Sunny Side Up

Stepping out from a neighbor's shadow is not always a good thing.

Joanne Chory uses genetics to study how plants respond to changes in their environments—from predictable cycles of day and night to unwanted shade and global warming.

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JOANNE CHORY

Jeffrey Lamont Brown

IT'S A CONCEPT THAT EVERY KINDERGARTNER UNDERSTANDS AFTER watching a seed sprout roots and shoot a stem out of a paper cup, reaching toward the sun. But plant researchers have struggled to identify the molecular pathway that explains this elementary phenomenon—that plants will do anything to get some extra rays of light. Recently, HHMI investigator Joanne Chory at the Salk Institute for Biological Studies has begun to lead the way out of the shadows. ¶ By studying the interactions between plants and their environment, Chory observes how plants respond to shade as well as to changes in water, day length, and temperature. She studies *Arabidopsis*—a small flowering mustard plant that is a favorite among biologists because of its fully sequenced genome and easy-to-observe growth changes.

Chory and colleagues recently uncovered a new pathway that is activated when a plant wants to outgrow an encroaching neighbor. Understanding this chain of events, which researchers call "shade avoidance syndrome," could help scientists engineer food crops that survive in crowded fields, where plants overshadow each other.

For a plant, the consequences of shade are drastic. Desperate for sunlight and striving to outgrow its neighbors, a plant's reaction upon sensing the specific type of shade caused by other plants (plants reflect far-red light and absorb red light, so their shade is low in red light) is to grow straight up, as fast as possible. The plant directs most of its energy into stem growth, sacrificing other important activities: leaf growth, root development, seed production, and immune function.

"There's a lot of stuff that a plant gives up just so it can get up there, above its competitors," says Chory. The seedlings that have been shaded are tall, but unusually skinny with dwarfed, pale leaves.

To find out what molecules might guide this growth pattern, Yi Tao, a postdoctoral researcher in Chory's group, set up a genetic screen for mutations that would stop plants from shade-induced gangliness. They looked for plants that didn't grow in simulated shade but that grew normally under full light and in complete darkness, reasoning that abnormalities in these two settings would likely mean the plants lacked the ability to elongate. Their screen revealed mutations in a number of genes that seemed to be involved specifically in shade avoidance, and they focused on one—dubbed *sav3* (shade avoidance 3). In the shade, *sav3* mutants look like they're growing in bright light—they are shorter, darker green, and have fuller leaves than the nonmutant, or wild type, *Arabidopsis* seedlings grown in the shade.

After isolating the normal version of this gene, Tao pinpointed its protein product and began exploring its function. Realizing the protein was an enzyme that catalyzes changes to small molecules such as amino acids, Tao and Chory turned to Salk colleague, HHMI investigator Joseph P. Noel, an expert in determining the function of plant enzymes. Noel and Chory reasoned that the enzyme might be involved in the biosynthesis of auxin, a hormone other studies have hinted plays a role in shade avoidance.

Their instincts were right. A series of experiments revealed that the *sav3* plants made less auxin, and that adding auxin allowed them to shoot up in the shade. They named the enzyme after its function—TAA1, for tryptophan aminotransferase of *Arabidopsis*. The results appeared in the April 4, 2008, issue of *Cell*.

"In the shade, wild-type plants make more auxin," Chory explains. "It seems that *sav3* plants can't do that." TAA1, they found, is integral to the synthesis of auxin that's triggered by plant shade.

Studying the genes and proteins that cause shade avoidance could help plant biologists eventually create plants that don't avoid shade, she says. These plants would still need light but wouldn't overreact to just a little shade. Instead, they would be green, lush, and healthy even in crowded conditions.

"In modern agriculture, farmers sow crops very densely," she explains. "The plants are always shading each other." While healthy competition is a good thing when it comes to the natural selection of plants over time, a constant state of shade avoidance is not good because shaded plants produce fewer seeds, says Chory. "If the seed is what you're eating—like rice—there will be loss of yield."

Yield is becoming increasingly important, says Chory, noting that by 2050 the world population is projected to exceed 9 billion. "It's all about sustainability," she says. "You have to feed all these people, plus today food crops have to compete with energy crops." ■

—SARAH C.P. WILLIAMS

A DELIBERATE RESPONSE

WHILE A PLANT'S RESPONSE TO SHADE IS QUICK—it only takes an hour for changes to begin—a plant takes its time to respond to other environmental cues, and with good reason, says HHMI investigator Joanne Chory. **"IF A CLOUD COMES OVER AND YOU'RE A PLANT,** do you want to start behaving like it's night? No. If there's a lightning flash in the middle of the night do you want to start behaving like it's day? No." **IN A PAPER PUBLISHED IN FEBRUARY** in *PLoS Genetics*, Chory and colleagues revealed new information about how plants turn on different sets of genes at different times of the day and night, by slowly taking into account their environment. They found that a full 89 percent of *Arabidopsis* genes cycle in response to temperature, light, and circadian variations throughout a 24-hour cycle.