out and also reddens as more of the cells' energy-producing mitochondria appear.

These changes strengthen the muscle, allowing it to generate more lift per unit of mass, although the stronger muscle also generates more heat, thus changing the operating temperature of the muscle. Marden and graduate student Gail Fitzhugh then figured out that mature muscle works better because it's 10 times more sensitive than the young muscle to calcium ions. "The [mature] muscle is becoming much more excitable at high temperatures," Marden says.

He thought the explanation for the difference might be found in the troponins, because these proteins, which are attached at regular intervals to the filaments of contractile proteins, receive and relay the calcium-ion signals to those filaments. Of the four types of troponins (designated C, I, H, and T), "there was a clear age-related change" only in troponin T, Marden says.

Melisande Wolf in Marden's lab then showed that the RNA copied from the troponin-T gene yields different forms of the protein through alternate splicing of the gene's coding regions. The protein from newly emerged adults has long strings of negatively charged amino acids at both ends, while that of mature insects has negative amino acids at one end, but positively charged amino acids at the other.

Previously, researchers thought that troponin T serves only to anchor other troponins to the contractile filaments. But Marden thinks the structural differences in these so-called isoforms of troponin T could account for the altered calcium sensitivity of the older dragonfly muscles.

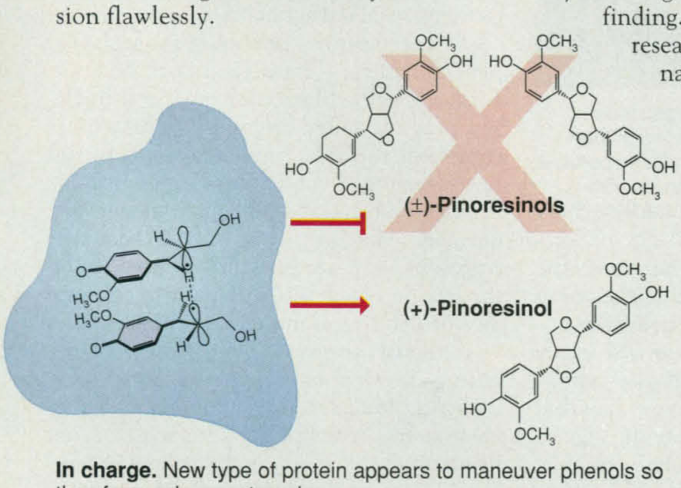
In young dragonflies, he suggests, the double negative ends keep nearby troponin-T proteins from interacting with one another. The insects don't fly much and instead need to devote most of their energy to growing. But in older insects, if the positive end of one troponin T is attracted to the negative end of another in an adjacent filament, then the two—or a whole series of troponin-T proteins—may line up and cooperate in initiating contraction. As a result, the muscle becomes more sensitive to calcium, maximizes its power output, and enables these dragonflies to do the high flying necessary to defend their territories and find their mates.

–Elizabeth Pennisi

CHEMISTRY

New "Guiding" Protein Discovered

Compared to nature's chemical sleight of hand, human chemists are all thumbs. Take molecules that can occur as mirror images of each other, or stereoisomers. Many test-tube reactions yield messy mixtures of stereoisomers, and because stereoisomers of the same molecule can have wildly different properties, chemists often have to put a great deal of effort into separating them. Yet somehow, the tiny chemical factories in cells manage to crank out just one version flawlessly.



In charge. New type of protein appears to maneuver phenols so they form only one stereoisomer.

Now, researchers may have discovered how nature controls the stereochemistry in a major class of compounds: substances made from small, biochemical building blocks called phenols (see diagram). On page 362, chemist Norman Lewis and colleagues at Washington State University in Pullman and Simo Sarkanen at the University of Minnesota, St. Paul, unveil a brand-new kind of protein in plants that seems to grab and maneuver phenols so they will tack together in the proper orientation. The scientists believe their finding could help explain how cells fashion a host of phenolic compounds, from small molecules in plants, called lignans, which can have medicinal properties, to large polymers, such as those forming insect cuticle and lignin, the glue that holds together trees. And it could also be a boon for drug companies and lignin-intensive industries like paper-making, says Jeffrey Dean, a biochemist at the University of Georgia, Athens: "This is a seminal finding. It opens up a new door in a research area that has been stagnant for a while."

This stagnation actually dates back to the 1930s, when chemists first postulated they could make artificial lignin by mixing a type of phenol, E-coniferyl alcohol, with enzymes called oxidases that link molecules together by oxidizing, or removing an electron from, a hydroxyl bond. Over the years, researchers experimented with a variety of oxidases, but no matter which they used, they inevitably ended up with mixtures of various isomers that only vaguely resembled lignin. Clearly, some other enzyme or cofactor was involved, but nobody could figure out what it was.

To search for this mystery substance, Lewis's team studied a particular lignan—just two building blocks linked together in one of two possible stereo forms—that plants manufacture in various forms as defenses against pathogens and predators. Lewis's group crushed stems from a forsythia plant and extracted the proteins. They then screened out those fractions capable of joining two E-coniferyl alcohol molecules.

The researchers purified the individual proteins in these fractions and, to tease out their role in lignan-making, mixed the proteins, one after the other, with E-coniferyl alcohol. To no one's surprise, several of the proteins turned out to be oxidases, which linked the alcohols into the usual mixtures of isomers. But one protein seemed to play an entirely different role: On its own, it couldn't join the alcohols. But when it was added to the test tube with one of the oxidases, the phenols combined into just one isomer—the one made naturally by the plant. Lewis dubbed the protein "dirigent" from *dirigere*, Latin for align or guide, because he thinks it clasps and steers two E-coniferyl alcohols so they come together in just one way.

"[Dirigent proteins] may really be a new class of enzymes," says pharmaceutical chemist Meinhard Zenk of the University of Munich in Germany. And if they are, their impact on the chemical industry could be enormous. With dirigent proteins, chemists might be able to synthesize improved versions of drugs derived from plants or bioengineer trees with lignin that has a different stereochemistry, which might make it easier to degrade. That could make the paper-pulping process much cheaper and less polluting (although some chemists question how important stereochemistry is to the structure of lignin).

The researchers are now working to verify the protein's role in lignan-making by tracking down the gene that codes for it so they can actually make the protein, Lewis says. They're also hot on the trail of other kinds of dirigent proteins. Other researchers may well join the chase, says Dean. If so, chemists might find out that they're not so ham-handed after all.

–Jocelyn Kaiser