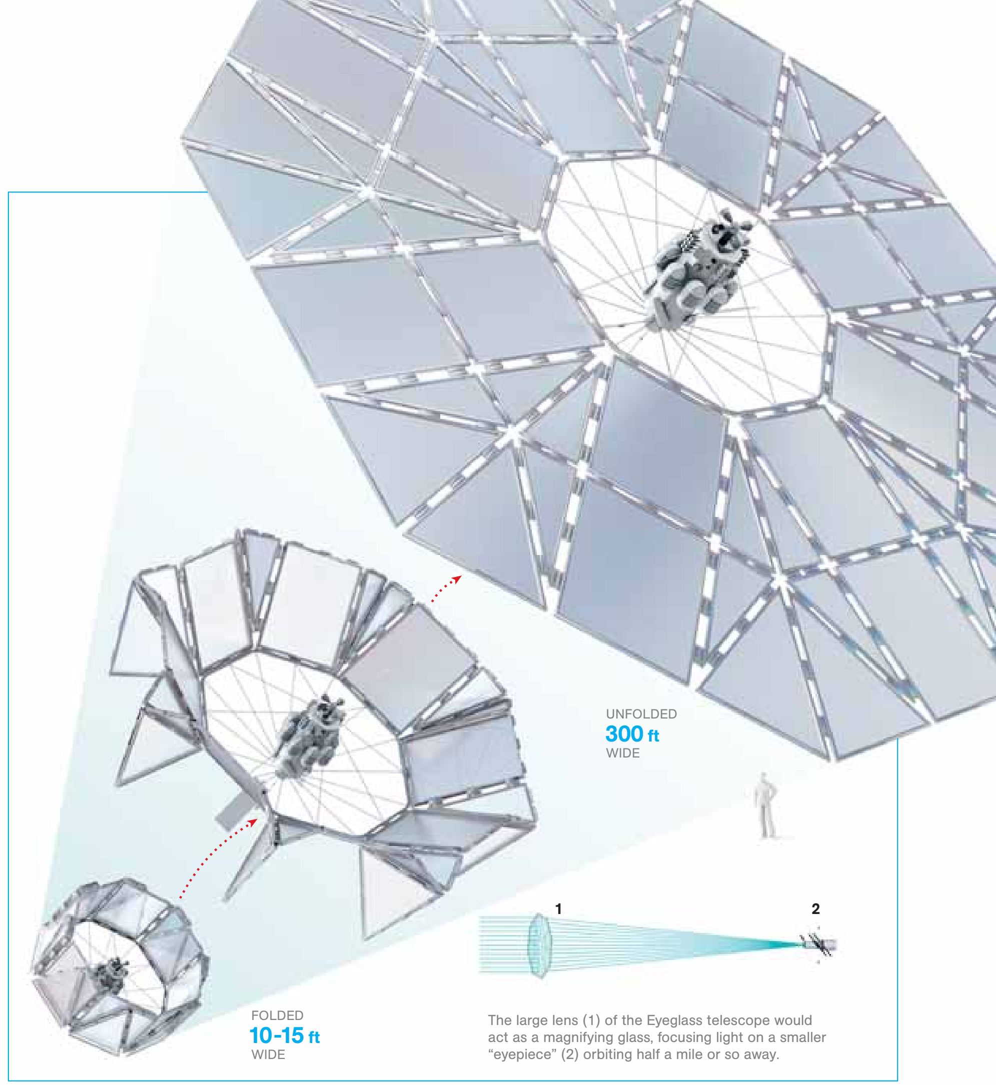
"It's now mathematically proven that you can pretty much fold anything," says physicist Robert J. Lang, who quit his job in Silicon Valley eight years ago to fold things full-time, including centipedes with a full set of limbs and snakes with a thousand scales. "We've basically solved how to create any appendage or shape."

Each appendage consists of a folded flap of paper, and each flap, origamists realized in the 1990s, uses a circular portion, or a quarter or half circle, of the original square. It was a crucial insight, Lang says, because it allowed them to connect their basic problem—how to plan creases that will give a sheet of paper a desired shape—to

1

PAPER PLANE

Japanese scientists hope to launch origami planes made of sugarcane-fiber paper from the International Space Station. If the planes' slow fall and protective coating keep them from burning up in the atmosphere, they might inspire new spacecraft designs.



The large lens (1) of the Eyeglass telescope would act as a magnifying glass, focusing light on a smaller "eyepiece" (2) orbiting half a mile or so away.

2

TELESCOPE LENS

Careful creasing would allow a plastic space telescope lens the size of a football field to fold small enough to fit into a payload bay. Scientists at Lawrence Livermore National Laboratory built a prototype of the Eyeglass telescope in 2002.

3

ARTERY LINING

A new stent graft developed by University of Oxford scientists folds along helical creases for insertion by catheter into the abdominal aorta, then expands in place to support the damaged artery. Human trials of the device could begin by 2012.

ART: BRYAN CHRISTIE DESIGN. PHOTOS: REBECCA HALE, NG STAFF (CRANE); SOHEI TERUI (PLANE). SOURCES: SHINJI SUZUKI, UNIVERSITY OF TOKYO (PLANE); SHAM DIXIT AND ROD HYDE, LAWRENCE LIVERMORE NATIONAL LABORATORY (TELESCOPE); KAORI KURIBAYASHI AND ZHONG YOU, UNIVERSITY OF OXFORD (STENT)

PLUGGING INTO THE SUN

SUNLIGHT BATHES US IN FAR MORE ENERGY THAN WE COULD EVER NEED–IF WE COULD JUST CATCH ENOUGH.

At an electric plant in southern Spain, mirrors as big as houses catch some of the 120 quadrillion watts of sunlight that constantly fall on Earth. Government subsidies for this pricey yet promising power source have made Europe the world's solar capital.

BY GEORGE JOHNSON

PHOTOGRAPHS BY MICHAEL MELFORD

Early on a clear November morning in the Mojave Desert, the sun is barely touching the peaks of the McCullough Range with a cool pink glow. Behind them, a full moon is sinking over the gigawatt glare of Las Vegas. Nevada Solar One is sleeping. But the day's work is about to begin.

It is hard to imagine that a power plant could be so beautiful: 250 acres of gently curved mirrors lined up in long troughs like canals of light. Parked facing the ground overnight, they are starting to awaken—more than 182,000 of them—and follow the sun.

"Looks like this will be a 700-degree day," says one of the operators in the control room. His job is to monitor the rows of parabolically shaped mirrors as they concentrate sunlight on long steel pipes filled with circulating oil, heating it as high as 750 degrees Fahrenheit. From the mirror field, the blistering liquid pours into giant radiators that extract the heat and boil water into steam. The steam drives a turbine and dynamo, pushing as much as 64 megawatts onto the grid—enough to electrify 14,000 households or a few Las Vegas casinos. "Once the system makes steam, it's very traditional—industry-standard stuff," says plant manager Robert Cable, pointing toward a gas-fired power plant on the other side of Eldorado Valley Drive. "We get the same tools and the same parts as the place across the street."

When Nevada Solar One came on line in 2007, it was the first large solar plant to be built in the United States in more than 17 years. During that time, solar technology blossomed elsewhere. Nevada Solar One belongs to Acciona, a Spanish company that generates electricity here and sells it to NV Energy, the regional utility. The mirrors were made in Germany.

Putting on hard hats and dark glasses, Cable and I get into his pickup and drive slowly past row after row of mirrors. Men with a water truck are hosing down some. "Any kind of dust affects them,"

George Johnson is the author of The Ten Most Beautiful Experiments *and seven other books. Michael Melford is a regular contributor; his photos on Herod the Great appeared in the December 2008 issue.*

As the lights come on in Los Angeles, solar evangelist Larry Kazmerski models the latest in PV: bendy thin-film panels that fit so many places, says the National Renewable Energy Laboratory researcher, they could one day power whole cities. "This is going to be on every roof and building," Kazmerski says.

Cable says. At the far edge of the mirror field, we stop and step out of the truck for a closer look. To show how sturdy the glass is, Cable bangs it like a drum. Above his head, at the focal point of the parabola, the pipe carrying the oil is coated with black ceramic to soak up the light, and it's encased in an airless glass cylinder for insulation. On a clear summer day with the sun directly overhead, Nevada Solar One can convert about 21 percent of the sun's rays into electricity. Gas plants are more efficient, but this fuel is free. And it doesn't emit planet-warming carbon dioxide.

About every 30 seconds there is a soft buzz as a motor moves the mirrors a little higher; by midday they will be looking straight up. It's so quiet out here one can hardly fathom how much work is being done: Each of the 760 arrays of mirrors can produce about 84,000 watts—almost 113 horsepower. By 8 a.m. the oil coursing through the pipes has reached operating temperature. A white plume is spewing from a cooling stack. Half an hour later, the sound of the turbine inside the generating station has reached a high-pitched scream. Nevada Solar One is ready to go on line.

The optimists say solar power could become as economical and efficient as fossil fuels. The pessimists say they've heard all this before.

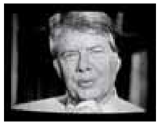
WITH A NEW ADMINISTRATION in Washington promising to take on global warming and loosen the grip of foreign oil, solar energy finally may be coming of age. Last year oil prices spiked to more than $140 a barrel before plunging along with the economy—a reminder of the dangers of tying the future to something as unpredictable as oil. Washington, confronting the worst recession since the 1930s, is underwriting massive projects to overhaul the country's infrastructure, including its energy supply. In his inaugural address President Barack Obama promised to "harness the sun and the winds and the soil to fuel our cars and run our factories." His 2010 budget called for doubling the country's renewable energy capacity in three years. Wind turbines and biofuels will be important contributors. But no form of energy is more abundant than the sun.

"If we talk about geothermal or wind, all these other sources of renewable energy are limited in their quantity," Eicke Weber, director of the Fraunhofer Institute for Solar Energy Systems, in Freiburg, Germany, told me last fall. "The total power needs of the humans on Earth is approximately 16 terawatts," he said. (A terawatt is a trillion watts.) "In the year 2020 it is expected to grow to 20 terawatts. The sunshine on the solid part of the Earth is 120,000 terawatts. From this perspective, energy from the sun is virtually unlimited."

There are two main ways to harness it. The first is to produce steam, either with parabolic troughs like the ones in Nevada or with a field of flat, computer-guided mirrors, called heliostats, that focus sunlight on a receiver on top of an enormous "power tower." The second way is to convert sunlight directly into electricity with photovoltaic (PV) panels made of semiconductors such as silicon.

Each approach has its advantages. Right now steam generation, also known as concentrating solar or solar thermal, is more efficient than photovoltaic—a greater percentage of incoming sunlight is converted into electricity. But it requires acres of land and long transmission lines to bring the power to market. Photovoltaic panels can be placed on rooftops at the point where the power is needed. Both energy sources share an obvious drawback: They fade when it's cloudy and disappear at night. But engineers are already developing systems for storing the energy for use in the darker hours.

The optimists say that with steady, incremental improvements—no huge breakthroughs are required—and with substantial government support, solar power could become as economical and efficient as fossil fuels. The pessimists say they've heard all this before—30 years ago, during the presidency of Jimmy Carter. That too was a period of national crisis, triggered by the Arab oil embargo of 1973. Addressing the nation in his cardigan sweater, President Carter called for a new national energy policy with solar energy playing a large part. In 1979 the Islamic revolution in Iran sent oil prices soaring again. American drivers lined up for gasoline, their radios blaring songs like "Bomb Iran," by Vince Vance and the



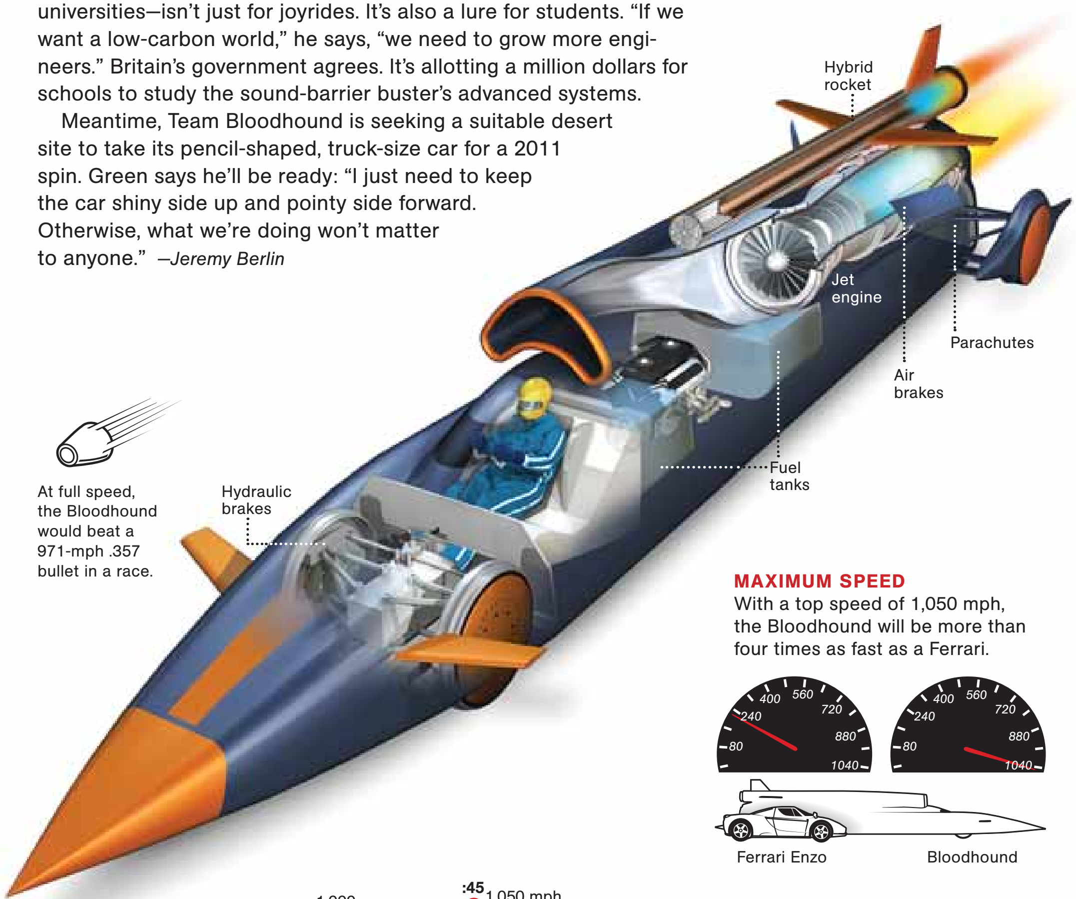
RETRO SOLAR The energy of the future has a past. Shards of old mirrors (top) lie under their replacements at California's 25-year-old SEGS I, the first commercial solar thermal plant in the United States. A 1977 speech by President Jimmy Carter (above) heralded the first federal push for renewable energy. But it faltered after Carter left office and oil prices later plummeted.

CARTER PHOTO: MARION S. TRIKOSKO, LIBRARY OF CONGRESS PRINTS AND PHOTOGRAPHS DIVISION

Fastest Car Quick, what's faster than a speeding bullet and *isn't* named Superman? The answer is the Bloodhound SuperSonic Car, or soon will be. Now being built in England, the jet-and-rocket-powered ride is designed to go, go, go 1,050 miles an hour. If it succeeds, it'll blast past the current land speed record of 763 miles an hour, set in 1997 by Andy Green in the jet-propelled Thrust SSC.

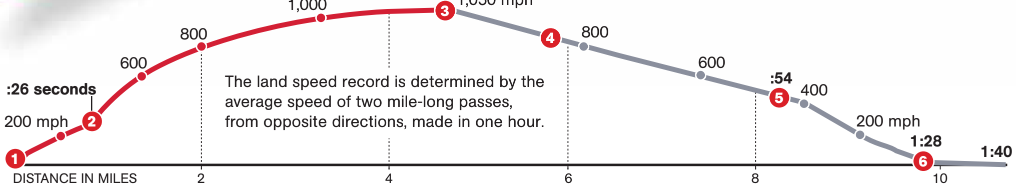
Green, a Royal Air Force pilot who'll also helm the Bloodhound, says the $15-million vehicle—funded chiefly by corporations and universities—isn't just for joyrides. It's also a lure for students. "If we want a low-carbon world," he says, "we need to grow more engineers." Britain's government agrees. It's allotting a million dollars for schools to study the sound-barrier buster's advanced systems.

Meantime, Team Bloodhound is seeking a suitable desert site to take its pencil-shaped, truck-size car for a 2011 spin. Green says he'll be ready: "I just need to keep the car shiny side up and pointy side forward. Otherwise, what we're doing won't matter to anyone." *—Jeremy Berlin*



At full speed, the Bloodhound would beat a 971-mph .357 bullet in a race.

MAXIMUM SPEED
With a top speed of 1,050 mph, the Bloodhound will be more than four times as fast as a Ferrari.



SIX SUPERSONIC STEPS

1 Driver fires jet engine, getting car to 350 mph in just 25 seconds.
2 Hybrid rocket engine ignites and adds thrust, pushing car to 1,000 mph.
3 After top speed of 1,050 mph is reached, rocket thrust stops.
4 Jet engine stops.
5 Driver deploys air brakes and, if needed, parachutes.
6 After car drops below 200 mph, hydraulic disc brakes bring it to full stop.

ART: DON FOLEY. DIAGRAMS: HIRAM HENRIQUEZ, NG STAFF; MINDY NICHAMIN
SOURCE: BLOODHOUND PROJECT

The Secrets of SLEEP

From birth, we spend a third of our lives asleep. After decades of research, we're still not sure why.

SEVEN-MONTH-OLD MILES JUSTE OF MIAMI, FLORIDA

By D. T. Max
Photographs by Maggie Steber

CHERYL DINGES IS A 29-YEAR-OLD

Army sergeant from St. Louis. Her job is to train soldiers in hand-to-hand combat. Specializing in Brazilian jujitsu, Dinges says she is one of the few women in the Army certified at level 2 combat. Level 2 involves a lot of training with two attackers on one, she explains, with the hope of "you being the one guy getting out alive."

Dinges may face an even harder fight in the years ahead. She belongs to a family carrying the gene for fatal familial insomnia. The main symptom of FFI, as the disease is often called, is the inability to sleep. First the ability to nap disappears, then the ability to get a full night's sleep, until the patient cannot sleep at all. The syndrome usually strikes when the sufferer is in his or her 50s, ordinarily lasts about a year, and, as the name indicates, always ends in death. Dinges has declined to be tested for the gene. "I was afraid that if I knew that this was something I had, I would not try as hard in life. I would allow myself to give up."

FFI is an awful disease, made even worse by the fact that we know so little about how it works. After years of study, researchers have figured out that in a patient with FFI, malformed proteins called prions attack the sufferer's thalamus, a structure deep in the brain, and that a damaged thalamus interferes with sleep. But they don't know why this happens, or how to stop it, or ease its brutal symptoms. Before FFI was investigated, most researchers didn't even know the thalamus had anything to do with sleep. FFI is exceedingly rare, known in only 40 families worldwide. But in one respect, it's a lot like the less serious kinds of insomnia plaguing millions of people today: It's pretty much a mystery.

IF WE DON'T KNOW WHY we can't sleep, it's in part because we don't really know why we need to sleep in the first place. We know we miss it if we don't have it. And we know that no matter how much we try to resist it, sleep conquers us in the end. We know that seven to nine hours after giving in to sleep, most of us are ready to get up again, and 15 to 17 hours after that we are tired once more. We have known for 50 years that we divide our slumber between periods of deep-wave sleep and what is called rapid eye movement (REM) sleep, when the brain is as active as when we're awake, but our voluntary muscles are paralyzed. We know that all mammals and birds sleep. A dolphin sleeps with half its brain awake so it can remain aware of its underwater environment. When mallard ducks sleep in a line, the two outermost birds are able to keep half of their brains alert and one eye open to guard against predators. Fish, reptiles, and insects all experience some kind of repose too.

All this downtime comes at a price. An animal must lie still for a great stretch of time, during which it is easy prey for predators. What can possibly be the payback for such risk? "If sleep doesn't serve an absolutely vital function," the renowned sleep researcher Allan Rechtschaffen once said, "it is the greatest mistake evolution ever made."

The predominant theory of sleep is that the brain demands it. This idea derives in part from common sense—whose head doesn't feel clearer after a good night's sleep? But the trick is to confirm this assumption with real data. How does sleeping help the brain? The answer may depend on what kind of sleep you are talking about. Recently, researchers at Harvard led by Robert Stickgold tested undergraduates on various aptitude tests, allowed them to nap, then tested them again. They found that those who had engaged in REM sleep subsequently performed better in pattern recognition tasks, such as grammar, while those who slept deeply were better at memorization. Other researchers have found that the sleeping brain appears to repeat a pattern of neuron firing that occurred while the subject was recently awake, as if in sleep the brain were trying to commit to long-term memory what it had learned that day.

Such studies suggest that memory consolidation may be one function of sleep. Giulio Tononi, a noted sleep researcher at the University of Wisconsin, Madison, published an interesting twist on this theory a few years ago: His study showed that the sleeping brain seems to weed out redundant or unnecessary synapses or connections. So the purpose of sleep may be to help us remember what's important, by letting us forget what's not.

Sleep is likely to have physiological purposes too: That patients with FFI never live long is likely significant. A lot of interest has focused on what exactly kills them, but we still don't know. Do they literally die from lack of sleep? And if not, to what extent does sleeplessness contribute

The genetic history of sisters Carolyn Schear (at right) and Cheryl Dinges puts them at risk for fatal familial insomnia, a deadly inability to sleep. Schear learned she doesn't carry the gene. Dinges declined testing. "Why let the knowledge rule your life?"

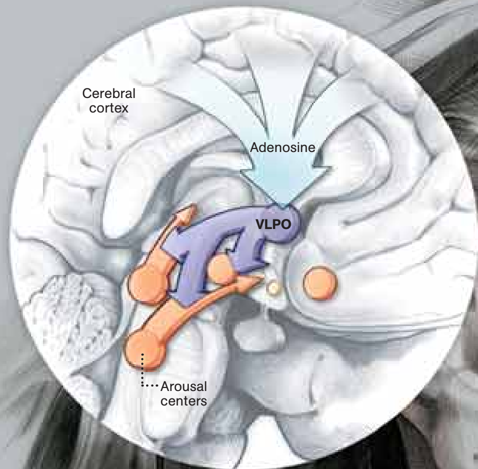
D. T. Max's book, The Family That Couldn't Sleep, *explores the mystery of fatal familial insomnia. Maggie Steber photographed the story on memory in the November 2007 issue of* Geographic.

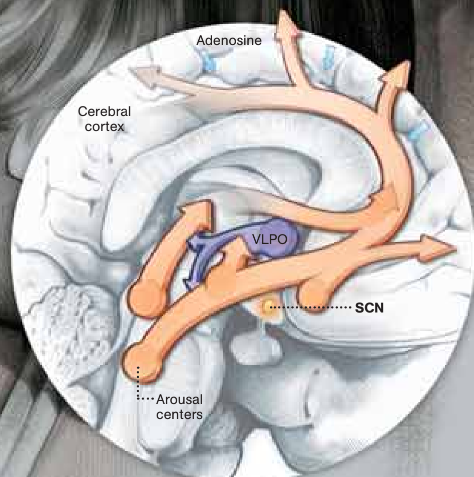
THE BRAIN IN SLUMBER

Sleep is no longer thought of as merely the time we spend unconscious. It is a dynamic state characterized by shifting levels of electrical activity and the ebb and flow of chemicals into various regions of the brain. Key to this give-and-take are two tiny structures in the hypothalamus deep in the brain. The neural dance they engage in determines when we fall asleep, and when we wake again to face the day.

FALLING ASLEEP

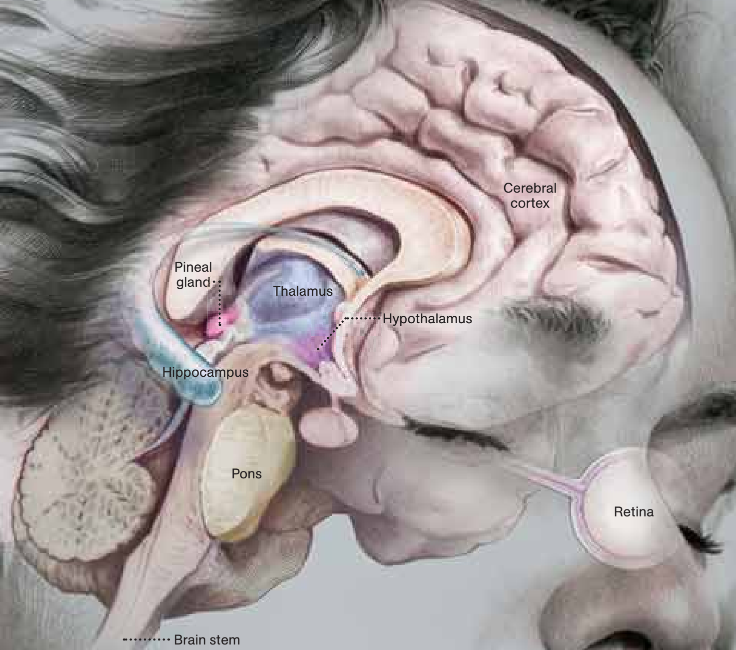
Sleep depends on a pinhead-size cluster of cells called the ventrolateral preoptic nucleus (VLPO). Triggered by the daily buildup of the chemical adenosine, the VLPO sends a signal to arousal centers to stop producing histamine and other chemicals that keep us alert.





WAKING UP

Awakening is initiated by the body's master biological clock, located in another tiny cell cluster called the suprachiasmatic nucleus (SCN). Responding to light, the SCN generates a "wake-up" cue that signals the VLPO to stop firing, reactivating the arousal system.



THE ANATOMY OF SLEEP

Hypothalamus: Critical to sleep; contains clusters of neurons that govern circadian rhythms and regulate chemicals promoting sleep and arousal

Thalamus: Blocks input from the senses, allowing the brain to focus on processing information from the day

Pineal gland: Produces melatonin when the body's clock senses darkness, helping the brain prepare for sleep

Hippocampus: Vital to memory formation; during REM sleep, replays memories to be stored

Pons: Involved in both arousal and the activation of dreams; during REM sleep, blocks signals to the spinal cord, preventing us from acting out our dreams

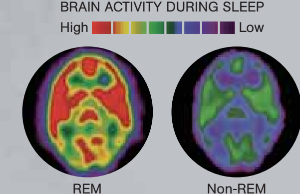
Cerebral cortex: Activated during REM sleep by signals from the pons; dreams may be the cortex's attempts to create a "story" out of information collected during waking hours

Retina: Contains special cells that send an arousal signal to the brain when they sense light

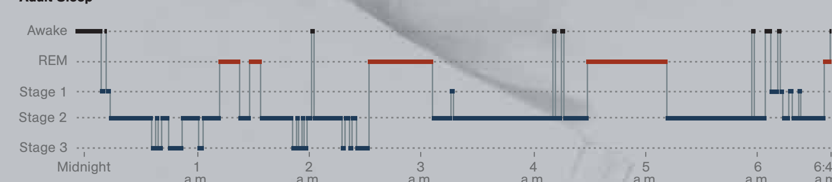
STAGES OF SLEEP

At night we cycle several times through ever deeper phases of sleep. In stage 1 (light sleep) we may drift in and out of wakefulness. Brain waves slow in stage 2, with occasional bursts of rapid waves. Stage 3 (split into 3 and 4 by some) is deep sleep, with extremely slow brain waves. More active periods of REM (rapid eye movement) sleep punctuate the stages: Heart rate and breathing grow more rapid; most dreams occur.

BRAIN ACTIVITY DURING SLEEP



Adult Sleep



HIRAM HENRIQUEZ AND ROBIN T. REID
ART: BRUCE MORSER

SOURCES: CLIFFORD B. SAPER, HARVARD MEDICAL SCHOOL; TIMOTHY H. MONK AND ERIC A. NOFZINGER, UNIVERSITY OF PITTSBURGH MEDICAL CENTER; CAROLE L. MARCUS, UNIVERSITY OF PENNSYLVANIA