

Sunflowers move by the clock

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Sunflowers near the UC Davis campus in Yolo County, northern California.

Growing sunflowers face dawn in the morning and swing west during the day. Sunflowers that track the sun in this way have more leaf area and biomass. Researchers at UC Davis, UC Berkeley and the University of Virginia now show that this tracking is enabled by the plant's internal circadian clock. Credit: Chris Nicolini, UC Davis

It's summertime, and the fields of Yolo County are filled with ranks of sunflowers, dutifully watching the rising sun. At the nearby University of California, Davis, plant biologists have now discovered how sunflowers use their internal circadian clock, acting on growth hormones, to follow the sun during the day as they grow.

"It's the first example of a plant's clock modulating [growth](#) in a natural environment, and having real repercussions for the plant," said Stacey Harmer, professor of plant biology at UC Davis and senior author on the paper to be published Aug. 5 in the journal *Science*.

Harmer is a molecular biologist who studies circadian clocks, usually in the lab plant *Arabidopsis*, which is distinctly smaller than a sunflower. Previously, Harmer's lab had discovered links between "clock" genes and the [plant hormone auxin](#), which regulates growth. But Harmer and her collaborator Benjamin Blackman at UC Berkeley and the University of Virginia needed an example to work on, and they found it in the sunflower.

East to West, and back

Growing sunflowers begin the day with their heads facing east, swing west through the day, and turn back to the east at night.

"The plant anticipates the timing and the direction of dawn, and to me

that looks like a reason to have a connection between the clock and the growth pathway," Harmer said. This behavior of sunflowers had been described by scientists as far back as 1898, but no one had previously thought to associate it with circadian rhythms.

Hagop Atamian, a postdoctoral researcher in Harmer's lab, in collaboration with Blackman's lab at the University of Virginia (now at UC Berkeley), carried out a series of experiments with sunflowers in the field, in pots outdoors, and in indoor growth chambers.

By staking [plants](#) so that they cannot move, or turning potted plants around daily so that they were facing the wrong way, Atamian showed that he could disrupt their ability to track the [sun](#). Following the sun provides a growth boost to the plants. Sunflowers staked so they can't move have decreased biomass and less leaf area than those that do, the researchers found.

When plants were moved into an indoor growth chamber with immobile overhead light, they continued to swing back and forth for a few days. That is the kind of behavior you would expect from a mechanism driven by an internal clock, Harmer said.

Finally, the indoor plants did start tracking "the sun" again when the apparent source of lighting was moved across the growth chamber by turning adjacent lights on and off during the day. The plants could reliably track the movement and return at night when the artificial day was close to a 24-hour cycle, but not when it was closer to 30 hours.

Clocks and two growth mechanisms

So how do the plants move their stems during the day? Atamian put ink dots on the stems and filmed them with a video camera. On a time-lapse video, he could measure the changing distance between the dots.

When plants were tracking the sun, the east side of the stem grew more rapidly than the west side, he found. At night, the west side grew faster as the stem swung the other way. The team identified a number of genes that were expressed at higher levels on the sunward side of the plant during the day, or on the other side at night.

Harmer said that there appear to be two growth mechanisms at work in the sunflower stem. The first sets a basic rate of growth for the plant, based on available light. The second, controlled by the circadian clock and influenced by the direction of light, causes the stem to grow more on one side than another, and therefore sway east to west during the day.

As the sunflower matures and the flower opens up, overall growth slows down and the plants stop moving during the day and settle down facing east. This seems to be because, as overall growth slows down, the [circadian clock](#) ensures that the plant reacts more strongly to light early in the morning than in the afternoon or evening, so it gradually stops moving westwards during the day.

Why face the sun?

Why do mature sunflowers face east, anyway? The researchers grew sunflowers in pots in the field, and rotated some of them to the west. By measuring the flowers with an infrared camera, they found that the east-facing sunflowers heated up more quickly in the morning - and also attracted five times as many pollinating insects. Heating up west-facing flowers with a portable heater brought more pollinators back to the flowers.

"Bees like warm flowers," Harmer said.

The research was funded by the National Science Foundation's Plant Genome Research Program.

"Just like people, plants rely on the daily rhythms of day and night to function," said the program's director, Anne Sylvester. "Sunflowers, like solar panel arrays, follow the sun from east to west. These researchers tap into information in the sunflower genome to understand how and why sunflowers track the sun."

More information: "Circadian regulation of sunflower heliotropism, floral orientation, and pollinator visits," *Science*
[science.sciencemag.org/cgi/doi ... 1126/science.aaf9793](https://science.sciencemag.org/cgi/doi/10.1126/science.aaf9793)

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