Inching closer to molecular electronics

When it comes to electronics, thinking small is thinking big. Cramming ever more components onto ever smaller chip areas has shrunk super-expensive, room-filling computers into affordable and even more capable gizmos that you can carry with one hand if you can fork over $1,000 or so with the other.

As the miniaturization trend continues, a diverse community of small-thinking scientists has set its sights on the tiniest imaginable electronic landscape, where components measure millionths of a centimeter or about the size of small protein molecules. That would translate to components at least 1,000 times smaller than today's — a prospect that some view as theoretically sound and others doom as wishful thinking.

In 1988, Ari Aviram of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., proposed a theoretical class of molecules, which his calculations indicated should behave as diminutive memory, logic and amplification components — that is, as a set of molecular computing devices.

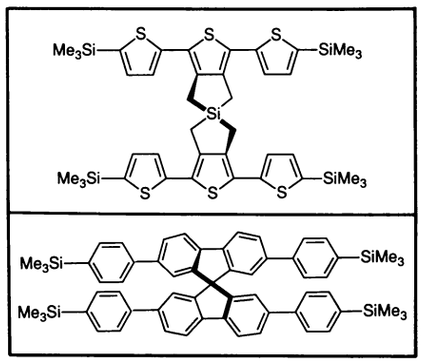
Excited by the chemical challenge of this proposal, James M. Tour of the University of South Carolina in Columbia began efforts to make real versions of Aviram's mind-confined molecules.

Now he has something to show for his efforts. In the July 4 JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, Tour and graduate students Ruilian Wu and Jeffry S. Schumm report making batches of two molecules with structures close to the ones Aviram proposed.

Aviram's hypothetical structures consist of two polymeric chains, each about a millionth of a centimeter long, linked to each other at a 90° angle via a twisted chemical bridge that would control the passage of electrons from one chain to the other. In an actual electronic component, the electrons would flow in and out through four electrodes, one at each end of the two chains. An additional pair of electrodes flanking the bridge would serve as a switch, opening or closing the bridge to electron traffic.

So far, the South Carolina chemists have made two types of twisted bridges and attached as many as three molecular chain links — either pentagonal thiophenes or hexagonal phenylenes — that extend from the bridge like outstretched arms. They still need to add three or more links to each arm to get chains that fit Aviram's specifications, Tours notes.

"The chemistry is lovely, a real *tour de force*," says Joel S. Miller, a solid-state chemist at Du Pont's Experimental Station in Wilmington, Del. "Tour has made a tremendous stride toward these molecules." But Miller questions an important assumption underlying Aviram's vision of molecular electronics — namely, that single molecules can behave like electronic devices.



Tour et al.

Potential chemical frameworks for molecular electronic devices. Top: Pentagonal, sulfur-containing thiophene molecules form two chains linked by a silicon-centered bridge. Bottom: Carbon-centered bridge links hexagonal phenylene subunits.

Inherent quantum fluctuations add a random factor to the location of electrons within individual molecules, and that would make the solo molecules unreliable components at best, Miller says. Reliability could be won by averaging the collective behavior of tens of thousands of such molecules, he adds, but such an ensemble would take as much space as the electronic components on today's chips.

Aviram and Tour acknowledge that molecular electronics research is a high-risk venture riddled with obstacles, but they say that experimental deeds, rather than theoretical words, will determine the venture's success or failure. Miller says he agrees that the time for experimental tests has nearly arrived. As Aviram puts it, "Let the molecules speak for themselves." — *I. Amato*

Hard evidence for bone-building therapy

Earlier this year, a nonhormonal treatment for osteoporosis succeeded in fortifying spinal bone and reducing spinal fractures in a small group of postmenopausal women (SN: 5/26/90, p.334). Now, a much larger study strengthens the notion that brittle bones could have a solid future under this new treatment.

The experimental therapy features oral doses of etidronate, a drug that suppresses bone-eating cells called osteoclasts. Healthy bone maintenance involves a somewhat evenly matched contest between these osteoclasts and bone-forming cells called osteoblasts. With age, however, and particularly in postmenopausal women, the balance often shifts to favor osteoclasts, resulting in the porous, brittle bone that typifies osteoporosis.

A team led by endocrinologist Nelson Watts of the Emory University School of Medicine in Atlanta studied 429 postmenopausal, osteoporotic women at seven medical centers across the United States. To prevent the crucial osteoblasts from getting lazy as their rival cells succumbed to drug treatment, Watts and colleagues simulated an osteoclast depress-and-release cycle throughout the two-year experiment. About half of the volunteers alternated between two-week periods of daily etidronate treatment and 10-week periods of osteoclast "release," in which treatment consisted only of dietary calcium supplements. The remaining patients followed the same schedule but received a placebo instead of etidronate.

Etidronate-treated women gained a significant 4 to 5 percent in spinal bone density after two years of treatment, Watts and his colleagues report in the July 12 NEW ENGLAND JOURNAL OF MEDICINE. And compared with the placebo group, these patients suffered less than half as many vertebral fractures over the course of the study. These results demonstrate the treatment's anti-fracture benefits more convincingly than the earlier, smaller study conducted by Danish and U.S. scientists, Watts says.

Today, people with advanced osteoporosis typically receive estrogen or calcitonin, the only two osteoporosis drugs currently approved by the FDA. Both of these hormonal drugs suppress osteoclasts but have serious drawbacks: Calcitonin requires injection and is very expensive, Watts says, while estrogen treatment may increase the risk of breast cancer.

Bone specialist B. Lawrence Riggs of the Mayo Clinic in Rochester, N.Y., says Watts' study is particularly encouraging because patients reported few side effects and apparently gained quality, fracture-resistant bone. Fluoride, also used experimentally to combat osteoporosis, did not fare as well in a study reported by Riggs and his colleagues in the May 22 NEW ENGLAND JOURNAL OF MEDICINE. Fluoride more often caused side effects, he notes, and did not reduce the rate of spinal fracture. "The bone formed was not of normal strength. In the peripheral skeleton, there was actually an increase in fractures," Riggs says.

Noting that the benefits of estrogen and calcitonin plateau after one or two years, Riggs says researchers need to determine how long patients can maintain the increased bone mass under intermittent etidronate therapy. Toward that end, Watts plans to follow his etidronate patients to see whether the treatment's bone-building properties will persist in the long run. — *W. Stolzenburg*