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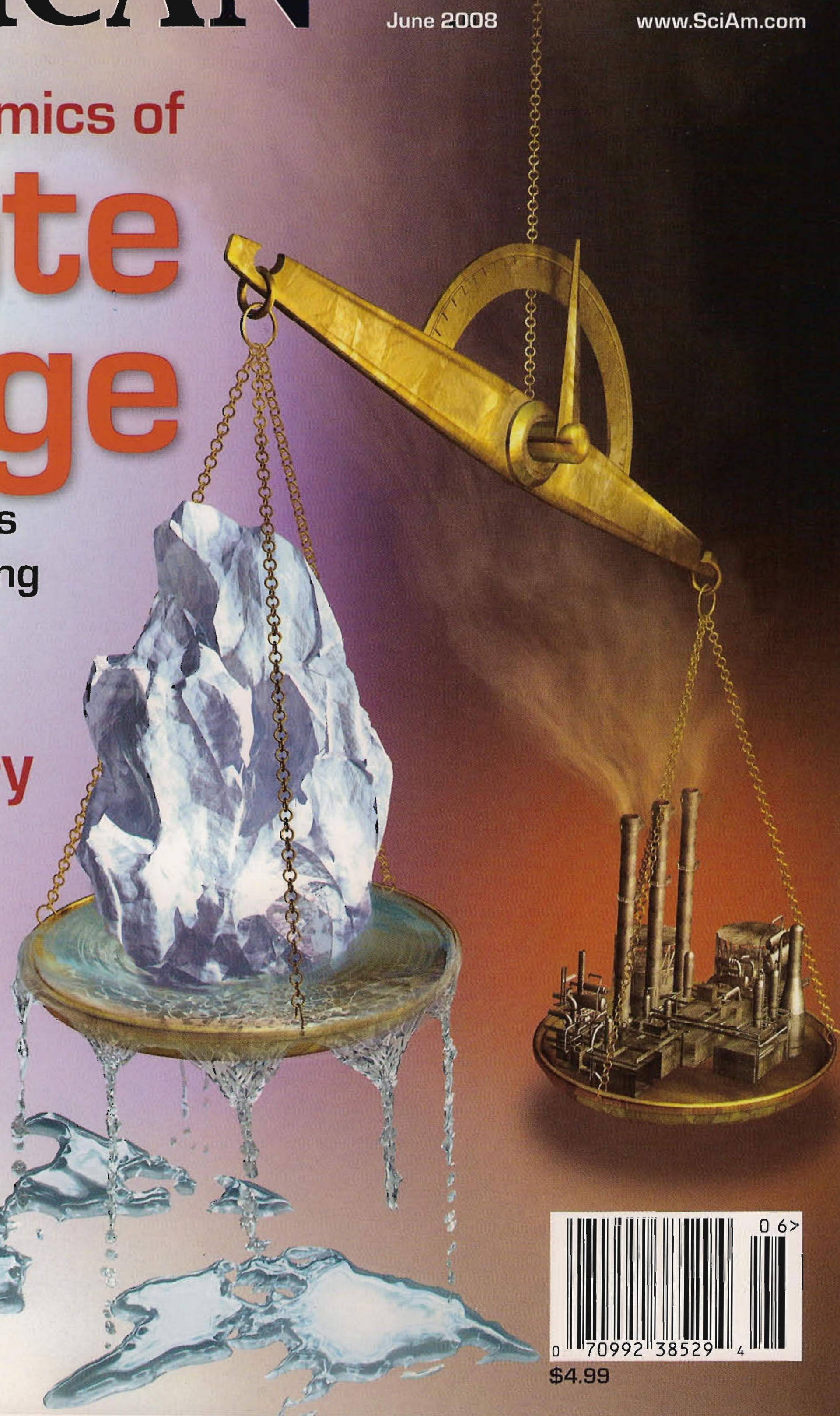

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PHYSICS

A New Iron Age

A high-temperature superconductor based on iron BY CHARLES Q. CHOI

COLD CASE: A new superconductor could iron out theoretical wrinkles in high-temperature superconductivity, which here produces magnetic levitation with liquid nitrogen.

DAVID PARKER IMI/University of Birmingham High TC Consortium/Photo Researchers, Inc.

For more than 20 years, the only known superconductors that worked far above liquid-helium temperatures were a few dozen compounds—virtually all based on copper. Now scientists have discovered the first high-temperature superconductors based on iron. These novel materials could help unravel one of the biggest mysteries in science—how exactly the high-temperature versions work.

In superconductors electric current flows completely without resistance. For decades, the phenomenon was thought to occur only near absolute zero. The cold tames the vibrations of the atoms making up the substance in such a way that electrons can overcome their natural repulsion for one another. The altered vibrations, called phonons, cause the electrons to pair up; so coupled, they can then move freely through the atomic lattice.

Starting in 1986, however, physicists began discovering a new class of superconductors operating well above absolute zero, to temperatures as high as 160 kelvins (–113 degrees Celsius). These materials, dubbed cuprates, typically consist of copper oxide layers sandwiched between other substances. The structure of the cuprates and the high temperature interfere with the mechanisms that drive conventional superconductors, leading physicists to try to come up with new explanations.

A serendipitous discovery is now forcing investigators to expand their ideas on superconductivity. Materials scientist Hideo Hosono of the Tokyo Institute of Technology and his colleagues were looking to improve the performance of transparent oxide semiconductors but ended up discovering the first iron-based, high-temperature superconductor.

The crystalline material, known chemically as LaOFeAs, stacks iron and arsenic layers, where the electrons flow, between planes of lanthanum and oxygen. Replacing up to 11 percent of the oxygen with fluorine improved the compound—it became superconductive at 26 kelvins, the team reports in the March 19 *Journal of the American Chemical Society.* Subsequent research from other groups suggests that replacing the lanthanum in LaOFeAs with other rare earth elements such as cerium, samarium, neodymium and praseodymium leads to superconductors that work at 52 kelvins.

High-temperature superconductivity in these layered iron compounds completely surprised investigators, who thought that the magnetic nature of iron would disrupt the pairing of electrons. Perhaps, as seems to be the case for cuprates, the electrons get paired with the aid of spin fluctuations—disturbances in the magnetic fields of atoms making up the superconductor. "These iron-based superconductors could give us new hints on how to understand cuprates," says physicist Kristjan Haule of Rutgers University.

On the other hand, the spin fluctuations that could glue together cuprate electrons might not be enough for those in the iron-based materials. Instead orbital fluctuations—or variations in the location of electrons around atoms—might also prove crucial, Haule speculates. In essence, the iron-based materials give more freedom to electrons than cuprates do when it comes to how electrons circle around atoms.

Orbital fluctuations might play important roles in other unconventional superconductors as well, such as ones based on uranium or cobalt, which operate closer to absolute zero, Haule conjectures. Because the iron-based superconductors work at higher temperatures, such fluctuations may be easier to research.

Besides illuminating the theoretical underpinnings of superconductivity, the discovery "makes us ask if there are other high-temperature superconductors we haven't found yet in unexpected places and if there are even higher temperatures these can work at," remarks theoretical physicist David Pines of the University of California, Davis, who is also founding director of the Institute for Complex Adaptive Matter. In trying to boost the critical temperature, experiments should focus not only on swapping in other elements but also on layering the compounds. That should improve them just as it does for cuprate superconductors, Haule thinks.

Being based on iron could make these substances more commercially enticing, too. The fragility of cuprates, which as ceramics are quite brittle, has long hampered applications such as superconducting power lines. If iron-based materials are easier to handle and manufacture than cuprates, "they will become very important," Haule adds.

Charles Q. Choi is a frequent contributor based in New York City.

NEURODEGENERATION

Your Brain on Diabetes

More signs that insulin ills set off neurodegenerative conditions BY MELINDA WENNER

Anyone who is diabetic—or knows a diabetic—recognizes the importance of insulin. The hormone helps cells store sugar and fat for energy; when the body cannot produce enough of it (type 1 diabetes) or responds inadequately to it (type 2 diabetes), a range of circulatory and heart problems develop. But that is not all: recent research suggests that insulin is crucial for the brain, too—insulin abnormalities have been implicated in neurodegenerative diseases, including Alzheimer's, Parkinson's and Huntington's. Among the latest findings is the discovery that a gene linked to insulin processing is located in a chromosomal area linked to Parkinson's.

Historically, scientists believed that insulin was produced only by the pancreas and had no business in the central nervous system. Then, in the mid-1980s, several research groups spotted the hormone and its receptor in the brain. It appeared that the hormone not only crossed the blood-brain barrier but that it was also produced, at low levels, by the brain itself.

Soon afterward, scientists discovered that insulin plays an important role in learning and memory. People who inject or snort insulin immediately get better at recalling stories and performing other memory tasks. Learning also raises insulin levels: rats mastering spatial memory tasks have higher brain insulin levels than sedentary rats do.

These observations led neuropathologist Suzanne de la Monte and her colleagues at Brown University to ask whether brain insulin might have a part in Alzheimer's, which is characterized by severe memory loss. They compared postmortem insulin and insulin receptor levels in healthy brains and brains of Alzheimer's patients. Average insulin levels in the neural parts associated with learning and memory were up to four times higher in the healthy brains, which also had up to 10 times as many insulin receptors.

SWEET TOOTH, SOUR BRAIN: **Recent studies emphasize the connection between neurodegeneration and insulin problems, such as those in diabetes.**

HERMAN AGOPLAN *Getty Images*

"That made it clear that one could get exactly the same problems as in regular diabetes except confined to the brain," says de la Monte, who refers to Alzheimer's as "type 3 diabetes." Because brain insulin is linked to insulin in the rest of the body via the blood-brain barrier, diabetics are more likely to develop Alzheimer's, too—nearly twice as likely, according to a 2002 study. They also suffer more memory and learning problems than the general population.

De la Monte and others, including neuroendocrinologist Ignacio Torres Alemán of the Cajal Institute in Madrid, have also found links between Alzheimer's and low brain levels of insulinlike growth factor 1 (IGF-1) and its receptor—proteins similar in structure to insulin and its receptor (insulin occasionally binds to the IGF-1 receptor, and vice versa). "We have suggested that Alzheimer's disease originates because of an exacerbated loss of IGF-1 sup-