Biotrodes: Food for Thought

It's 1987—do you know where your banana is? How about your sugar beets or pork kidneys? They might be part of someone's new, improved electrode . . .

By IVAN AMATO

Next time you see a scientist buying bananas, squash, mushrooms, beets, kidney, jack beans or crabs, don't asssume they're for dinner. The researcher might use a slice of banana to detect dopamine, jack beans to measure urea levels, or crab antennules for detecting glutamate. It's part of a new effort to make biologically based electrodes or "biosensors" that selectively detect amino acids, neurotransmitters and other biologically important compounds.

Several labs in different parts of the world are developing a new breed of biosensors that are cheaper, longer lasting, easier to construct and often more efficient than their high-tech counterparts. And because they are made out of foodstuffs, these electrodes could be easily constructed in developing countries where materials, such as purified enzymes, for high-tech electrodes cannot be had.

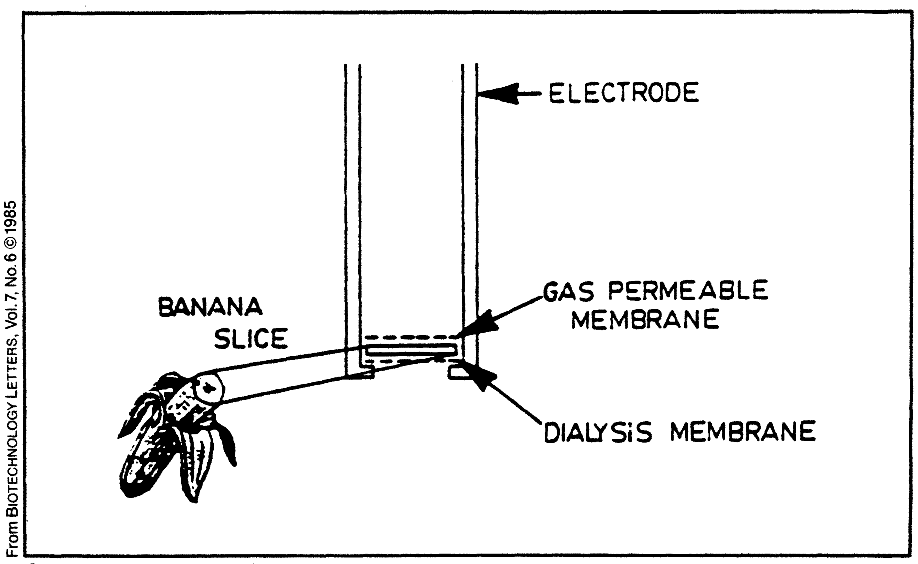
Garry A. Rechnitz and his colleagues at the Biosensor Research Group at the University of Delaware in Newark are one group that is coming up with new concepts for biosensors that seem to circumvent the limitations of existing technologies. They have published more than 250 articles on their research in journals including SCIENCE, NATURE, ANALYTICAL CHEMISTRY and BIOTECHNOLOGY LETTERS. "Evolution has devised for us some systems that are hard to duplicate in the laboratory," says Rechnitz. "Tissues and cells have packaged up in a convenient way all of the cofactors and other materials that might be needed" to make a wide range of biosensors.

Currently, scientists use purified-enzyme biosensors in health care, environmental monitoring and food processing, with specific applications in patient monitoring, drug testing and antibody production. In many cases, these sensors are based on enzymes that are isolated from biological sources and purified before they are coated onto the surface of an electrode that detects a chemical either produced or consumed during the enzymatic reaction.

But these enzyme electrodes deteriorate quickly at room temperature and are expensive. In addition, scientists would like to have enzyme electrodes that are now technically impossible to construct because the necessary enzymes cannot be isolated from their biological sources. In some cases, a battery of enzymes and helper molecules would have to be isolated and immobilized on the electrode surface.

Enter the food-based electrodes. For detecting the neurotransmitter dopamine, Rechnitz and his University of Delaware colleague James S. Sidwell developed the bananatrode. Banana pulp contains an enzyme — polyphenol oxidase—that catalyzes a series of reactions with dopamine during which oxygen is consumed. By combining banana tissue with an oxygen electrode, the scientists have constructed what is effectively a dopamine-detecting electrode.

The researchers sandwich a thin slice of banana between a gas-permeable membrane, which allows oxygen to pass through to the oxygen electrode, and a dialysis membrane, through which dopamine dissolved in a solution can diffuse to the banana slice, where the enzymatic reaction takes place. Rechnitz uses this basic architecture for making a large variety of biosensors. By mixing and



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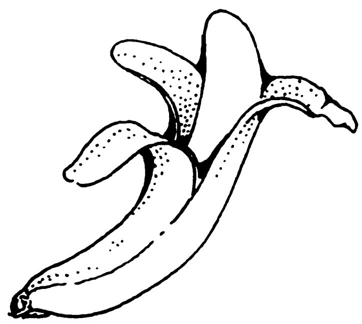
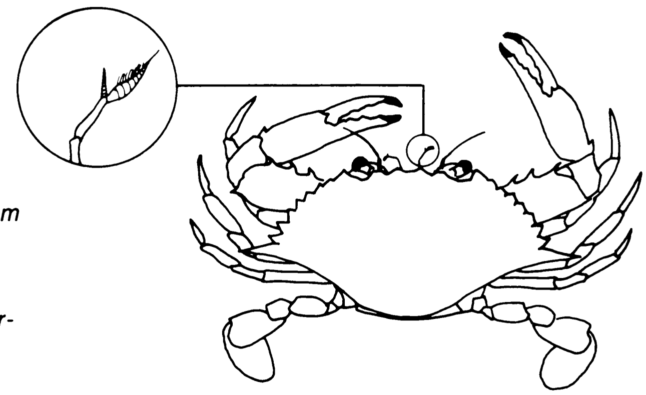
Schematic diagram of the bananatrode, an electrochemical biosensor used for the neurotransmitter dopamine.





Schematic diagram of blue crab with enlarged view of antennule that is used to detect certain amino acids.

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matching sensors that respond to different gases or ions with tissues that are especially endowed with specific enzymatic systems, Rechnitz says, it is possible to construct many biosensors that respond to only one or a few biomolecules.

By combining slices of corn kernel with a carbon dioxide electrode, Rechnitz, Shinichi Kuriyama, who has returned to Japan, and Mark A. Arnold, now at the University of Iowa in Iowa City, constructed an electrode that detects pyruvate, the end product of glucose metabolism. The corn kernels contain a multienzyme complex, called the pyruvate decarboxylase system, which lops off carbon dioxide molecules from certain compounds, including pyruvate. Unless large amounts of pyruvate-like compounds that also undergo carbon dioxide amputation are also present, the amount of carbon dioxide detected corresponds to the pyruvate concentration in the solution being analyzed. The scientists found the corntrode to be more sensitive, faster and more responsive in a wider range of pyruvate concentrations than existing electrodes based on isolated and purified enzymes from the pyruvate decarboxylase system.

Three years ago, a group of scientists from the German Democratic Republic Academy of Sciences in Berlin used sugar beet slices and an oxygen electrode to construct a tyrosine-sensing electrode. Tyrosine, one of the 20 amino acids that make up proteins and enzymes, is a precursor of several neurotransmitters. Sugar beets contain a lot of the enzyme tyrosinase, which converts tyrosine into L-dopa, the precursor of dopamine. During the reaction, oxygen is consumed and the oxygen sensor detects changes in concentration of dissolved oxygen.

To measure urea concentration, University of Iowa's Arnold combined jack bean meal and an ammonia-sensing electrode. An enzyme in the jack beans — urease — breaks down urea, thereby releasing ammonia, which is detected by the ammonia-sensing part of the "beantrode." The amount of ammonia detected is proportional to the amount of urea in the solution being tested.

Tissue-based biosensors are not restricted to vegetarian versions. Arnold made an electrode that detects the amino acid glutamine by combining enzymatic systems found in pork kidney with a pH electrode that measures the acidity of a solution. Other researchers made an electrode that senses antidiuretic hormone, a chemical that decreases urine excretion, by combining toad bladder tissue membrane and a sodium-ion-sensing electrode. Others have married bacteria with gas- or ion-sensing electrodes to detect amino acids, ethanol and nitrate ions.

In the newest category of tissue-based biosensors, scientists couple the sensory anatomy of organisms to an electrical pickup. Rechnitz and his University of Delaware colleague Stuart Belli built a biosensor out of the antennules of blue crabs. In the presence of certain amino acids, the neurons of the antennule fire. The rate of firing corresponds to the amino acid concentration. In effect, Rechnitz is using the crab's version of the human nose to sniff around in solutions for dissolved biomolecules. Rechnitz's group is now exploring sensory anatomy from crayfish and electric eels for other biosensors.

Rechnitz says his aim is to "discover and demonstrate useful properties of natural materials" and to "push for new ideas and concepts relevant to biosensors." Most of the biosensors he is developing are years away from being applicable outside of the lab, he adds. But he says hundreds of scientists, especially from Japan, Great Britain and Germany, have requested reprints of articles published by his biosensor group.

Out of this interest in his brand of biosensors, Rechnitz forecasts the appearance of practical and inexpensive devices that will be used in biotechnological and biomedical applications all over the world. □