Yang examined receptor endocytosis, the process by which cells absorb materials—such as a drug attached to folic acid—that have been captured by receptors on the cell surface. The compound is then broken down and processed, releasing the drug.

One of the key mechanisms of this breakdown is disulfide reduction, which involves the breaking of chemical bonds. It was thought that disulfide reduction relied on the movement of the material along microtubules (hollow tubelike structures) and fusion with special digestive-enzyme-containing compartments within the cell called lysosomes. However, the research showed that disulfide reduction occurred even when such components were removed from the process.

By inactivating different cellular components, Yang discovered which components are essential to the disulfide reduction process.

"It was surprising to learn that many other components of the cell, aside from those previously assumed to be responsible, were capable of releasing the drug from folic acid," Yang said. "This significantly increases the opportunity for the drug to be released. For instance, we used to believe it had to get to a specific location to be released, and now we know it can happen almost anywhere during endocytosis."

Theory Predicts that Cycloaddition Functionalizations May be Used to Manipulate CNT Conductance

Nicola Marzari, an associate professor at the Massachusetts Institute of Technology (MIT), and Young-Su Lee, an MIT graduate student in materials science and engineering, have used density functional theory to determine that cycloaddition functionalizations can be used to manipulate carbon nanotube (CNT) conductances. The researchers report their findings in the September 15 issue of *Physical Review Letters* (#116801; DOI: 10.1103/PhysRevLett. 97.116801).

With an internal bonding structure rivaling that of diamond, CNTs are extraordinarily strong and can be highly efficient electrical conductors. However, one problem in working with them is that there is no reliable way to arrange CNTs into a circuit, partly because growing them can result in a randomly oriented structure. Researchers have attached to the sidewalls of the CNTs chemical molecules that work as "handles" that allow the nanotubes to be assembled and manipulated. However, these molecular bonds also change the CNTs' structure and destroy their conductivity.

Now, Marzari and Lee have identified a class of molecules—carbenes and nitrenes—that preserve the metallic properties of CNTs and their near-perfect ability to conduct electricity with little resistance (see Figure 1).

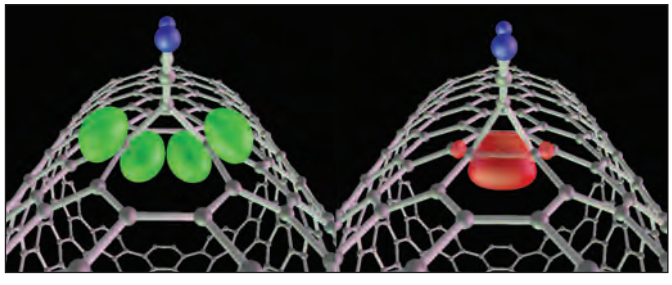

Figure 1. Certain molecules can attach themselves to metallic carbon nanotubes without interfering with the nanotubes' exceptional ability to conduct electricity. At left, the high conductance state has two molecular orbitals, shown in green. Some molecules let the nanotube switch between (left) highly conductive and (right) poorly conductive (with one red molecular orbital), creating the potential for new applications. (Image courtesy of N. Marzari.)

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The hexagon of carbon that makes up a nanotube has a predilection for clinging to other hexagons. One of the many challenges of working with CNTs is that they tend to stick to each other. Attaching a molecule to the sidewall of a nanotube serves a double purpose: It stops nanotubes from sticking, so that they can be processed and manipulated more easily, and it allows researchers to control and change the electronic properties of the nanotubes. Still, most such molecules also destroy the CNTs' conductance because they make the nanotube structurally more similar to diamond, which is an insulator, rather than to graphite, a semimetal.

The researchers indicate that their studies show that carbenes and nitrenes work by breaking a molecular bond on the nanotube's wall while creating their own new bond to the nanotube. This process—one bond formed, one bond lost—restores the perfect number of bonds each carbon atom had in the original nanotube; thus, "conductance is recovered," Marzari said.

The theory indicates that some molecular handles can even transform between a "bond-broken" and a "bond-intact" state, allowing the CNTs to act like switches that can be turned on or off in the presence of certain substances or with a laser beam.

"This direct control of conductance may lead to novel strategies for the manipulation and assembly of nanotubes in metallic interconnects, or to sensing or imaging devices that respond in real time to optical or chemical stimuli," Marzari said.

The next step is for experiments to confirm that the approach works.

Model of Collagen Nanostructure Explains Its Strength

Collagen's characteristic nanostructure may be the reason for its high strength and ability to sustain large deformation in its physiological role in tissues such as bone, tendon, and muscle. Previous experimentation has shown that collagen isolated from different tissue sources universally displays a design that consists of a staggered assembly of tropocollagen molecules with lengths of approximately 300 nm. The reason why strands of amino acids associate to form tropocollagen molecules consistently at this length has been an unexplained phenomenon.

M.J. Buehler, principal investigator at the Atomistic Mechanics Modeling Laboratory at the Massachusetts Institute of Technology, has used a combination of theoretical and molecular modeling that led to a breakthrough in understanding how molecular and tissue properties are linked. Buehler has reported his findings in the August 15 issue of the *Proceedings of the National Academy of Sciences* (p. 12285; DOI: 10.1073/pnas.0603216103).

Buehler discovered that the characteristic design of collagen displays a clever strategy that enables nature to take advantage of the nanoscale properties of individual molecules at larger scales, leading to a tough material. This is achieved by arranging tropocollagen molecules into a staggered assembly known as collagen fibrils, tiny fibers with diameters of 50–200 nm and lengths of several micrometers. When a tensile force is applied at the end of a collagen fibril, the force is transmitted as shear forces between molecules and a tensile force within molecules. Whereas the elastic tensile strength of the tropocollagen mol-

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