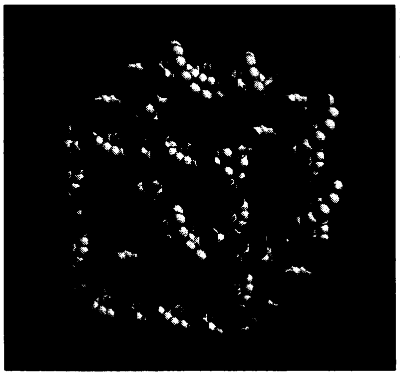
construction kit, Seeman and his colleagues can specify a particular assembly pattern. It's like having an unlimited number of specific glues that connect only those parts you want to link.

Seeman drew his inspiration from naturally branched DNA structures called Holliday junctions, which form during genetic recombination, when two chromosomes swap parts. "I realized that these provided us with [corners]," he says. "When linked with straight segments [of DNA, the corners] would open a route to making two- and perhaps three-dimensional molecular networks made entirely of DNA."



SEEMAN

DNA does double duty. The double helix as molecular scaffolding.

He and colleagues were quick to act on the realization by making a DNA square in the mid-1980s. They followed that achievement 2 years ago with their most intricate DNA construction to date: a bona fide cube fashioned from intricately twined segments of DNA. To make the cube, the scientists relied on DNA's sequence specificity—the specific glue trick—to interlace six DNA components, each forming one face of the cube. Next, Seeman hopes to join multiple cubes into a lattice, a task that will require the development of more complex building blocks resembling jacks, with six, eight, or even 12 arms.

One goal of the work is to develop materials that will trick noncrystallizable molecules such as membrane proteins into an orderly, crystalline array. That way, crystallographers (and crystallography is Seeman's original specialty) might be able to determine their structures. The key here, Seeman notes, is to build three-dimensional beehives of DNA, each cell able to host one copy of a noncrystallizable molecule. The result would be a regular array of the molecules—an arrangement that would open the way to x-ray analysis. Or, Seeman suggests, the DNA structures could serve as frameworks for the assembly of other molecules into intricate architectures, after which the DNA scaffolding could be dismantled. In this case, the DNA would serve as a template for some other structure—a distant echo of its original role in biology.

A growth industry

Tinkertoys, Meccano, and the various molecular scaffolds aren't all that can be found in the molecular toy store. Many other researchers have created their own construction kits, each with its own principles of assembly and potential technological niches. James Wuest of the University of Montreal and his colleagues, for example, have been developing what they call "molecular tectonics" (from a Greek word meaning builder). In work that parallels Moore's, they concoct building blocks of various shapes from simple chemical ingredients and then rely on hydrogen bonding to gather the building blocks into airy crystals. Fagan and Michael Ward, who recently moved from du Pont to the University of Wisconsin, are rekindling a molecular construction project that they had started in the late 1980s. Their goal is to design artificial crystals in which both electrostatic interactions and hydrogen bonds conspire to assemble the crystals' components into pillars that could, say, conduct electricity like minuscule molecular wires, or align to form novel magnetic materials. Even the buckyball crowd has jumped into the nanoscaffolding fray with speculations about latticeworks of buckytubes—tubular relatives of the all-carbon soccerball molecules that now are all the rage.

For the moment, the competition among all these approaches is muted. Things may get dead serious in the future, say researchers, but for now, their field has a playful quality because it's far too early to know which approaches to molecular construction will test out. Indeed, the spirit of play is so strong that some of these gridwork chemists admit to playing with construction toys. Says Michl, "It helps me think about what I'm doing in my nanoscopic world."

–Ivan Amato

Additional Reading

Pier Lucio Anelli *et al.*, "Molecular Meccano. 1. [2]Rotaxanes and a [2] Catenane Made to Order," *Journal of the American Chemical Society* (*JACS*) **114**, 193 (1992).

Junghuei Chen and Nadrian Seeman, "Synthesis From DNA of a Molecule With the Connectivity of a Cube," *Nature* **350**, 631 (1991).

P. Kaszynski, A.C. Friedli, J. Michl, "Toward a Molecular-Size 'Tinkertoy' Construction Set. Preparation of Terminally Functionalized [n]Staffanes from [1.1.1]Propellane," *JACS* **114**, 601 (1992).

Jean-Marie Lehn, "Perspectives in Supramolecular Chemistry—From Molecular Recognition Toward Molecular Information Processing and Self Organization," *Angewandte Chemie, International Edition* **29**, 1304 (1990).

Jinshang Zhang, Jeffrey S. Moore, Zhifu Xu, Ryan A. Aguirre, "Nanoarchitectures. 1. Controlled Synthesis of Phenylacetylene Sequences," *JACS* **114**, 2273 (1992).

MATERIALS SCIENCE

Finally, a Hotter Superconductor

To the community of researchers fashioning new high-temperature superconductors (HTSs), 127 degrees Kelvin was starting to look like a permanent barrier. Since 1988, when researchers reported a thallium-based material with the composition $Tl_2Ca_2Ba_2Cu_3O_{10}$ that loses its electrical resistance if chilled to 127 K or lower, no new superconductor—and there have been dozens of them—has worked at a higher temperature. Now that barrier has gone the way of the 4-minute mile.

> **This work "shows that things are still out there to be found."**
> **—David Larbalestier**

A quartet of researchers led by Hans Ott at the Eidgenossische Technische Hochschule (ETH) in Zurich reports in the 6 May *Nature* that they have broken the 127 K barrier with a new material, made of two distinct compounds, that starts to become a superconductor at about 133 K. The material, which is difficult to make and has toxic ingredients, isn't likely to find practical uses, says Andreas Schilling, one of the ETH scientists. But he thinks the finding "will have a high psychological value" to the HTS research community as it searches for commercially viable superconductors. "This work is absolutely fantastic for the field," agrees David Larbalestier of the University of Wisconsin's Applied Superconductivity Center. "It shows that things are still out there to be found."

The key to this discovery was a new ingredient, mercury. Just 7 weeks earlier, in the 18 March *Nature*, another group led by S. N. Putilin of Moscow State University had dropped a hint that mercury was worth some serious attention. They reported that a new compound composed of mercury, barium, copper, and oxygen becomes a superconductor at 94 K. Although that's lower than the 127 K of the thallium-based compound, the new material's molecular structure hinted that it might be just the first and simplest member of an ever improving new family of superconductors.

One clue lay in its multilayered crystal structure, each unit of which includes only one copper oxide layer. Experience with analogous copper oxide compounds based on thallium or bismuth atoms had shown that the transition temperature generally increases as the number of copper oxide layers in the compounds' crystal units ratchets up from one to two to three. Members of the new mercury family having more than one copper oxide layer, it seemed, might have higher transition temperatures, too.

The ETH group took the hint. Their record-beater sports a pair of related compounds with two and three copper oxide layers, respectively. Last week, when preprints of the ETH paper began circulating, researchers in many labs including ones at Argonne National Laboratory and the Texas Center for Superconductivity at the University of Houston (TcSUH) began the key ritual of trying to replicate the results and make similar compounds that might even have higher transition temperatures. By press time, Paul C. W. Chu, director of TcSUH, told *Science* his group had reproduced the ETH results. And rumors of 144 K materials were already circulating, notes Ellen Feinberg, editor of *High Tc Update*, a newsletter published by the Ames Laboratory at Iowa State University.

But HTS researchers, having been through similar research frenzies before, have learned to cool their optimism. "It is always exciting when a promising new material comes around," says Chu. But he and others caution that there are plenty of unknowns, among them the stability of this new class of mercury-based compounds and the amount of electrical current they can carry, both of which are critical criteria for practical superconductors. Moreover, mercury, like thallium and bismuth, packs some toxic might.

In spite of these potential pitfalls, the presence of mercury in this benchmark compound may be a good omen for the field. Mercury, after all, is the Roman god of Commerce.

–Ivan Amato

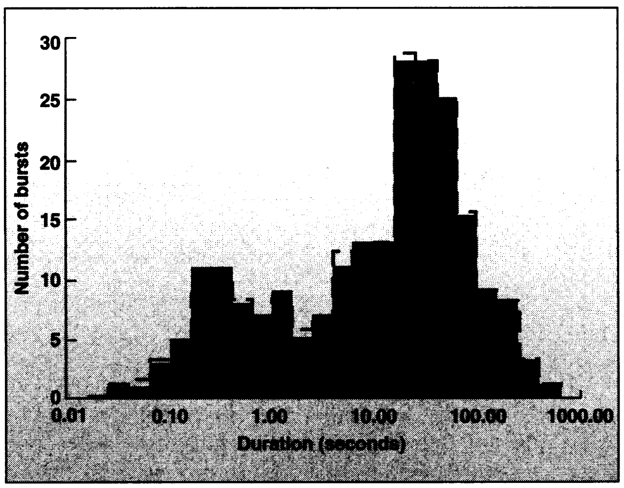
ASTRONOMY

A Double Dose of Gamma-Ray Bursts

Few astronomical mysteries have been as unyielding as the powerful flashes of gamma rays that erupt about once a day from random directions in the sky. After 20 years of cataloguing these gamma-ray bursts, astronomers still have not been able to link any one of them to a known object—a star, quasar, or galaxy—make any sense of their distribution around the sky, or find other clues to their nature. Even the latest results from National Aeronautics and Space Administration's orbiting Gamma Ray Observatory (GRO), which triggered a flurry of press attention last month, showed no break in the uniform distribution of bursts around the sky. But a less publicized analysis of GRO data is finally yielding hints of a pattern in these puzzling events.

The analysis, by investigators working with the Burst and Transient Source Experiment (BATSE) aboard GRO, suggests that there may actually be two different classes of events: one made up of bursts lasting just fractions of a second and the other of bursts that go on for tens to hundreds of seconds. Theorists pondering the origin of the bursts don't know what to make of the finding. But they are hailing it as a potential clue—one that is all the more tantalizing because another analysis based on different criteria, by Donald Lamb of the University of Chicago, also hints at two classes of bursts. "This has profound implications for future models" of these events, says Princeton theorist Bohdan Paczynski.

For Paczynski, the result, while welcome, is something of an embarrassment, because he and fellow theorists had overlooked earlier hints of the pattern. The first came in data from a detector flying aboard the Pioneer Venus Orbiter in 1990. Then, in 1991, a French-Soviet group presented a more complete analysis of data from the Soviet satellite GRANAT, which not only pointed to distinct classes of long and short bursts, but also showed that the shorter ones shot out a higher proportion of energetic "hard" gamma rays than the longer ones. But back then, says Paczynski, there were all kinds of claims about gamma-ray bursts, and he didn't think these experiments had enough data to prove their case. "Somehow I had so little confidence in other experiments that I was blind," says Paczynski. "Now I see there was evidence everywhere."



KOUVELIOTOU

Doubling up. Two classes of gamma-ray bursts stand out in both raw *(green)* and corrected *(dashed line)* data.

What finally convinced him was the announcement by Chryssa Kouveliotou of the Universities Space Research Association, based in Columbia, Maryland, and her colleagues on the BATSE team that they found a similar pattern when they analyzed 200 of the 600 bursts recorded by GRO since its launch 2 years ago. The BATSE group, which announced the finding in an electronic mail bulletin in February and has submitted a paper to the *Astrophysical Journal*, also notes that although events in the two classes differ in average duration by factors of 100 or so, their peak brightness is always about the same. That consistency impresses theorist Paczynski. "This tells us something very important," he says, though he is quick to admit he doesn't know exactly what that is.

Indeed, it seems that with gamma-ray bursts, nothing is ever straightforward. While the BATSE group sees one kind of division, Lamb sees a somewhat different one. Lamb analyzed the same set of bursts but classified them by their variability—the degree to which they flickered—instead of their duration. He found that the bursts fell into two classes, "smooth" and "rough." On further analysis, he discovered that his two classes also exhibited striking differences in a number of other properties, including brightness, duration, and spectrum.

At bottom, the two analyses may have uncovered the same thing, says Harvard University theorist Ramesh Narayan. "What Lamb calls variable is the same as what the BATSE group calls long," he says. Lamb concedes that there may be some overlap, but he thinks his classification scheme is more valuable, because his two sets of bursts differ in many other characteristics besides duration. Kouveliotou and colleagues argue that Lamb's results arose from misleading systematic effects—not a real physical distinction.

The confusion may be dispelled once both groups' methods and conclusions are published (Lamb has also submitted his findings for publication, in *Astrophysical Journal Letters*). Then theorists can start applying the findings to try and narrow the field of theories explaining the bursts. There are now no less than 117 different explanations, by Paczynski's count. Some place the sources around the galaxy, others say they lie at the very edge of the universe, and each gives a different scenario for the energy release, often invoking some kind of detonation or collision of a neutron star or black hole. "How do you believe any of them?" asks Paczynski. With so many models and so few data, he and his colleagues are hoping this clue will be just the first of many.

–Faye Flam