Researchers synthesize molecule with self-control

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Plants have an ambivalent relationship with light. They need it to live, but too much light leads to the increased production of high-energy chemical intermediates that can injure or kill the plant.

The intermediates do this because the efficient conversion of sunlight into chemical energy cannot keep up with sunlight streaming into the plant.

“The intermediates don’t have anywhere to go because the system is jammed up down the line,” says ASU chemist Devens Gust. Plants employ a sophisticated process to defend against damage.

To better understand this process, Gust, along with fellow ASU researchers Thomas Moore and Ana Moore, both professors of chemistry and biochemistry, designed a molecule that mimics what happens in nature. They report results with their molecule in the advanced online publication of *Nature Nanotechnology* (May 4, 2008).

In nature, plants defend against this sunlight overload process using non-photochemical quenching (NPQ). This process drains off the excess light excitation energy as heat so that it cannot generate the destructive high-energy species.

The ASU-designed molecule works in a similar fashion in that it converts absorbed light to electrochemical energy but reduces the efficiency of the conversion as light intensity increases. The ASU-designed molecule has several components including two light gathering antennas – a porphyrin electron donor, a fullerene acceptor and a control unit that reversibly photoisomerizes between a dihydroindolizine (DHI) and a betaine (BT).

When white light (sunlight) shines on a solution of the molecules, light absorbed by the porphyrin (or by the antennas) is converted to electrochemical potential energy. When the white light intensity is increased, the DHI on some molecules change to a different molecular structure, BT, that drains light excitation energy out of the porphyrin and converts it to heat, avoiding the generation of excess electrochemical potential. As the light becomes brighter, more molecules switch to the non-functional form, so that the conversion of light to chemical energy becomes less efficient. The molecule adapts to its environment, regulating its behavior in response to the light intensity.

"One hallmark of living cells is their ability to sense and respond to surrounding conditions," explains Thomas Moore. "In the case of metabolic control this process involves molecular-level recognition events that are translated into control of a chemical process."

"Functionally, this mimics one of the processes in photosynthesis that severely limits the energy conversion efficiency of higher plants," he added. "One way in which this work is important is that by understanding these events at the molecular level one can imagine redesigning photosynthesis to improve energy conversion efficiency and thereby come closer to meeting our energy needs."

The research is also important to one aspect of the exploding field of nanotechnology, that of regulation, Gust adds. Biological systems are known for their ability to engage in adaptive self-regulation. The nanoscale components respond to other nanoscale systems and to external stimuli in order to keep everything in balance and functioning properly. The ASU research shows how a bio-regulation system has been captured in a non-biological molecular scale analog process.

"Achieving such behavior in human-made devices is vital if we are to realize the promise of nanotechnology," adds Gust. "Although the mechanism of control used in the ASU molecule is different from that employed in NPQ, the overall effect is the same as occurs in the natural photosynthetic process."

Source: Arizona State University

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