Indigestion's basis as a plant defense

An invasion of insects ravaging alfalfa leaves is likely to be courting malnutrition. The plant quietly responds, in a matter of hours, by producing a chemical throughout that inhibits the insects' digestion. Related chemicals are found in large quantities in seeds of many legume species, where they may be part of a complex system boosting plant survival, biologists now report.

Scientists used to think of plants as generally defenseless against foragers, says Clarence A. Ryan of Washington State University in Pullman. But recent work demonstrates that plants can marshall a complex array of chemical countermeasures.

When a leaf of tomato, potato or alfalfa is injured by a chewing insect or by other mechanical means, a chemical message travels rapidly throughout the plant and induces the synthesis and accumulation of proteins that inhibit digestion in an animal's gut. That signal is a fragment of the plant cell wall; and the characterization of one of the digestion-inhibiting chemicals has just been reported. Called alfalfa trypsin inhibitor, it is a member of a family of protein-breakdown inhibitors that had previously been detected only in legume seeds.

Members of this set of inhibitors, called the Bowman-Birk family, make up a sizable fraction, about 5 percent, of the protein in the typical legume seed. They had been considered simply as storage proteins — materials broken down for their components as the seed germinates into a plant. "But they might be there as a protective agent," Ryan says.

In laboratory experiments, the wound-induced inhibitors have serious effects on animal nutrition, Ryan says. Chicks fed inhibitor die. Rats and mice not only become malnourished because they cannot break down the protein they ingest, but their health is further undermined by an internal feedback system. Their pancreases enlarge to produce more and more protein-breakdown enzymes, which are ineffective in the presence of the wound-induced inhibitor.

In insects, scientists find that the inhibitors delay growth of larvae, allowing diseases and other predators to increase their toll. "Small larvae within a day or so will be in trouble," Ryan says. "Larger insects may take longer."

Although legumes (including alfalfa) and solanaceous plants (including potatoes and tomatoes) have similar wound-regulated defense systems, their inhibitors are distinct. Ryan now wants to analyze the underlying genes to determine whether the systems share an ancestor. "It is possible that similar gene-regulating systems are present in many plant families that activate genes coding for a variety of defense proteins," Ryan and colleagues Willis Brown of Washington State University and Koji Takio and Koiti Titani of the University of Washington in Seattle say in the April 23 BIOCHEMISTRY.

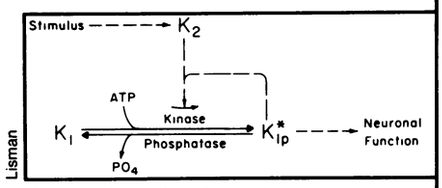
Ryan is also searching for the DNA "switchbox" that is regulated by wounding. He envisions using genetic engineering techniques to increase the amount of inhibitor produced by a plant or to introduce other genes, such as those encoding bacterial toxins, that would be produced only when the plant is under attack. The digestion inhibitors are broken down by heat, so an increase in their amounts would not be harmful to consumers of cooked food. In fact, Ryan says the inhibitors are themselves high-sulfur, high-lysine proteins, so they would build up the nutritive value of a plant.

"They could increase the quantity of the yield and also increase the quality," Ryan says. "That excites us very much."

—J. A. Miller

Molecular switch makes memory stick

How unstable molecules can store information stably has long baffled scientists. Human long-term memory may depend on such a mechanism. Recently, a biologist at Brandeis University in Waltham, Mass., proposed a theoretical model for a molecular "switch," made up of two enzymes with opposite actions. The system could store information indefinitely despite continual turnover of the individual molecules that make up the switch.



Lisman

A bistable molecular switch may be a mechanism for memory storage. K_{1p} is activated kinase-1; K_1 is unactivated kinase-1.*

John E. Lisman describes in the May (Number 9) PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES a hypothetical chemical switch made of a kinase (an enzyme that catalyzes phosphate group transfer to form triphosphates like ATP) and a phosphatase (an enzyme that cleaves a phosphate group from a molecule). The switch is bistable, Lisman says, because it can be either "on" or "off" but is never in between. It is local, he says, because it could be located in specific compartments of neurons — such as dendrites, the spiny processes that conduct impulses to other neurons — rather than centralized in DNA of the cell nucleus.

In his paper, Lisman discusses how this molecular switch could be turned on permanently by an external stimulus. In the "off" state, the kinase, which Lisman calls kinase-1, is unphosphorylated and inactive. A stimulus such as a protein binding to a receptor on a cell membrane, Lisman says, could activate a second kinase, kinase-2, which phosphorylates kinase-1. Kinase-1 is activated briefly until the phosphatase removes a phosphate group and returns kinase-1 to its inactive state.

When kinase-2 stimulation reaches a critical level, kinase-1 becomes activated permanently. Phosphorylation of kinase-1 happens faster than phosphatase can reverse it, and kinase-1 starts to phosphorylate and activate other kinase-1 molecules. Thus, even if the stimulus is removed and kinase-2 activity is eliminated, kinase-1 activity continues. The natural replacement of kinase-1 molecules over time does not inactivate the system. "Thus long-term information can be stored by this switch," Lisman says, "even though the molecules that make up the switch turn over rapidly and completely."

Lisman's model and a similar one proposed last year by Francis Crick of the Salk Institute for Biological Studies in La Jolla, Calif., differ from previous models for memory storage. According to these earlier models, Lisman says, an elementary bit of information is stored in a neuron by phosphorylating a key enzyme and turning it on. The "on" state lasts as long as the phosphatase that can dephosphorylate the enzyme is not present. Even in the absence of phosphatase, he says, the phosphorylated enzyme molecules would be gradually replaced by new unphosphorylated enzyme. Such a switch would be "on" only for the lifetime of the enzyme.

Because of these limitations, the previous models hypothesized that the switch would be in a cell's DNA. However, Lisman says, "It is hard to see how nuclear DNA could independently control (or be controlled by) events in subcellular compartments, such as the thousands of spines that constitute the input regions of neuronal dendrites." In contrast, he says, kinase molecules localized in dendritic spines could easily phosphorylate other kinase molecules within the same spine "and thereby form local bistable switches that are independent of the switches in other spines."

Lisman cautions that the molecular switch model is theoretical and has not been observed in any living systems. "But the surprise of the model," he says, "is how you can take known types of biochemical reactions and get something as complicated as memory storage."

—D. D. Bennett