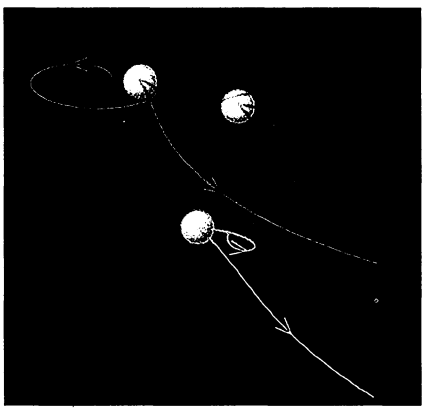
a puzzling phenomenon that, on the face of it, should be impossible.

The affront to scientific common sense turned up in the late 1980s. Scientists had long known that if you zap an atom with a photon, its electron can pick up a packet of energy that sends it into an excited state. Like a rock raised on high, the excited electron stores the energy. Eventually, it falls back to its ground state, releasing a photon that carries the spare energy away.



Neoclassical. Electron orbits à la Newton can make quantum problems solvable.

Zap an atom hard enough, however, and its electron flies free, like a rock boosted beyond Earth's escape velocity. So an electron in an atom should be able to store only so much energy, even if it is hit with a huge barrage of photons. "You would expect, wffft! The atom is ionized—nothing more would happen," says Pascal Salières, a physicist with France's Atomic Energy Commission in Gif-sur-Yvette.

Au contraire. A little more than a decade ago, scientists experimenting with lasers discovered that atoms could absorb hundreds of photons beyond their binding energy and could emit photons with much more energy than should be allowed. "By the 1990s, there was much confusion on how to describe these phenomena," says Gerhard Paulus, a physicist at the Max Planck Institute for Quantum Optics in Garching, Germany. "It was a big controversy."

Physicists were stymied because their usual quantum problem-solving methods broke down under the extreme conditions caused by the laser. But Caltech's Richard Feynman had already suggested a totally different approach that seemed to hold the answer. Most quantum theorists had tackled the problem by using the Schrödinger equation to find the distribution of electron wave functions—smeary particle-wave beasties that inhabit a large parcel of space all at one time. Feynman, on the other hand, treated electrons as ordinary point-particles that circle their nuclei just as planets orbit their star.

But quantum weirdness took its toll: To make the method work, physicists had to take *all* possible orbits into account simultaneously, rather than just one as in classical mechanics. Ordinarily, the infinite variety of possible orbits makes Feynman's method impractical. But on page 902, Salières, Paulus, and colleagues show that the method does indeed hold the key to solving the mystery of the superionized atoms.

Using a titanium-sapphire femtosecond laser, the team zapped a sample of xenon, sending the atoms' electrons into fits. Ordinarily, the electrons would take many different paths around their nuclei. But Salières and colleagues polarized their laser beam so that most of the electrons' paths cancel one another, leaving only a handful of possible orbits around the nuclei. For instance, one path sends the electron looping around, smashing back into the atom and scattering off into the distance. By summing up the contributions for the paths, the team figured out the energy of the electrons coming off the sample, as well as the high-energy light that gets released in the process—and it matched their observations admirably well. When they adjusted the laser to emphasize certain paths over others, the spectrum changed in just the way the Feynman path method predicted.

"The elliptical case is an interesting test of this [theory]. I don't think anyone's given a good demonstration before," says Ken Kulander, a physicist at Lawrence Livermore National Lab in California who helped formulate the Feynman-based theory behind the experiment. "It really shows that you have all the information about the system in a few paths." Kulander hopes that the theory will suggest a way to boost the number of high-energy photons coming from such laser-matter interactions, perhaps yielding powerful extreme-ultraviolet lasers.

–CHARLES SEIFE

CREDITS: (TOP) P. SALIÈRES *ET AL.*

TECHNOLOGY

Liquid Crystal Displays Rub Out the Rub

The sprinkle of black magic behind making liquid crystal displays (LCDs) may finally be ready for its own vanishing act. IBM researchers report in this week's issue of *Nature* that they've come up with a way to eliminate a cumbersome and little understood step of rubbing separate layers of plastic in a display to align liquid crystals placed in between. The advance could simplify and speed display manufacture, drop costs, and help LCDs fight off emerging competition from new flat displays made with light-emitting plastics.

Not long ago, LCDs were themselves an emerging technology. The screens got their start at the now-defunct RCA Labs in the late

ScienceScope

More Is Better Marine scientists say federal officials are being too cautious when it comes to planning the future of the aging U.S. oceanographic fleet.

The government's Ocean Research Advisory Panel last week reviewed a draft plan that recommends that the United States aim for a smaller but more capable fleet of large research vessels over the next 2 decades. The U.S. currently operates 16 vessels longer than 40 meters. A discussion paper drafted by the National Science Foundation (NSF) and other agencies suggests that researchers could get by with as few as 10 new ships in light of funding constraints and the rise of buoy- and satellite-based data collection systems.

But the University-National Oceanographic Laboratory System (UNOLS), which represents ship users, says planners should recommend a "prudently larger" fleet. In a 30 March letter to NSF, UNOLS chair Robert Knox of Moss Landing Marine Laboratories in California urged fleet planners to be "realists but not defeatists. ... If ever there was a time to make strong cases for ... basic oceanographic research, it is now."

NSF's Mike Reeve says officials hope to have a revision within a couple of months "that will reflect a workable agreement."

Resigned Harvard University astronomer Margaret Geller (right) ended a 4-year tenure battle this week by submitting her resignation. Geller will remain employed by the Smithsonian at the joint Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, but she plans to stop teaching at Harvard after 1 July.

A member of the National Academy of Sciences, Geller was offered a Harvard chair but not tenure in 1997, an unprecedented arrangement (*Science*, 12 November1999, p. 1277). She held out for tenure or a salary guarantee, suspecting sex discrimination as the reason for the unusual offer. University officials rejected her request, however, saying that they would be forced to make the same deal with other Smithsonian employees.

statement on the RIAA Web site insisting that the consortium never intended to sue and that the association "strongly believes in academic freedom and Freedom of Speech." He has declined further comment. In an unusual twist, a French group that cracked three of the four watermarks also presented a paper at the workshop but was never contacted by RIAA. Felten says it's because his team had cracked all four watermarks, including the one chosen to be SDMI's technology.

In the digital video case, the Motion Picture Association of America successfully argued in court that publishing a few lines of code that remove the encryption from DVDs is prohibited by a clause in the DMCA that outlaws disseminating information that aids circumvention of technological copy-protection measures. The appeal of that ruling by a computer magazine, *2600*, is being heard this week in federal circuit court in New York.

Jessica Litman, a law professor at Wayne State University in Detroit, Michigan, says the Felten case highlights the overbroad nature of the act. "One of the things that is surprising is that the free speech and academic freedom implications are coming up so quickly," she says. Princeton University president Harold Shapiro believes that the music consortium's actions could have a chilling effect on researchers. "If it is interpreted narrowly, then it might not be a problem," he says. "But if interpreted broadly, there would be very serious concerns for academic freedom."

Felten says the researchers had hoped that the industry would learn from the results and improve its security measures. "Instead they tried to suppress it," he says. He worries that RIAA's actions will inhibit "a large body of research ... [with] very serious consequences for progress in computer security."

–DAVID VOSS

ORIGINS OF BSE

Intriguing Clues to a Scrapie–Mad Cow Link

PARIS—Apart from scandals involving the royal family, few stories are better at firing up the British press than the latest in the sad saga of bovine spongiform encephalopathy (BSE), or "mad cow disease." In the 27 April issue of *The Independent* newspaper, a headline suggested that the mystery of BSE's origins was solved, proclaiming that "Tests Show BSE Caused by Infected Sheep." The truth is far more complex, say scientists, who nonetheless laud the unpublished research described in the article as a possible step toward understanding how the puzzling disease got started.

The human form of BSE, variant Creutzfeldt-Jakob disease (vCJD), has killed nearly 90 people in the United Kingdom and three in France. Uncertain about how many more people may be incubating the invariably fatal disease, scientists are anxious to understand the relation between BSE, vCJD, and scrapie, which afflicts sheep. All three fatal neurodegenerative diseases have been linked to abnormal proteins called prions.

Scourge? Scrapie-BSE link may get a boost.

The new work is by a team led by veterinarian Danny Matthews, chief of prion disease research at the U.K.'s Veterinary Laboratories Agency in Weybridge. In July 1999, his team injected the cerebrums of 10 calves with brain tissue from sheep that had died from scrapie before 1975, well before the BSE epidemic got going in the early 1980s. A second group of calves was injected with brain matter from sheep that had died after 1990. So far, one calf from each group has died from a neurodegenerative disease resembling BSE. However, Matthews told *Science*, tests to unmask the disease-causing agent are still under way.

If it turns out that the scrapie agent is the killer, says prion researcher Moira Bruce of the Institute for Animal Health in Edinburgh, it would strengthen the hypothesis that BSE arose from cattle feed that included ground-up sheep carcasses. But, Bruce cautions, "it would not prove" the link. Indeed, says epidemiologist Peter Smith, acting chair of the U.K.'s Spongiform Encephalopathy Advisory Committee, "it is going to be very difficult to sort out the origins of the epidemic."

Last October, the so-called "scrapie hypothesis" was dismissed in a major report from a U.K. panel chaired by Lord Andrew Phillips (*Science*, 3 November 2000, p. 911; www.bse.org.uk). The report threw its weight behind the hypothesis that BSE arose from a spontaneous mutation in cattle, creating a new form of prion. Among the evidence for this scenario, it cited experiments by U.S. Department of Agriculture scientists showing that while some cattle infected with scrapie-infected brain extracts displayed neurological symptoms, these did not resemble BSE. Matthews speculates that the U.S. experiments may have used extracts harboring different scrapie strains from those in his experiments.

Several scientists believe the Phillips report discarded the scrapie hypothesis too

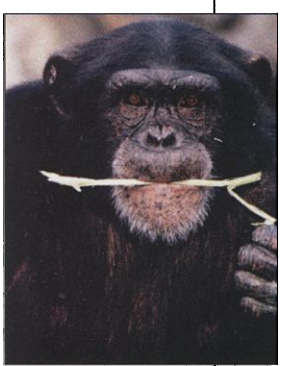
CREDITS: (TOP TO BOTTOM) M. BAYLIS; TAD MOTOYAMA/LOS ANGELES ZOO/AP

ScienceScope

Life-and-Death Decisions Heads may soon roll at Paris's Pasteur Institute, a topflight research center that has produced eight Nobel laureates in the past century. Over the next few months, director-general Philippe Kourilsky and the Pasteur's scientific council will decide whether to ax several research units that failed to pass muster in a recent evaluation.

When Kourilsky took the helm in January 2000, he promised to subject the institute's 39 research units to much tougher scientific scrutiny and to limit the terms of their directors (*Science*, 28 January 2000, p. 567). In February, the scientific council put 22 of the units under the microscope: Fourteen passed with flying colors, and several others were renewed pending changes in their research priorities. But four units received a thumbs down. Although Pasteur officials decline to name the failing labs, Kourilsky told *Science* that "there will be some closures."

Chimp Reprieve Europe's only chimpanzee research facility will be closed. Dutch officials last week said they will follow an expert panel's recommendation to end chimp research at the Biomedical Primate Research Center (BPRC) in Rijswijk.



Animal-welfare groups have criticized the facility for its cramped cages and obsolete facilities. And the Royal Netherlands Academy of Arts and Sciences panel—led by cancer researcher Anton Berns of the Netherlands Cancer Institute in Amsterdam—found that few academic researchers were using it. In 1999, for instance, just seven of the center's 100 chimps were involved in experiments. The panel said that the animals should be retired to zoos or sanctuaries, and that researchers needing chimps could look to the United States for subjects.

Dutch officials say research on the BPRC's 1000 rhesus monkeys will continue and have not yet set a timetable for ending the few ongoing chimp experiments.

Contributors: David Malakoff, Andrew Lawler, Michael Balter, Gretchen Vogel