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Illuminating How Plants Adapt to Light

Studies of 141 varieties of the plant *Arabidopsis thaliana* gathered from different regions of the world indicate that genetic variation in key light-sensing proteins may explain how the plants can fine-tune their responses to light.

The research team, which included Howard Hughes Medical Institute investigator Joanne Chory along with Detlef Weigel of The Salk Institute, published its study in *Nature Genetics*.

"Tracing the source of natural variation in light sensitivity should help in understanding the molecular machinery that controls a plant's responses to light."

— Joanne Chory

Arabidopsis is a small flowering plant that is widely used by plant scientists as an experimental organism because it is easily grown, prolific, and has the smallest genome of any flowering plant. Last year, researchers announced sequencing of the entire *Arabidopsis* genome.

Chory, Weigel and their colleagues sought to understand the natural variation in light sensitivity in *Arabidopsis* by studying 141 varieties of the plant gathered from different geographic locations. In their experiments, they exposed germinating seedlings of all of the plants to the same levels of blue, red, or far-red light, as well as to white light and to total darkness. The exposure to different light wavelengths was intended to reveal variation in signaling pathways known to be sensitive to those wavelengths. The scientists also exposed seedlings to two plant hormones known to affect light-sensitive pathways.

By measuring the length of the embryonic shoot, or hypocotyl, in the plants, the scientists could quantify each plant's sensitivity to light. Hypocotyls tend to extend longer in lower light — as the plant delays full germination — so their length under standard light conditions reflects the plant's sensitivity to light.

These experiments revealed substantial variation in light sensitivity across the varieties, found Chory, Weigel and their colleagues. The experiments showed that varieties from lower latitudes, where light is more intense, tend to be less sensitive to light. Also, the researchers found differences among strains in their relative response to light of different wavelengths.

“We found that we could group the strains by how they responded to blue light or red light, or far-red light,” said Chory. The researchers compared these response patterns with those of known laboratory-induced mutants in the plant photoreceptor molecules, called phytochromes. “It was important to study these kinds of natural variations in the context of a pathway in which we understand some of the components,” said Chory. “We could have seen all this natural variation and merely described it, but we wouldn’t have been able to follow up by exploring the genetic source,” she said.

According to Weigel, tracing the genetic origin of natural variation in light sensitivity represented a golden scientific opportunity. “We do not have a very good picture of such variation, including what kinds of genes it occurs in and in what parts of the genes,” he said.

To detect genetic variation, the researchers compared the growth responses to different light conditions in the naturally varying strains to those of known laboratory-induced mutants in the receptor genes. “The idea was that if any of these natural variants looked like a laboratory mutant across the growth conditions, maybe the reason it looked like the mutant is because it is a natural variant that mimics a lab-induced mutant,” said Weigel.

The scientists found one strain of *Arabidopsis* from Le Mans, France, called LM-2, resembled a laboratory mutant with an alteration in the gene for the light-sensing molecule phytochrome A. Further analysis showed that the phytochrome A in this strain differed from the normal molecule by only a single amino acid. “If this photoreceptor is working properly, excitation by light induces a turnover of the protein. But with the LM-2 allele, we found that the protein wasn’t turned over but was accumulating, which indicated that it wasn’t signaling properly,” said Chory.

Additional studies revealed that the mutated phytochrome A in the LM-2 variant was “tuned” differently, resulting in a molecule that was 100-fold less sensitive to the far-red end of the spectrum. Also, the scientists found that the photoreceptor molecule was not producing sufficient enzymatic activity to transmit its signal to downstream signaling pathways.

“So, we concluded that the amino acid change in this protein affected its ability to transmit a signal from the chromophore domain, which is where it is excited by light, to the output to a metabolic pathway,” said Chory. The analyses showed that the mutation affected neither the light-sensing nor the enzymatic domains of the protein, but rather a “hinge” region that linked the two. To confirm whether this hinge was critical, the scientists changed the same amino acid in a related photoreceptor, called phytochrome B, and noticed a similar effect on sensitivity to light.

According to Chory and Weigel, their studies showed that tracing the source of natural variation in light sensitivity should help scientists understand the molecular machinery that controls a plant's responses to light. The studies may also offer insights into variation in other organisms. "There little known about the genetic basis of natural variation in plants, but that's pretty much true for all organisms, and certainly also true for humans," Weigel said. "In humans, these variations include susceptibility to disease and how they react differently to medications. We hope these studies will help us find general principles of genetic architecture that can apply to more complex organisms."