sufficient details about the field that they can become more effective researchers. Those who have not had the benefit of this will not know what they missed (I am sure their employers do not miss this point). (5) MSE departments enhance the level of interdisciplinarity on a university campus in that they provide a natural bridge between areas of engineering, medicine, and the natural sciences. Schools with the largest interdisciplinary multi-investigator proposals predominantly have diverse and healthy MSE departments.

The big challenge is in identifying how the curriculum in MSE departments should evolve to reflect the developments in the field. Major technological challenges such as energy and sustainability and problems at the interface of medicine and materials are interdisciplinary ones in which materials research plays a central role. In order to fulfill this role, the MSE department of the future needs to continue developing as the major player in the interdisciplinary research infrastructure of universities.

In light of the rapid changes in the field and associated changes in the curriculum, MRS should play a very active role in accreditation issues. The impact of MRS goes far beyond meetings: MRS has helped define a field and a profession, and as a professional society, MRS helps define the expectations of the next generation of researchers to tackle the difficult interdisciplinary problems.

PETER F. GREEN
2006 MRS President

RESEARCH/RESEARCHERS

Color-Coded Method Visualizes Drug Release in Cancer Cells

Philip Low, the Ralph C. Corley Distinguished Professor of Chemistry at Purdue University, and his colleagues at Purdue and Endocyte Inc., have discovered details of how drugs are released within a cancer cell, improving the ability to deliver drugs to a specific target without affecting surrounding cells. "Most new drugs under development will be targeted directly to the pathologic, disease-causing cells, and we have shed light on the details of one mechanism by which this is achieved," Low said.

As reported in the September 12 issue of the *Proceedings of the National Academy of Sciences* (p. 13872; 10.1073/pnas.0601455103), Low and his team developed a color-coded method to visualize the cellular mechanisms by using a technique called fluorescence resonance energy transfer imaging (see Figure 1). "The drug turns from red to green when it is released inside the cell, clearly illuminating the process," said Jun Yang, a postdoctoral research associate in Low's group.

In targeted drug therapy, drugs are linked to molecules that are used in excess by pathologic cells—for example, a required nutrient—in order to transport drugs directly to the targeted cells while avoiding significant delivery of the toxic drug to normal cells. One commonly used agent, referred to as a ligand, is the vitamin folic acid. Cancer cells need folic acid to grow and divide and therefore have developed abundant receptors to capture it. These receptors are largely absent in normal cells. This means folic acid, and the drug linked to it, are attracted to the pathologic cells and are harmless to healthy cells, Low said.

"It is desirable to have the drug released from the ligand, folic acid, once the folate-linked complex enters the cell," Yang said. "This 'conditional drug release' is usually realized by attaching folate to the drug through a linker that falls apart inside the cell. There were several linkers in common use, but with mixed efficiency. In this study, we undertook to interrogate the full details of this breakdown process."

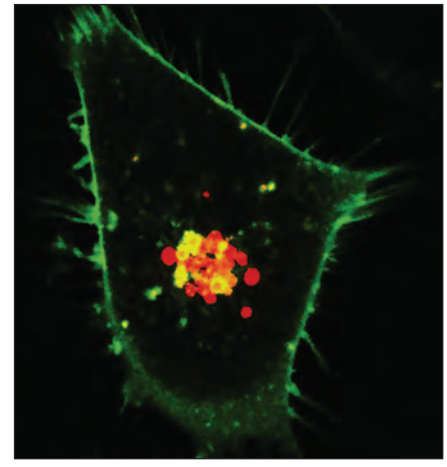

Figure 1. Depiction of drug release within a treated cancer cell. Once inside the cell, the drug turns from red to green as receptor endocytosis releases it from its folate-linker. By linking to the vitamin, toxic drugs are transported directly to the cancer cell and do not harm healthy cells. (Image courtesy of Proceedings of the National Academy of Sciences*).*

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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).

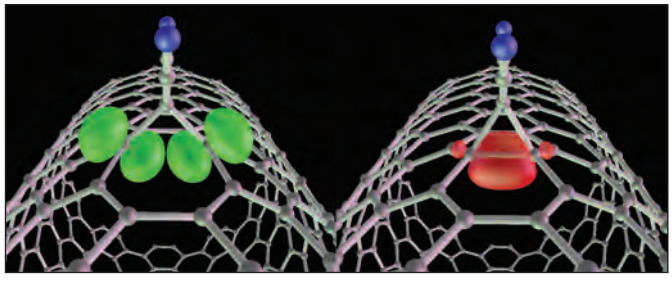

Figure 1. Certain molecules can attach themselves to metallic carbon nanotubes without interfering with the nanotubes' exceptional ability to conduct electricity. At left, the high conductance state has two molecular orbitals, shown in green. Some molecules let the nanotube switch between (left) highly 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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