Chemistry

The amazing molecular maquettes

Proteins, in a manner of speaking, act as the body's busy bees. Whereas DNA's genetic code lays out the architectural plans for making an organism, proteins carry out many of the building and operating functions.

That is, they do the work.

Thus the ability to design and make proteins from scratch has great appeal for biochemists. Once they've decided what task they want done, chemists can — at least in theory — make a simple version of the molecule needed to do that task. This could make possible many creative applications, ranging from medical treatments to biological sensors.

In the March 31 NATURE, Dan E. Robertson, a chemist at the University of Pennsylvania in Philadelphia, and his colleagues describe a way to design and make a multiheme protein, one distinguished by its ability to transfer energy. Falling into the same category as myoglobin, hemoglobin, and certain enzymes, proteins like these can accept and reject electrons. Thus, they can move energy across cell membranes and do bona fide biological work. Photosynthesis and cell respiration, for example, require this type of electron travel.

Robertson's team reports fashioning a peptide — or chunk of a protein — with four helices. Hooked to that peptide are the four key heme groups — similar to those of red blood cells' oxygen-ferrying molecules — characterized by iron atoms embedded in them.

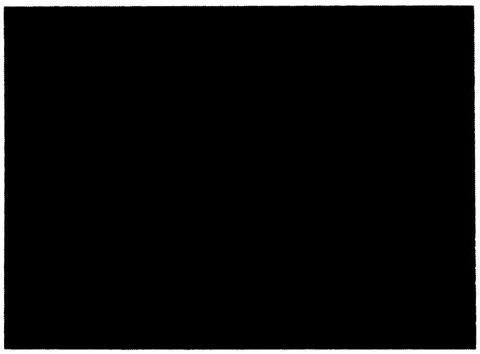
This molecule is an "essential intermediate" — or stepping-stone — for synthesizing "molecular maquettes," the researchers declare. Like sculptors and architects who make tiny, preliminary models (maquettes) of big sculptures and buildings, these chemists make "stripped-down, functional versions" of biologically useful proteins, says P. Leslie Dutton, a chemist at the University of Pennsylvania and a study coauthor.

"The question we're asking is this," says Dutton, himself a weekend painter: "If you start with a complex, naturally occurring protein with, say, 100 amino acids, how could you make a simple version of that protein that would work the same way?"

The synthetic molecule would "dodge the excessive, irrelevant information" contained in a protein by "dumping its biological baggage," leading to a less complex version that does the same thing, Dutton says. "We just want its fundamental activity."

Calling this group's report a "feasibility study" for engineering a specific molecule, Dutton nevertheless sees potential for general protein design. "What we've brought to this area of research are principles for engineering protein electron transfer and the desire to construct something," he says.

"This approach is different from other ways of making proteins," Dutton adds. "We're hanging heme components on a protein frame, the way nature does. But this direction, I hope, will open the doors to some new and exciting [biochemical] games."



Dutton et al.

A protein maquette.

Physics

Ivars Peterson reports from Pittsburgh at an American Physical Society meeting

Counting electrons for a new standard

Nearly every electronic circuit in a stereo, computer, or scientific instrument requires at least one capacitor. This crucial component — often just a small ceramic disk or cylinder with two wires sticking out of it — stores electrical charge. In its simplest form, the device is nothing more than a pair of metal plates separated by a thin layer of electrically insulating material. Incorporated into circuits that handle changing voltages and currents, capacitors can shape, filter, shunt aside, or block electrical signals.

Measured in farads, capacitance represents the amount of stored charge per volt. Scientists and engineers have a variety of methods for determining capacitance, but the most accurate techniques are cumbersome, complicated, and inconvenient. Now, researchers at the National Institute of Standards and Technology (NIST) in Boulder, Colo., are in the midst of a program to develop a new standard for measuring capacitance based on fundamental physics. "We hope to come up with something that's simpler and more reliable," says NIST's John M. Martinis.

At the heart of the new technique lies the ability to count individual electrons and pump them through a circuit to charge up a standard capacitor with a known number of electrons. So far, Martinis and his colleagues have demonstrated that their microscopic electron pump works with sufficient accuracy to meet their needs. "We've proven that the technology works — that we can control electrons one by one," Martinis says.

The trickiest part, however, lies ahead. "The main unknown now is building the capacitor where we're going to store those electrons," Martinis says. "We need a new kind of capacitor, one that is very stable. This really hasn't been looked at before."

Swirls of superfluid flow

Chilling liquid helium to temperatures below 2.172 kelvins has a curious effect. The helium changes into a superfluid, a state in which the liquid flows without friction. The picture gets somewhat more complicated when liquid helium sits as a thin film, only a few atomic layers thick, atop a solid hydrogen surface. In this case, the critical temperature at which the liquid becomes a superfluid depends on the film thickness and characteristics of the underlying surface.

Two years ago, a team led by Jack M. Mochel of the University of Illinois at Urbana-Champaign discovered that sound waves passing through a frigid helium film behave differently than they do in either the normal liquid or superfluid. This unexpected finding suggested that in a thin film over a certain temperature range, liquid helium apparently goes into an intermediate phase unlike the normal or superfluid state.

One way to model the behavior of liquid helium in a thin film is to think of it as a collection of tiny whirlpools. In the normal liquid, these vortices move freely; in the superfluid, they are bound together tightly in pairs. Physicist Shou-Cheng Zhang of Stanford University now proposes that the intermediate state can be interpreted as a particular pattern of vortices in the liquid.

Zhang suggests that the intermediate stage is dominated by an array of clockwise and counterclockwise eddies that settle into a relatively stable, orderly pattern — much like the regular arrangement of negatively and positively charged ions in a crystal. Interactions between this lattice of whirlpools and sound waves produce the distinctive signal detected by Mochel and his coworkers, he says.

Zhang's theory has already passed one experimental test. It correctly predicted that adding atoms of a lighter helium isotope — helium-3 — to a helium-4 film would widen the temperature range over which the intermediate phase is observed.