Crystal-coated lipids promise new materials

Nature is the ultimate material maker. Whether in the form of mollusks' shells or vertebrates' bones, nature can produce some of the lightest, strongest substances known.

Taking their cues from nature, Douglas D. Archibald and Stephen Mann of the University of Bath in England report in the July 29 NATURE their success in using tiny lipid tubules as templates for growing minute crystals. Their process mimics some aspects of bone formation, where crystals grow in an organic matrix, hardening the soft tissue.

Specifically, the straw-shaped microtubules, measuring some 120 nanometers in diameter, are made of the sugar-based lipid galactocerebroside. Incorporating a charged, sulfated version of the lipid on the tubules' surface and then soaking them in a solution containing iron causes small iron oxide crystals to grow on the outer surface. Scientists have already coated lipid tubules with metals, but only now have they done so with minerals.

By changing the conditions under which they make the lipids, the researchers can also alter the lipids' shapes, generating crystal-studded tubes, disks, and even fibrous webs. In fact, Archibald and Mann believe other mineral-containing fibers and organic-ceramic composites may be within reach.

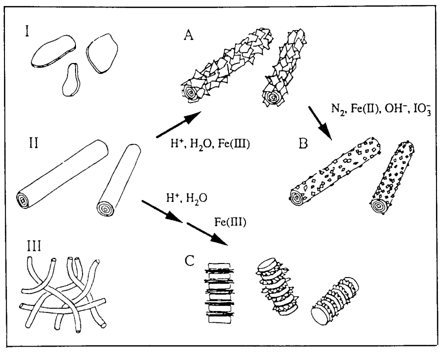
The new materials have the added advantage of being exceptionally biocompatible, or friendly to living systems. Many new composites require toxic resins, high temperatures, and organic solvents, making them difficult to manufacture and leaving much toxic residue. In contrast, Archibald thinks scientists can produce these new crystal-coated tubules at low temperatures without corrosive solvents or toxic by-products, thus helping to promote a cleaner environment.

These materials also build their own structures out of simple, repeating patterns — a process called self-assembly that nature has mastered but scientists are just learning.

"Self-assembly occurs all the time in nature," says Archibald, now at the U.S. Naval Research Laboratory in Washington, D.C. "Whenever you grow a crystal, it's self-assembling. In the biological world, we see self-assembly when bones form in animals or sea creatures make shells. In both cases, crystal structures are building themselves on templates. The inorganic crystals are deposited out of aqueous solutions, giving the softer, organic materials some rigidity. That's why shells and bones are so strong. It's the crystals embedded within the organic material."

Mastering self-assembly is a formidable task, but one promising the ability to make entirely new types of fabricated materials. "Once the mechanisms that govern the self-assembly of these organic-inorganic composites have been worked out, the possibility of designing new materials will really be with us," notes Mark E. Davis, a chemical engineer at the California Institute of Technology in Pasadena.

"Without self-assembly," Archibald adds, "bones and shells couldn't grow. This process is very important, and much of it is a great mystery. We're learning a lot about the biology of mineralization as we go along, about what gives these organic structures their special physical and chemical properties." — *R. Lipkin*



Lipid disks (I), tubes (II), and fibrous webs (III) grow iron oxide crystals when ionized and soaked in iron-containing solution.

Dark matter: A cosmos that runs hot and cold

Speculating about the interplay of subatomic particles in the early universe, astrophysicists say they have found a way to forge a more coherent theory from two seemingly disparate models of the evolution of large-scale structure in the cosmos.

In part, the researchers were motivated by a long-standing cosmological puzzle: Although the universe began as a smooth mix of matter and energy, it somehow evolved into a lumpy collection of stars and galaxies.

To account for the clumpiness of the present-day universe, many researchers have invoked the notion of dark matter — weakly interacting, invisible material that doesn't glow like ordinary matter but does exert a gravitational tug. Dark matter in the early universe, astronomers theorize, could increase the size of tiny "seeds," or lumps, in the density of primordial matter rapidly enough to create the large-scale structure now observed.

For a time, two theories of dark matter battled for acceptance. Cold dark matter would move slowly and form smaller structures first, eventually building larger features such as superclusters of galaxies. In contrast, hot dark matter would move at nearly the speed of light and form bigger lumps first; these would then fragment into smaller features. For most of the 1980s, cold dark matter dominated cosmological theory. But researchers came to believe that the standard model of cold dark matter couldn't entirely explain all observations (SN: 5/22/93, p.328).

This prompted some cosmologists to suggest that both hot and cold dark matter played a significant role in the universe's evolution. However, each type would seem to originate from an entirely different physical process.

Now, Robert A. Malaney and his colleagues at the Canadian Institute for Theoretical Astrophysics at the University of Toronto propose that if a novel decay process occurred in the early universe, it would allow hot and cold dark matter to form together. In the proposed reaction, a certain type of elementary particle, called a neutrino, would act like a laser. But instead of pumping out light, the decay of these neutrinos would produce a cascade of low-energy particles that would group together as cold dark matter; the same decay process would also produce hot dark matter. Malaney and his co-workers, Nick Kaiser and Glenn D. Starkman, detail their study in the Aug. 2 PHYSICAL REVIEW LETTERS.

"In the typical mixed dark matter model, the cold dark matter forms from one part of physics and the hot from a completely different [part of] physics," comments astrophysicist Scott Dodelson of Fermi National Accelerator Laboratory in Batavia, Ill. "This study is a way of connecting the two."

In their work, the Toronto researchers focused on a proposed subatomic process involving unconventional particles known as heavy neutrinos. These decay into pairs of particles, each from a different family of matter, that obey strikingly different physical laws. The boson family, which includes particles of light, can be packed together into the same quantum energy state. In contrast, the fermion family, which includes protons, cannot occupy the same energy state.

As the heavy neutrinos decay, more bosons pack together into a low-energy state, stimulating the decay of more neutrinos, Malaney says. He notes that the process, eventually halted by the fermions, mimics the way coherent light emitted by atoms induces the atoms to produce even more coherent light, creating a laser. Malaney adds that the low-energy bosons become cold dark matter, whereas the high-energy bosons become hot dark matter.

While calling the theory intriguing, Dodelson cautions that it assumes the existence of unknown types of fermions and bosons that interact little with their surroundings. — *R. Cowen*