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NEWS OF THE WEEK

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Millennium Special Report

75th ANNIVERSARY ISSUE

ACTIN + MEMBRANE = TUBULAR CAPSULES

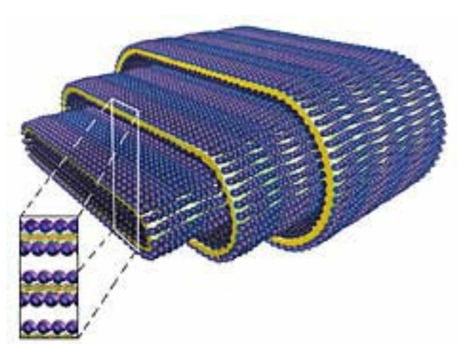
Simple interactions lead to complex material with a range of potential uses

Mitch Jacoby

By balancing entropy and electrostatics, researchers at the University of California, Santa Barbara , and Harvard University have prepared tubular capsules with a structure that resembles bacterial cell walls [*Science,* **288,** 2035 (2000)].

The protein-lipid complex forms spontaneously from its components and exhibits structural ordering on several length scales. In addition to providing insight into the physics of self-assembling systems, the study may lead to materials useful in drug- and chemical-delivery applications and in other areas.

"We've found a general strategy that uses simple and nonspecific interactions to make very complex objects," comments Gerard C. L. Wong , the paper's lead author. By complexing actin, a key cellular structural protein, with cationic membranes, Wong and coworkers prepare hierarchically ordered materials that are organized on length scales ranging from nanometers to fractions of millimeters.



Self-assembling actin rods (blue strands) sandwich a cationic lipid bilayer (yellow), forming trilayed membranes (inset) which curl up into tubes. Stacks of membranes are separated by water layers of roughly 50-Å thickness.

UCLA physics professor Robijn Bruinsma notes that actin currently is attracting a lot of interest in physics research because the protein is considered a model stiff polymer. Rheological properties--flow characteristics--of such materials are expected to deviate from polymer physics scaling laws. And indeed, actin does deviate, he says.

Joel M. Schnur, director of the Center for Biomolecular Research & Engineering at the Naval Research Laboratory , Washington, D.C., remarks that, in addition to the UCSB-Harvard report, the field of nanoscale materials and structures has enjoyed a number of successes recently that may soon lead to uses of these complex structures in advanced materials applications.

For example, recent simulation studies at the University of Pittsburgh show how nanoscale rods may be directed to form supramolecular assemblies by using mixtures of fluids [*Science*, **288,**1802 (2000)]. And investigations carried out by Schnur's research group have led to new methods for imaging nanoscale patterns on self-assembled three-dimensional submicrometer structures [*Langmuir*, published May 26 ASAP, http://pubs.acs. org/journals/langd5/index.html].

"All of this work is leading us to better understand how to rationally design, fabricate, and then manipulate ultrasmall structures," Schnur says. "This portends well for the development of important new materials applications."

The present study was conducted by UCSB materials science professor Cyrus R. Safinya , graduate student Alison Lin, staff scientist Youli Li, and Wong, who was a UCSB postdoctoral associate at the time of the study and currently is an assistant professor of materials science and engineering and of physics at the University of Illinois, Urbana-Champaign. The team also includes postdoctoral researcher Jay X. Tang and professor Paul A. Janmey of Harvard University's Brigham & Women's Hospital.

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To coax the new material's constituents into self-assembling, the UCSB-Harvard team complexes a globular monomeric form of actin with charged (cationic) lipid membranes. That coupling causes the protein to polymerize, forming highly charged rods or filaments of actin (F-actin).

Long F-actin filaments self-assemble into close-packed, two-dimensional parallel arrays, reminiscent of log rafts. Wong points out that an interplay of electrostatic forces and entropy help pack like-charged actin rods into the two-dimensional arrays. Log rafts bind via electrostatic forces to both sides of the ionic lipid bilayers, leading to sandwich structures--that is, three-layer composite membranes.

Composite membranes curl up into ribbonlike structures known as tubules. These small tubes have an average width of 0.25 µm and a length of up to roughly 100 µm.

The group notes that osmotic pressure controllably swells the stacked trilayered membranes, leading to water layer separations between the membranes of 40 to 69 Å. This spacing suggests that active molecules could be incorporated in these hydrated regions, making the material potentially useful for controlled drug-delivery applications.

The length scale and controlled manner in which the tubule networks are fabricated, Wong points out, suggest other possible uses for the new material--such as templates for processing metal tubules for electronic or magnetic applications. Or the novel substance could act as a smart gel capable of regulating and restructuring itself in response to a solution's ionic strength, he says.

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