

SCIENTIFIC AMERICAN

AUGUST 1994
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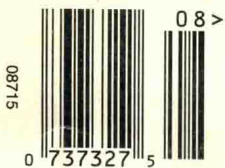
Red tides—a growing hazard.

The extreme ultraviolet universe.

SQUIDS for ultrafaint signals.



*The daily grind of preparing flour
left its mark on Neolithic bones.*



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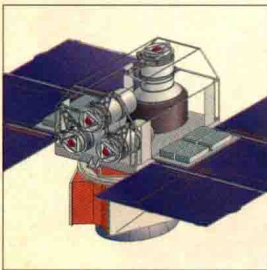


Third World Submarines

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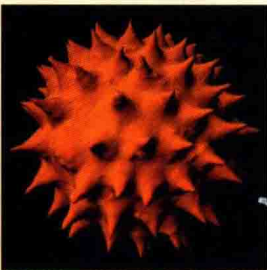


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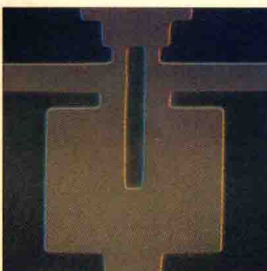
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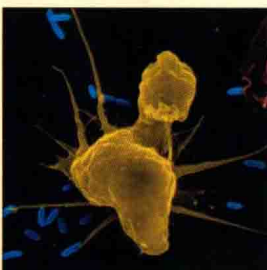


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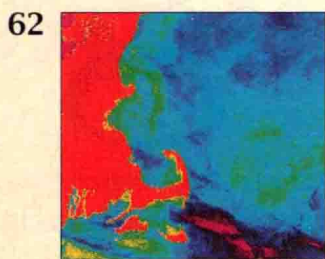
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How Cells Present Antigens

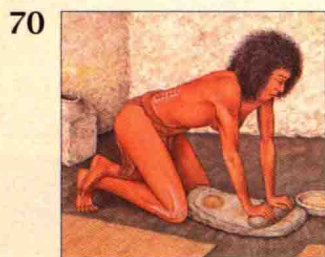
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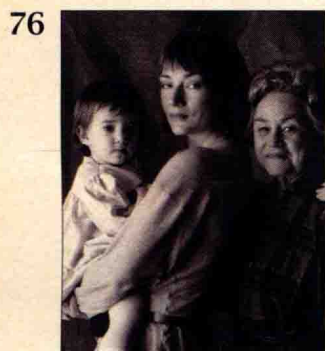
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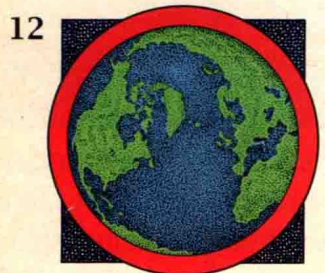


TRENDS IN WOMEN'S HEALTH

A Global View
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Science and Business

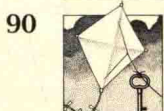
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Essay: Lynn Margulis
A novel view of the origin of sex and death.

Windows NT™ the latest operating system from Microsoft® is launching a new era in high-end personal computing. It's an era of openness, in which users have greater freedom of hardware choice.

To run DOS or Windows 3.1 applications under the old order, you had to depend on Intel®'s x86 microprocessors and clones which have an architecture called CISC (Complex Instruction Set Computing). Windows NT expands your choices because it runs DOS and Windows applications not only on CISC, but also on microprocessors with a speed-oriented architecture called RISC (Reduced Instruction Set Computing).

NEC's RISC microprocessor is faster than Pentium.™

NEC has developed a RISC microprocessor that offers more speed than its CISC competitor. Our VR4400™ is a 200MHz, 64-bit processor (based on MIPS® RISC architecture) which runs Windows NT faster than the Pentium CISC processor. NEC has also developed a low-power, low-cost RISC processor called the VR4200™ which brings Windows NT performance to notebooks.

From supercomputers to games.

RISC chips are destined to dominate in high-end information processing. NEC has the industry's broadest line of 32-bit and 64-bit RISC processors. They will be the engines powering a new generation of high-speed products, ranging from PCs to supercomputers, from office automation to multimedia and games.

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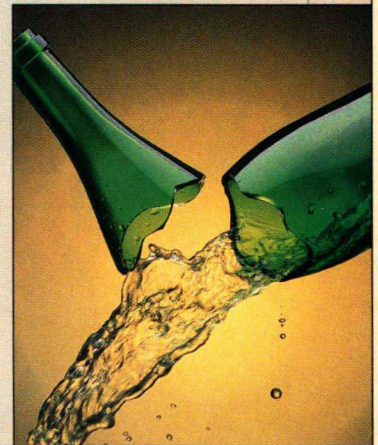
**Breakthrough
or bottleneck?
Memories make
the difference.**

Here's a trick question: does the PC with the fastest microprocessor deliver the speediest performance? Not necessarily. Because the microprocessor-to-memory access is what really determines system performance. If memories lag behind, even

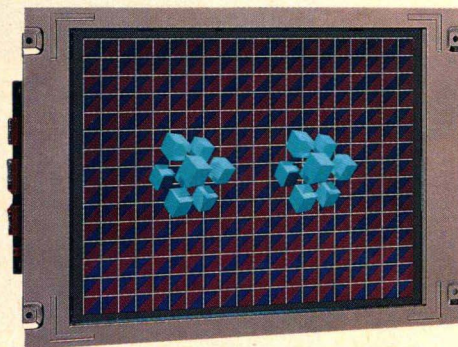
the most sophisticated microprocessor will bog down in "wait states." And the fact is that processor speeds are soaring while memories remain relatively stagnant.

To break the bottleneck, NEC has introduced a new species of ultra-fast dynamic random access memories (DRAMs). Our 16-Megabit DRAMs eliminate wait states by operating synchronously with 100MHz microprocessors.

Four times faster than the speediest conventional DRAMs, our new synchronous memories provide a quantum leap in PC system speed. They also offer significant savings for workstations by replacing the fast but costly cache SRAMs (static random access memories) now used to close the microprocessor-to-memory speed gap.



Setting the standard for color notebook displays.



Color notebooks are one of the fastest growing segments of the computer market. The brilliant, colorful liquid crystal displays (LCDs) on high-end models are a powerful source of consumer appeal.

NEC helped launch the trend by developing the 24cm (9.4-inch) LCD for

the world's first color notebook. The screen offers high resolution and brilliant color, created by an "active matrix" of 921,600 dots for the display of red, green or blue. Each dot is switched on or off by its own transistor. *The 24cm screen pioneered by NEC* has become the de facto standard for color notebooks.

NEC is a technology leader in color LCDs. We concentrate on thin-film-transistor (TFT) active-matrix displays because they offer vivid, natural color and fast response to moving pictures.



The new
Air Max^{2™}
shoe's dual air
pressure technology
modifies the ride so
it matches the move-
ment and impact of
the foot.

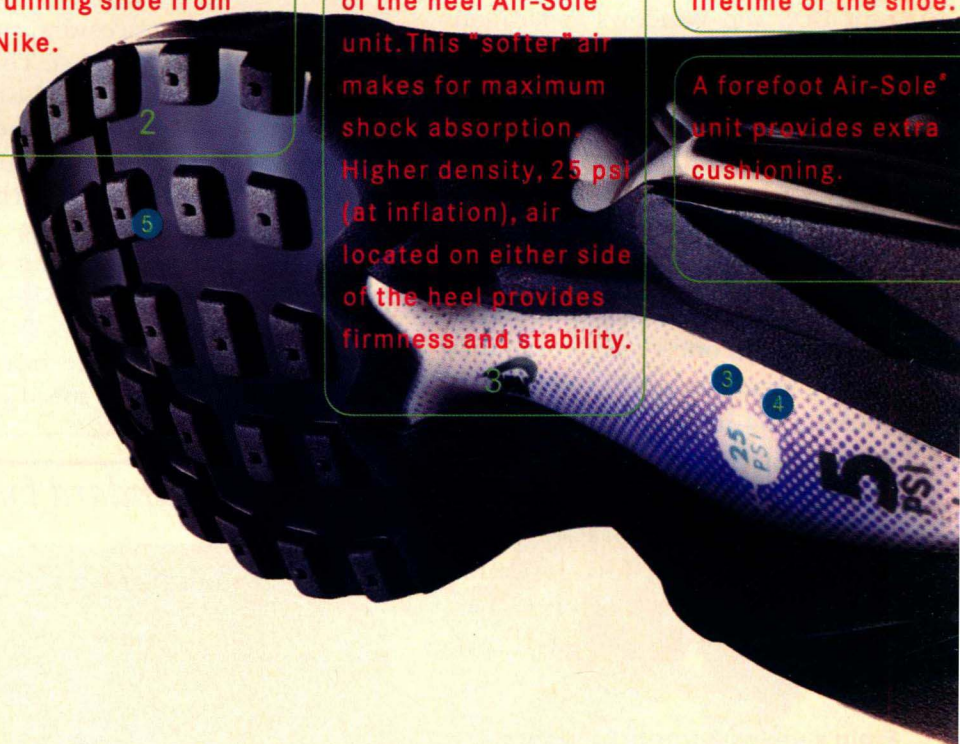
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Kevin Young, track
and field athlete,
wears the Air Max²
running shoe from
Nike.

Five psi (at inflation),
lower density air is
located at the center
of the heel Air-Sole[®]
unit. This "softer" air
makes for maximum
shock absorption.
Higher density, 25 psi
(at inflation), air
located on either side
of the heel provides
firmness and stability.

The "air" used is
actually a gas that
won't deflate over the
lifetime of the shoe.

A forefoot Air-Sole[®]
unit provides extra
cushioning.



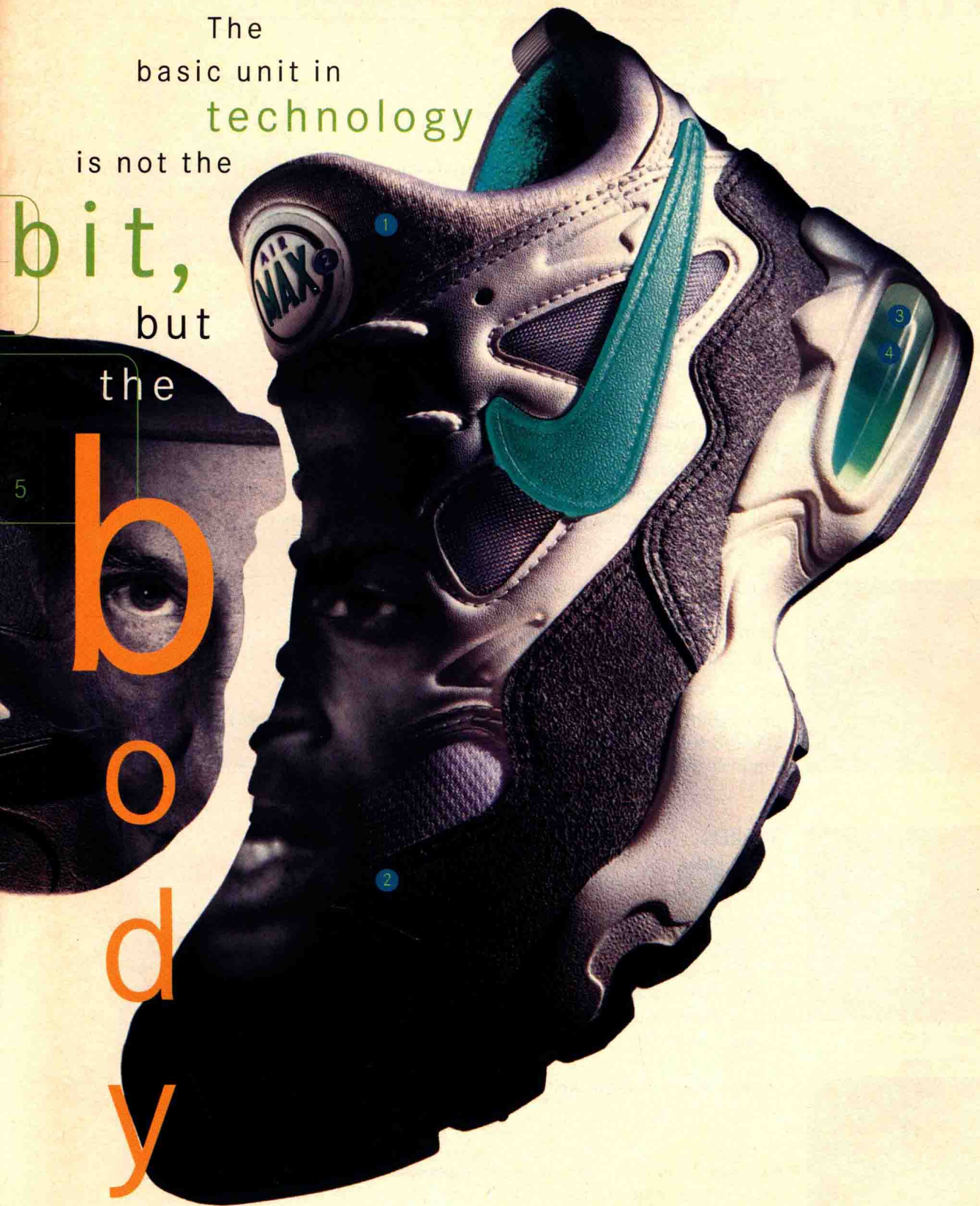
NIKE

The
basic unit in
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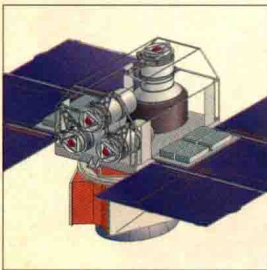


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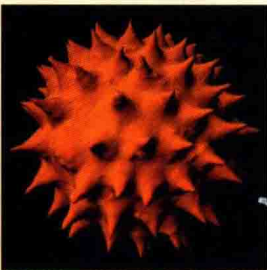


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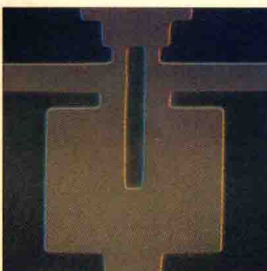
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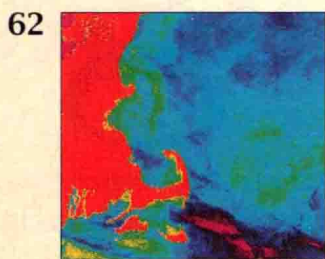
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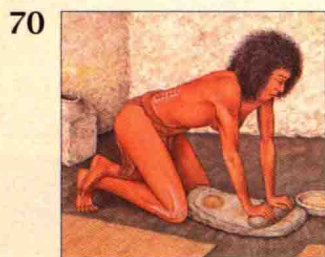
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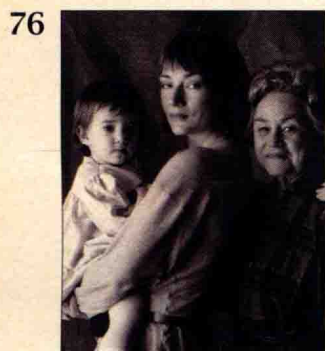
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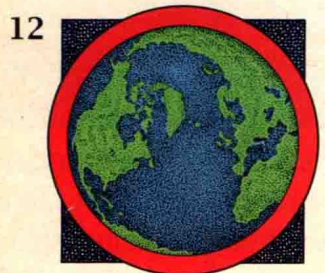


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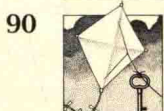
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Everything e

With four out of five Accords being made in America, the future has never looked better. The new Accord Sedan from Honda is more aerodynamically beautiful than ever.

However, a closer examination reveals that this Accord is unlike any you've ever seen before. Everything about it has changed, with all-new technology.

Testing showed how changes in the body's internal structure could reduce road noise. So we added high-tech baffling materials. It's very quiet.

To make the Accord stronger, we reinforced the outer body panels with thicker steel and we added steel beams and pads inside the doors. It is easy to see why the new Accord meets the

federal side-impact standards for 1997, three years early.

While we're on the subject of safety, you'll find that driver's and front passenger's airbags SRS are standard. The Accord EX, here, even includes a refined anti-lock braking system (ABS). Which, of course, is also available on the LX and DX models.

The compact 2.2 liter, 16-valve

engine in the new Accord will be a topic of engineering lectures for years to come. The version in DX and LX models produces 130 horsepower, while the EX model develops 145 horsepower, the most ever in an Accord. Both are

After computer analysis of how our automatic transmission shifted, our engineers designed a new transmission so smooth and quiet that you will hardly notice when it changes gears.

A computer inside the new



fuel-injected and feature Honda's innovative second-order balance system that cancels vibrations that cause other engines to twist and shake. Both are very smooth.

You'll find a new version of our Variable Valve Timing and Lift Electronic Control system (that's VTEC for short) increases both power output and fuel efficiency in the Accord EX engine.

Accord's transmission uses an advanced Grade Logic Control System that can detect special driving situations, such as hills or stop-and-go traffic. Automatically, it then changes the transmission shift points for the best possible performance. For example, it knows when the Accord is going uphill and shifts to third gear for more pulling power.

else is history.

Grade Logic is smart enough to know the difference between up and down, too. When going downhill, it downshifts to help control your speed. Which adds a higher level of refinement and further driving enjoyment.

well. Their concave design frees up more knee room for those passengers riding in the back. Up front, a padded center armrest with storage is ideally positioned for driver and passenger comfort in the new Accord.

Honda engineers wrote the book on ride and handling. The Accord adds yet another chapter. Its four-wheel double wishbone suspension system expertly soaks up bumps, dips and rough pavement without sacrificing

responsiveness or agility. You'll find that it tracks steadily and accurately through tight curves and corners, responding immediately to steering inputs from the driver. At highway speeds, you'll feel more comfortable and in complete control.

But since you need to feel the road, we have designed a new power steering system to do the same. It works like this. As you turn the steering wheel, it senses resistance from the tires and provides a precise

amount of power assist. It never feels unnecessarily heavy, numb or over-assisted.

The Accord has always had a history of sending everybody else back to the drawing board. With the new Accord, history is bound to repeat itself.

A Car Ahead



On the inside, you'll find the look is warm and inviting, with pleasing textures and soft, plush fabrics. A rich, leather-trimmed interior is available on the Accord EX model, naturally.

Seats have been reshaped to better fit your shape. They are wider and more supportive in the hip, back and shoulder areas. The front seatbacks are new as

The new instrument panel is a model of intelligent design and layout. It gracefully wraps around the interior and is darker on top to reduce irritating glare. Gauges are large and easy to read. And switches are right where they should be. The center console is slanted to improve your access to heater and ventilation controls and audio components.



THE COVER painting evokes a daily task that left strong marks on the bones of Neolithic women. The task was grinding grain on a stone quern, shaped like a saddle so it could contain the grain and flour. Working for hours on her knees, a woman would push the rubbing stone forward to the far end of the quern and pull it back. In doing so, she put constant strain on the bones and joints of her back, arms, thighs, knees and toes. The work caused structural damage and arthritis (see "The Eloquent Bones of Abu Hureyra," by Theya Molleson, page 70).

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Stale Bread Mystery

Thank you for the delightful and informative article "Chemistry and Physics in the Kitchen," by Nicholas Kurti and Hervé This-Benckhard [SCIENTIFIC AMERICAN, April]. It's just the thing to amuse and console a lot of us physicists who are looking at other fields as we see our own evaporating (or in culinary terms, "reducing").

Perhaps the authors can help with a problem that has troubled me for years. The science of bread making has made progress in understanding how the gluten protein in flour is converted to give chewable bread with a tender crumb. We know that the sugars on the exterior caramelize to produce a golden-brown crust. We know that gluten gives the dough body and holds it together until baked. We know that the heat of baking alters the molecular bonds so the finished bread remains moist but no longer tough and elastic like the raw dough.

But what happens when slightly stale bread is freshened in a microwave oven? A conventional oven somehow partially restores the moist, tender constitution of fresh bread. A microwave oven, on the other hand, restores the moistness but also revives the undesirable toughness and elasticity of the gluten in the raw dough.

GERALD T. DAVIDSON
Menlo Park, Calif.

Kurti and This-Benckhard reply:

We inquired at the INRA Center in Nantes, where the laboratory of cereal technology is headed by Bernard Gordon. Unfortunately, this effect has not yet been studied.

It is clear that in stale bread, water bound to the carbohydrates in a gel is slowly lost to either the air or the gluten network. When heated, the water bound to the gluten is taken up again by the carbohydrates, which partially gel. Heat enters the bread differently in the two types of ovens, however. The traditional oven creates a strong temperature gradient because the bread is a poor conductor of heat. The microwave oven heats the bread uniformly because the bread absorbs the energy directly. The microwaves can be absorbed by both the water and gluten molecules. Yet the behavior of the water can depend on whether it is bound

to the carbohydrates or the gluten. These variables could affect the freshening of stale bread.

Prostate Cancer Screening

The impact of Marc B. Garnick's "The Dilemmas of Prostate Cancer" [SCIENTIFIC AMERICAN, April] went miles beyond the scope of most magazine articles. This one is literally a lifesaver. A friend sent the story to me from California. I was galvanized into being tested and discovered a cancer-causing polyp. I passed the article on to two friends, who had tests showing that both had prostatic malignancies. Because of your powerful story, we became some of the lucky ones: we can now do something about our problems.

Let's hope your article will impel researchers to get busy with serious study of this unglamorous disease.

SAMUEL A. HOUSTON
Houston, Tex.

Implicit in Garnick's endorsement of the screening recommendations of the American Cancer Society is a radical departure from the traditional medical ethic "first do no harm." Translated into a basic principle for the mass screening of asymptomatic individuals, that ethic means: do not recommend screening unless there is an effective proven treatment whose benefit outweighs the harm. As Garnick points out, the benefit/harm ratio of prostate-specific antigen (PSA) screening cannot be calculated at this time, because *there is no proven benefit*. We physicians must inform patients of that fact before asking them to consent to PSA testing.

DAVID L. HAHN
Madison, Wis.

All the scientific studies cited in the article recommended less aggressive treatment of mild disease. Yet Garnick favors aggressive treatment. Where are the data to substantiate his contention that the average patient in the U.S. benefits from early surgery for cancers detected by the PSA assay? Physicians in Europe use the PSA test less aggressively than those in the U.S.

Do you think the Food and Drug Administration would approve a new drug

that rendered 70 to 80 percent of patients impotent, as early surgery does, based on the currently available data regarding its effectiveness?

MICHAEL D. SWEET
San Diego, Calif.

Garnick replies:

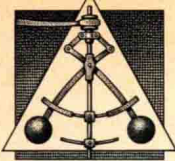
It may take years before the true value of screening becomes known. We are now witnessing, however, more men being diagnosed at a much less advanced stage of disease when their cancer is detected through PSA screening. It will probably require years of follow-up before the benefit of improved survival is realized through treating these patients at an earlier stage. Early diagnoses of breast and colon cancers have raised survival rates, but those benefits also sometimes did not appear until years later. On the basis of what is known today, some patients will decide early treatment is worthwhile; others will not. Many diseases that are vigorously treated in the U.S. do not receive the same attention in other countries.

Data suggest that prostate cancer, when detected and treated early, can be cured. If suffering and premature death can be avoided through early diagnosis and treatment, a physician will have behaved honorably. As recently stated in a national meeting on prostate cancer, the 70-year-old man dying of metastatic disease was probably at age 50 a man with a curable prostate cancer.

Letters selected for publication may be edited for length and clarity. Unsolicited manuscripts and correspondence will not be returned or acknowledged unless accompanied by a stamped, self-addressed envelope.

AMPLIFICATION

The biography box for "The Molecular Architects of Body Design" [February] neglected to mention that William McGinnis and Michael Levine collaborated on the homeobox discovery with Walter J. Gehring in his laboratory in Basel. The text should also have mentioned that the first "redesign" of the *Drosophila* body plan with an inducible promoter directing ectopic expression of *Antennapedia* was done by Gehring, Stephan Schneuwly and Roman Klemenz in 1987.



AUGUST 1944

"Engineers for years have sought a practical method of gasoline injection for supplying fuel to the cylinders of gasoline engines. Such a method has now been perfected and is in production, according to Donald P. Hess, President of American Bosch Corporation. 'The gasoline, by this system, is delivered uniformly to every cylinder of the engine. The result is that all cylinders pull together in harmony, producing a smoother flow of power and quieter engine operation than has ever been possible with any other method,' Mr. Hess states."

"Cereals disguised as candy bars are the latest idea of the food industry, determined to make us eat cereals whether we want to or not."

"Sorting of mail electronically could be accomplished if a row or rows of black and white squares were used to designate the first main geographical subdivision in addresses. A second row would identify the postal substation and a third row the city postal carrier district. Envelopes could then be run through a scanning machine. As the letter whisked in front of the electric-eye, the machine would do the equivalent of reading the address in the coded squares and then automatically route

the letter to the correct mail bag or container. This would be repeated for the second row and again for the third row when the letter arrived in the final postal sub-district. Thus it would have to be looked at only by the carrier."

"Magnesium threatens to take the place of celluloid as the most feared flammable material used in industry. The National Board of Fire Underwriters is preparing special data to show factories how to control this hazard. Absent from this will be the weird tales of factories which forbade their women operators to wear silk panties (if they could get any) lest sparks from friction set off the magnesium chips in their lathes."



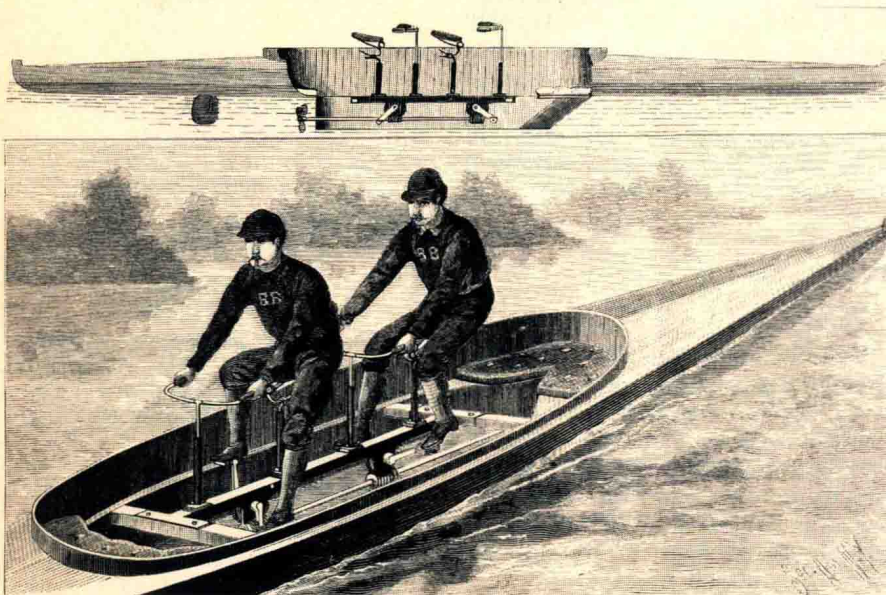
AUGUST 1894

"June 30, 1894, was a gala day in London, the occasion being the opening of a new bridge over the Thames River located near the Tower. It is a heavy piece of work, occupying much more valuable space than was necessary. But it was considered by those who had the say that such a work, located, as it was, near the historical Tower of London, ought to be massive, and present a me-

diaeval architectural look. So they sank a pair of great piers in the narrow river, erected strong steel frames thereon to carry the cables and other parts, and then clothed the steel work with a shell of stone, the work, as a whole, being thus made to represent a structure of massive masonry."

"In writing of the last Royal Society conversazione, the *Lancet* mentioned an invention by Mr. C. T. Snedekor for heating by electricity a quilt or cushion. This quilt, which he named the thermogen, the *Lancet* has since had an opportunity of putting to practical trial, and has no hesitation in reporting upon it thoroughly favorably as an appliance that might be of great value in all hospitals or, for that matter, in all private houses where an electric main is handy."

"The citizens of Buffalo, N.Y., were treated to a remarkable mirage between 10 and 11 o'clock on the morning of August 16. It was the city of Toronto, with its harbor and small island to the south of the city. Toronto is fifty-six miles from Buffalo, but the church spires could be counted with the greatest ease. This mirage is what is known as a mirage of the third order. That is, the object looms up far above the real level and not inverted, as is the case with mirages of the first and second class, but appearing like a perfect landscape far away in the sky."

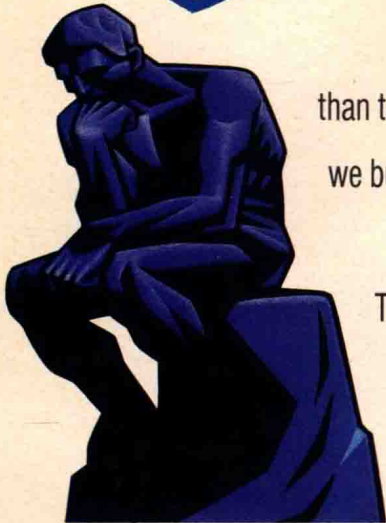


Oden's marine velocipede, or bicycle boat

"As plainly shown in the illustration, a boat invented by Mr. H. B. Oden, No. 204 Carroll Street, Brooklyn, N.Y., is propelled through the water in the same manner as one propels a bicycle on land. The boat is a long, easy running one, with the propelling machine dropped through its bottom into a very small brass boat or fin keel, large enough for the pedals. As shown in the sectional view at the top, the pedal cranks turn a gear which meshes into a worm of long pitch on the screw shaft; steering is effected by a rudder connected with the forward handle. These boats are designed to furnish a delightful means of recreation and healthful exercise, as well as serve useful purposes. Especial advantages are claimed for these boats for gunning service, as they are quiet, may be run fast, and the hands may be freed to use the gun at any time."

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In fact, it didn't get any bigger
than the geothermal power plant turbine
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color notebook computer.*

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Star Gobbler

A black hole is identified in the core of the galaxy M87

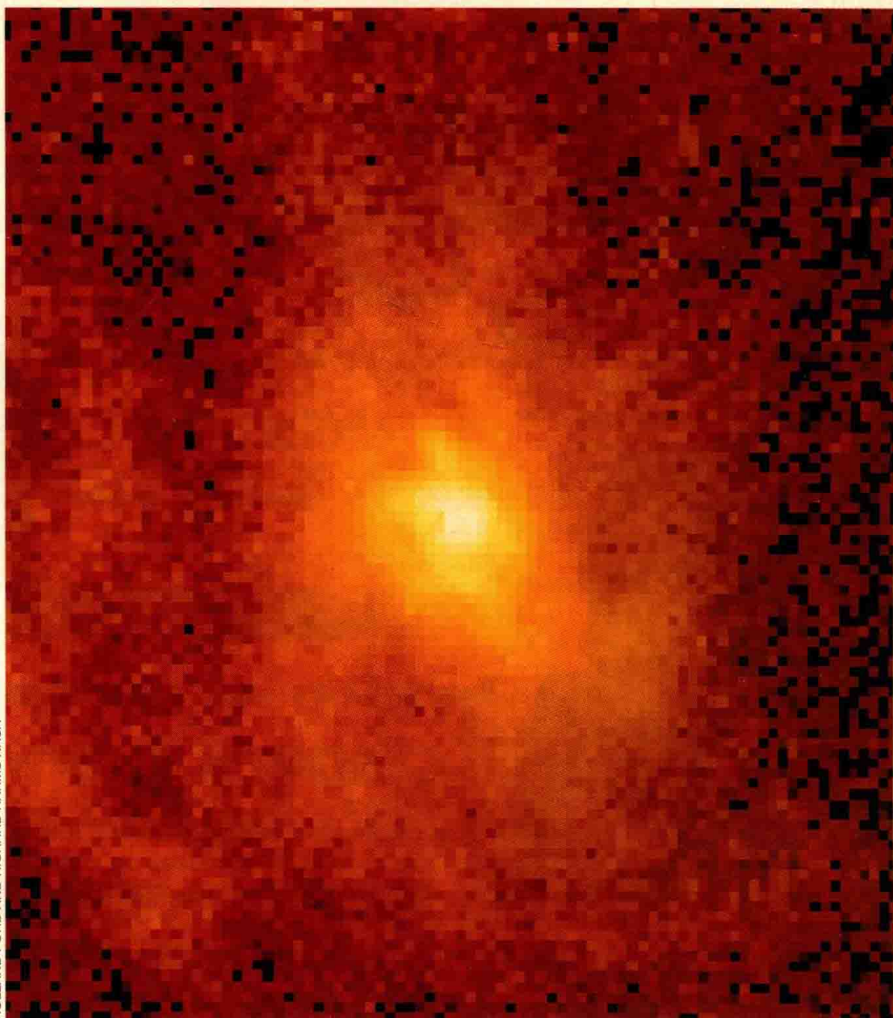
Scientists may not believe in monsters, but many astronomers believe—in the metaphoric sense—that ravenous beasts truly exist at the centers of some galaxies. These cosmic creatures are giant black holes, collapsed objects having millions or even billions of times the mass of the sun packed into a space no larger than our solar system. The gravitational field of such objects is so powerful that matter and even light that fall in cannot return to the outside universe.

For three decades, astronomers have eagerly sought signs that monster black holes were more than a figment of their imaginative theorizing. Now the *Hubble Space Telescope* has provided the strongest sign yet that these objects are indeed real. A team of astronomers led by Holland Ford of the Space Telescope Science Institute in Baltimore and Richard Harms of the Applied Research Corporation in Landover, Md., carried out the observations.

The scientists used *Hubble* to study the inner regions of M87, a huge elliptical galaxy located in the Virgo Cluster, some 50 million light-years from the earth. There they happened on a previously unknown disk of gas that, 60 light-years from its center, is whirling at a speed of 750 kilometers per second, some 25 times the velocity at which the earth orbits the sun.

From that exceedingly rapid motion, Harms and his colleagues estimate that the gas is orbiting a central mass possessing between two billion and three billion solar masses. The disk is oriented roughly perpendicular to the gas jets that shoot from the center of M87, exactly as astrophysical theory predicts. "All the evidence just fits together—it's kind of amazing!" Harms marvels.

"Many of us have believed in black holes for circumstantial evidence—this strengthens the evidence," says Martin Rees of the University of Cambridge, who traditionally takes a cautious view toward findings about black holes. Tod R. Lauer of the National Optical Astronomy Observatories, who has used *Hubble* before to probe the inner regions of M87, assumes a more definite stance.



HOLLAND FORD AND RICHARD HARMS NASA

ROTATING DISK at the heart of the galaxy M87 was discovered using the Hubble Space Telescope. The hot gas probably orbits an unseen black hole at the center.

"I'd bet a good bottle of scotch, a good dinner and a trip to Hawaii" that the black hole is real, he says.

The new observations come 30 years after Edwin E. Salpeter, now at Cornell University, and the late Soviet astrophysicist Yakov B. Zel'dovich proposed that matter falling into black holes could power quasars and radio galaxies. As astronomers came to suspect that quasars merely represent an extremely active period in the early development of many galaxies, they realized that dormant black holes must remain in the cores of most large galaxies.

The long, radio-emitting jet of gas emanating from the center of M87 pegged the galaxy as a particularly likely place to find a massive black hole. In 1978 Peter Young of the California Institute

of Technology conducted studies of stellar motion in the core of M87 that hinted at stars crowding around such an object. Images made by Lauer using *Hubble* before its recent optical fix strengthened the case. But the gas disk found by Ford and Harms and their co-workers presents a much more convincing argument. Rather than having to measure the motions of stars near the hole—a messy and inconclusive process—they could make a much simpler measurement of the rotation of what seems to be a single rotating disk. "Nature has given us a nice clean system here," Harms comments.

Alas, the search for black holes still fundamentally relies on indirect clues. Even the repaired *Hubble* cannot resolve the black hole itself; the hole

should measure about five billion kilometers in radius, 1/100,000th the size of the part of the disk seen by *Hubble*. But the small size and rapid motion of the disk effectively rule out just about any object except for a black hole. For instance, some devil's advocates have proposed that the concentrations of mass at the centers of some galaxies could be tightly bound clusters of faint, dense neutron stars or white dwarf stars; given the new observations of M87, "I don't think that's plausible anymore," Harms says.

Harms and his colleagues plan a follow-up *Hubble* session to determine velocities deeper in the disk, which should yield a nearly airtight case for the black hole. Astronomers can then ponder whether the seemingly exotic monster black holes are really a rather ordinary result of the way galaxies form. Rees, for instance, argues that massive black holes probably developed routinely during the process in which vast gas clouds gathered together into galaxies in the early universe, billions of years ago. "This has been fun, but I wouldn't mind seeing a second black hole," Harms laughs. "It's pretty hard to generalize from just a sample of one."

So will the black hole hunt never end? "The public doesn't understand what a human enterprise science is," Lauer muses. "It's like following Columbo on the chase. That's where the real excitement is." Black holes, well-camouflaged monsters that they are, will be keeping astronomers entertained for quite some time to come. —Corey S. Powell

Darling Clementine?

NASA-DOD tension may orphan the little probe that could

Clementine is a lightweight, low-cost, high-tech spacecraft that has produced the first comprehensive look at the moon since the termination of the Apollo missions more than 20 years ago. It is also a living (if limping) embodiment of the "better, faster, cheaper" mantra espoused by National Aeronautics and Space Administration head Daniel S. Goldin. So how is it possible that *Clementine* may be both the first and last of its breed?

Part of the answer lies in the craft's parentage. *Clementine* was built not by NASA but by the BMDO (Ballistic Missile Defense Organization—son of Star Wars) as a test bed for such antimissile technology as target acquisition and tracking equipment. At the same time,

however, it was designed to produce scientific results useful to the civilian community.

Researchers involved with *Clementine* sound uniformly thrilled by the experience of working with the Department of Defense. Paul Spudis of the Lunar and Planetary Institute in Houston relates that planners at the BMDO "have bent over backward to accommodate every scientific request." Eugene Shoemaker of the U.S. Geologic Survey, who led the *Clementine* scientific team, also praises the efficient manner in which the spacecraft was built and managed. BMDO claims that it completed *Clementine* in two years at a cost of \$75 million; both figures are a small fraction of those typical for NASA probes.

The outpouring of affection becomes even more apparent when *Clementine* scientists describe the mission's results. "The data from the moon are fantastically great," Spudis exults. *Clementine*'s most significant product is a digital map of the moon made at 11 separate wavelengths. Planetary scientists will be able to correlate the colors of the lunar surface seen on that map with studies of lunar samples returned by the Apollo missions. The product will be a vastly improved understanding of the distribution of rock types and, by extension, the geologic evolution of the moon.

Clementine also conducted detailed studies of the moon's topography and gravitational field. David E. Smith of the NASA Goddard Space Flight Center reports that the range of elevations on the moon is much greater than scientists had realized. In particular, *Clementine* has revealed the surprising extent of the Aitken Basin near the south pole on the lunar farside. This basin, which averages 14 kilometers deep across a quarter of the moon's circumference, is

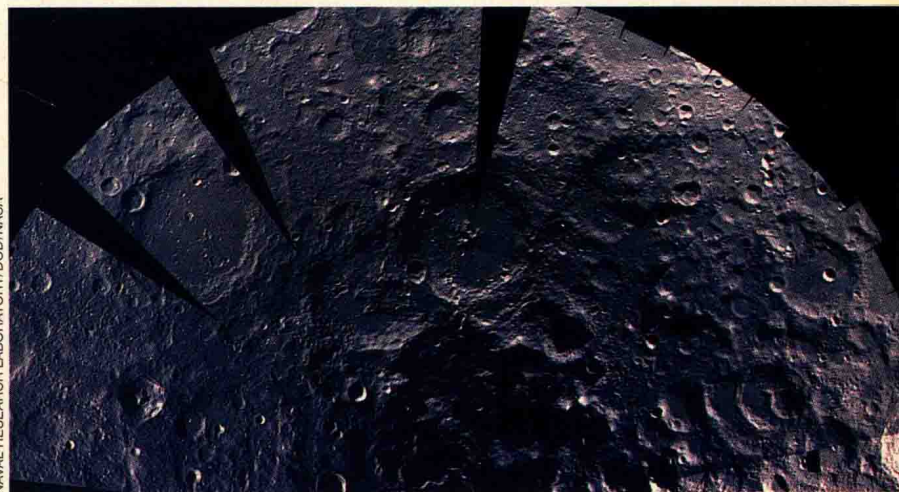
one of the largest formations of its type in the solar system.

Cost and weight considerations lead to scientific trade-offs. For example, *Clementine* lacks a gamma-ray spectrometer, which could have searched for ice lining the shadowed craters at the moon's south pole. And the scientific part of the mission received a blow on May 7, when a software glitch sent *Clementine* into a spin. That accident scuttled the most exciting item on the spacecraft's agenda: a close encounter with the asteroid Geographos, one of the small rocky bodies whose orbits carry them perilously near the earth.

Stewart Nozette of the BMDO, who is the *Clementine* mission manager, claims that workers have identified the bug in the software and that fixes are in the works. Such mishaps are endemic among complicated robotic probes (recall the recent loss of the *Mars Observer* and the stuck antenna on *Galileo*). But *Clementine* has cost less than one tenth as much as those missions.

Will the *Clementine* concept overcome its political hurdles? NASA seems uncomfortable about embracing a project whose technology and can-do spirit come from the dark side. At the same time, the BMDO has distanced itself from the mission, leaving *Clementine* a bit of an orphan.

But a funding crunch looming in 1995 intensifies the long-simmering sense that NASA must radically change course if space science is to survive. Shoemaker judges *Clementine* to be "the wave of the future." Nozette acknowledges the "age-old rivalry between NASA and DOD" but sees an even deeper historical bond. "This is like old-style, 19th-century research," he reflects. "It's like Captain Cook taking the astronomers with him." —Corey S. Powell



PERMANENTLY SHADOWED CRATERS at the lunar south pole, seen in this mosaic view from *Clementine*, may contain hidden deposits of ice.

Radon's Risks

Is the EPA exaggerating the dangers of this ubiquitous gas?

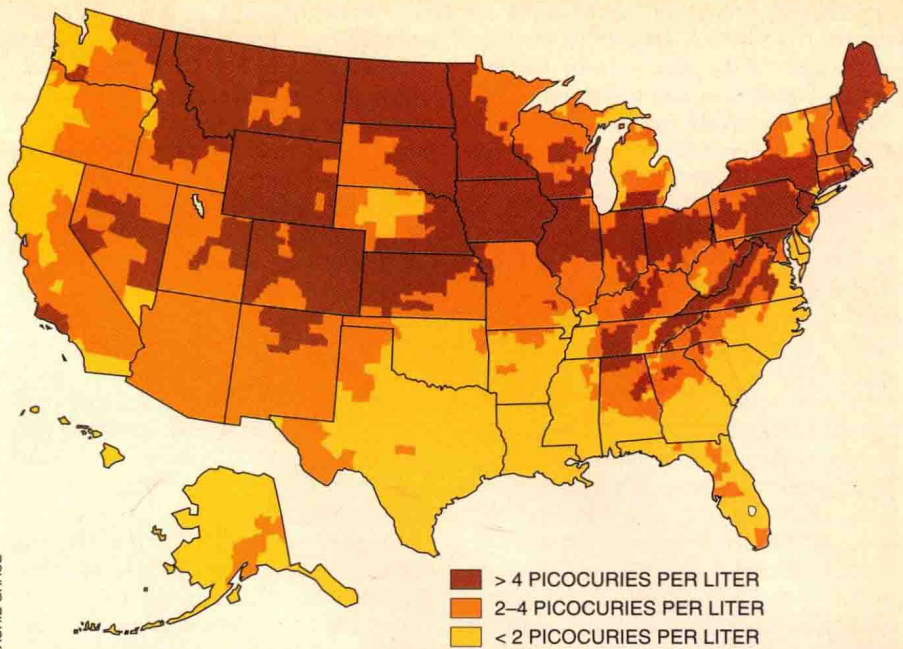
This very moment you are breathing radon, a naturally occurring gas generated by the decay of trace amounts of uranium found throughout the earth's crust. Should you be concerned? The Environmental Protection Agency thinks so. The agency has declared that five million or so of the nation's 80 million homes may have indoor radon levels that pose an unacceptably high risk of lung cancer to occupants.

The EPA has recommended that all homes be tested for radon and that they be structurally altered to reduce exposure should levels exceed a certain threshold established by the agency. Some scientists have challenged the EPA's recommendations, which could cost homeowners and landlords more than \$50 billion if carried out. Critics claim that scientific data gathered to date do not support the EPA's estimates of the health risks from radon.

This issue can be traced to studies done decades ago showing that radon might be responsible for unusually high rates of cancer suffered by miners—particularly uranium miners. Whereas outdoor radon levels generally measure less than 0.5 picocurie per liter (pCi/L) of air, miners were often exposed to levels hundreds or even thousands of times higher. (A picocurie is a trillionth of a curie, which is the amount of radioactivity emitted by a gram of radium.)

Some 15 years ago tests revealed that radon seeping into homes and other buildings through fissures in foundations often accumulates to levels considerably higher than those measured outdoors. Only after the discovery in the mid-1980s of homes with levels as high as 1,000 pCi/L did the EPA take action. It based its policy on the controversial assumption that any amount of radiation exposure poses some risk and that the risk-exposure ratio is linear. That is, if long-term exposure to 100 pCi/L of radon in a mine increases the risk of lung cancer by 50 percent, then exposure to 10 pCi/L in a home increases the cancer risk by 5 percent, all other factors being equal.

The EPA now estimates that indoor radon causes between 7,000 and 30,000 of the 130,000 deaths from lung cancer a year in the U.S., making it second only to smoking as the leading cause of lung cancer. The agency contends that some 15 percent of these deaths could be avoided by reducing radon levels in the



AVERAGE INDOOR RADON levels of U.S. counties are estimated in this EPA map. Although the map's calculations are tentative, a bill before Congress requires EPA-approved radon-reduction measures in all new buildings in high-radon (brown) zones.

five million homes thought to have levels above 4 pCi/L.

Congress takes these claims seriously. A bill in the House of Representatives would require contractors in designated high-radon areas, which encompass roughly one third of the nation's counties [see map above], to follow new EPA guidelines for reducing radon. Such measures include installing pipes in the foundations of houses to route the gas outdoors. In addition, sellers of homes throughout the U.S. would have to provide buyers with EPA literature on radon and with the results of any previous radon tests. Every contract of sale would also warn buyers: "The U.S. Surgeon General has determined that prolonged exposure to radon can be a serious health hazard."

The EPA's position was bolstered this past January by a paper published in the *New England Journal of Medicine*. A team of Swedish workers compared 1,360 Swedish men and women who had cancer with a group of controls. The workers concluded that "residential exposure to radon is an important cause of lung cancer in the general population. The risks appear consistent with earlier estimates based on data in miners."

But other recent studies, while involving fewer subjects, have failed to corroborate this conclusion. A group led by Ernest G. Létourneau of the Radiation Protection Bureau of Health Canada measured radon levels in the homes of 738 lung cancer victims and an equal number of control subjects in Winnipeg,

Manitoba. The average radon exposure of the cancer victims was slightly less than the exposure that the controls experienced.

An examination by a group from the University of Kansas School of Medicine of women living in 20 counties in Iowa corroborated previous evidence that radon may hasten the onset of lung cancer in smokers but does not pose a threat to nonsmokers. In *Health Physics*, the Kansas investigators reported a correlation between radon and risk of lung cancer in counties with high smoking rates. Counties with low rates of smoking showed an inverse relation between radon and cancer.

Finally, a study headed by Jay H. Lubin of the National Cancer Institute, published this year in *Cancer Causes and Control*, compared 966 women with lung cancer in Sweden, China and New Jersey with 1,158 controls. The workers found a slight but statistically insignificant correlation between radon and cancer. Asked if the studies done so far justify the EPA's 4 pCi/L threshold, Lubin declines to offer his personal opinion. But he says virtually all researchers would agree that levels above 20 pCi/L represent a genuine threat. That is the maximum amount of exposure to radiation now allowed by U.S. regulations.

Margo T. Oge, director of the EPA's Office of Radiation and Indoor Air, notes that over a dozen more radon studies are under way, and the EPA has asked the National Academy of Sciences to do a meta-analysis of available data. "We