Los Alamos NATIONAL LABORATORY EST. 1943

Spotlight

Goodbye to Pinpricks

For millions of patients with diabetes, pain inevitably accompanies blood-sugar monitoring. Pricking a finger to extract a drop of blood onto a testing strip for a glucose reading—repeated maybe four to seven times a day—is necessary to control glucose levels and to prevent serious complications such as kidney failure, blindness, nerve damage, and poor blood circulation.

Los Alamos scientist Yixiang Duan and his colleagues are developing a new noninvasive breath test to replace the painful prick.

In diabetics, low insulin levels allow sugar to accumulate in the blood instead of being metabolized and made available to cells. The body compensates by digesting fatty acids and producing chemical byproducts called ketones. Acetone, one of those ketones, builds up in the blood and gets transferred preferentially to the breath, where a high concentration is a sure sign of increased blood sugar. In healthy people that concentration is about several hundred parts per billion, but it can be 10 to several hundred times greater in diabetics, depending on the level of insulin in the body.

Duan and his colleagues have designed and developed a very-sensitive compact device for testing the breath acetone level. First, a small precision device ionizes a stream of inert gas (helium or argon) to form a stable micro-size volume of plasma the size of the tip of a ballpoint pen.

A sample of breath is allowed to mix with the microplasma, breaking the acetone molecules and creating a special set of excited or ionized fragments that emit optical light. A palm-size spectrometer analyzes that light and displays the results on a screen. For a certain range of acetone concentrations, the amplitude of the light signal is proportional to, and therefore a quantitative measure of, the breath acetone level.

This method has been patented, and both the device that generates the microplasma and the palm-size spectrometer have been developed and implemented. Duan and his colleagues expect to integrate their apparatus into a compact hand-held device for on-site breath-gas monitoring and analysis in hospitals and private homes.

A Boost for Wireless Monitoring

The Internet and cell phones have revolutionized telecommunications. The next revolution could be in wireless sensor networks, which are webs of distributed battery-powered sensors that monitor such things as temperature, vibration, or nearby movement—movement on a battlefield or border, for example.

In Los Alamos, computer scientist Sami Ayyorgun helps these networks reach their potential with his new operational scheme: BSTeR (pronounced "booster"), for Boost by Smart Transmit-power Random-variables. The BSTeR scheme adjusts the sensors' transmission powers intelligently, while dynamically adapting to changes in the network's condition (sensor locations, for example), resulting in a "self-organizing" network.

Unlike cell phones, which use an array of towers to pass messages between phones, wireless sensor networks deal directly with their fellows. One sensor "hops" a message to another, which relays it forward until, sensor by sensor (multihopping), the information reaches its destination.

In a standard, fixed-power scheme, each sensor always transmits each hop at the same power level, over the same distance, and through the same forwarding sensors. Since the same sensors are always being activated, their batteries run down more quickly. "Energy efficiency is a first-class design criterion," says Ayyorgun, so he has designed the BSTeR scheme to not always send messages down the same path. With BSTeR, each sensor chooses one of many possible power levels for each hop it transmits, basing that choice on a random number generated by an internal processor. A higher power level turns a hop into a leap, sending a message to a more-distant sensor, which then generates its own randomly powered hop.

The diversity of transmission powers for each sensor exponentially yields many different pathways, activating different sensors and spreading power usage across the network. Over many messages, the improvements on speed and other performance metrics add up significantly, resulting in concurrent performance gains over many metrics—the first such concurrent gains reported in the literataure.

Ayyorgun presented the BSTeR scheme in the Plenary Session of the Institute of Electrical and Electronics Engineers' (IEEE) International Conference on Mobile Ad Hoc and Sensor Systems (a premier publication venue of the IEEE) in Atlanta on September 30.

Building a Better Plant

Growing more and better food crops has traditionally meant pouring on the nitrogen fertilizer, which is expensive to use and pollutes waterways through runoff. This is not a good situation, especially now when the world needs to add biofuel production to a global agricultural system that is struggling to feed rapidly growing populations. Can we cost effectively produce more food and biofuel and do so without further degrading the environment?

Pat Unkefer and her team in Bioscience Division say yes, and they've got a product that proves it.

Take-Off, licensed by Biagro Western, is a metabolite, an amino acid that coordinates aspects of a plant's metabolism. It increases both the amount of carbon dioxide that the plant converts to carbohydrates and the amount of nitrogen it draws from the soil. When Take-Off is sprayed on crops, they grow faster, mature earlier, and leave less nitrogen fertilizer in the ground to contaminate water supplies. Plants treated with Take-Off also use more of their nitrogen for growth instead of storing it in their tissues.

Unkefer and her team discovered the metabolite—2-oxoglutaramate—while studying plant metabolism. They learned they could stimulate growth, without the use of hormones, by increasing a plant's supply of this naturally occurring substance.

Synthesizing 2-oxoglutaramate proved prohibitively expensive, however, so the team identified a cheaper compound of similar structure (an analog) that replicates the metabolite's function. It is that analog that is now on the market as Take-Off. The analog is biosynthesized and biodegradable and is thus a very eco-friendly technology, certifiable even for organic farming.

Take-Off is now being used commercially on wheat, barley, and grapes and on the biodiesel crop canola. It is significantly increasing overall yields, and is being developed for additional crops as well. The farmers are also realizing greater profitability, thus increasing their own sustainability.

In July the Federal Laboratory Consortium, a nationwide network of federal laboratories, honored Take-Off with a Notable Technology Development Award during a Denver meeting of regional members of the organization.

A Sweet Reaction

Recent studies done at Los Alamos on an enzyme that turns one type of sugar into another have yielded some unexpected insights into the reaction.

The enzyme xylose isomerase (XI) can convert the sugar glucose into fructose and is used in manufacturing high-fructose corn syrup for food products. Similarly, XI can convert the sugar xylose into xylulose, which can be used in producing different kinds of biofuels. Understanding those conversion reactions in detail may aid efforts to make the enzyme work better and hence contribute to more-efficient production of fuel and food products.

Xylose has five carbon atoms and one oxygen atom bonded into a hexameric ring, with several hydrogens and hydrogen-oxygen pairs dressing the carbons. To convert from xylose to xylulose, the enzyme helps the ring to open and then helps move two hydrogen atoms from the second to the first carbon in the now-linear molecule.

Researchers from Fox Chase Center, the University of Toledo, the University of Tennessee, and Los Alamos used the Bioscience Division's Protein Crystallography Station (PCS) for their studies. They collected neutrons diffracted from a crystal of XI that had been soaked in a solution of xylose and that the enzyme had converted to xylulose. The neutron crystallographic data revealed the location and charge states (positive or negative charges) of atoms in the XI-xylulose complex. When the results were compared with the team's studies of XI alone, it became possible to see how the atoms had been rearranged during the reaction.

In particular, the researchers discovered that a water molecule held in the active site of XI loses a hydrogen, whereas the enzyme itself acquires one during the shuffling of atoms. The finding, which suggests the water may play some role in the conversion reaction, may help researchers differentiate among several possible reaction mechanisms.

Paul Langan, who built the PCS with Benno Schoenborn, led the Los Alamos team, which also included Andrey Kovalevsky, Marat Mustyakimov, and S. Zoe Fisher. The work was published as a Rapid Report in the journal Biochemistry (Vol. 47, p. 7595, 2008) and listed as a "Hot" article.