

# Researchers trace path of light in photosynthesis

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Pictured is the ultrafast optical setup in the Laboratory for Ultrafast Multidimensional Optical Spectroscopy at the University of Michigan. Credit: Yin Song and Rong Duan

Three billion years ago, light first zipped through chlorophyll within tiny reaction centers, the first step plants and photosynthetic bacteria take to convert light into food.

Heliobacteria, a type of bacteria that uses photosynthesis to generate

energy, has reaction centers thought to be similar to those of the common ancestors for all photosynthetic organisms. Now, a University of Michigan team has determined the first steps in converting [light](#) into energy for this bacterium.

"Our study highlights the different ways in which nature has made use of the basic reaction center architecture that emerged over 3 billion years ago," said lead author and U-M physicist Jennifer Ogilvie. "We want to ultimately understand how energy moves through the system and ends up creating what we call the 'charge-separated state.' This state is the battery that drives the engine of photosynthesis."

laser 2.jpegPhotosynthetic organisms contain "antenna" proteins that are packed with [pigment molecules](#) to harvest photons. The collected energy is then directed to "reaction centers" that power the initial steps that convert [light energy](#) into food for the organism. These initial steps happen on incredibly fast timescales—femtoseconds, or one millionth of one billionth of a second. During the blink of an eye, this conversion happens many quadrillions of times.

Researchers are interested in understanding how this transformation takes place. It gives us a better understanding of how plants and photosynthetic organisms convert light into nourishing energy. It also gives researchers a better understanding of how photovoltaics work—and the basis for understanding how to build them better.

When light hits a photosynthetic organism, pigments within the antenna gather photons and direct the energy toward the reaction center. In the reaction center, the energy bumps an electron to a higher energy level, from which it moves to a new location, leaving behind a positive charge. This is called a charge separation. This process happens differently based on the structure of the reaction center in which it occurs.

In the reaction centers of plants and most [photosynthetic organisms](#), the pigments that orchestrate charge separation absorb similar colors of light, making it difficult to visualize charge separation. Using the heliobacteria, the researchers identified which pigments initially donate the electron after they're excited by a photon, and which pigments accept the electron.

Heliobacteria is a good model to examine, Ogilvie said, because their reaction centers have a mixture of chlorophyll and bacteriochlorophyll, which means that these different pigments absorb different colors of lights. For example, she said, imagine trying to follow a person in a crowd—but everyone is wearing blue jackets, you're watching from a distance and you can only take snapshots of the person moving through the crowd.

"But if the person you were watching was wearing a red jacket, you could follow them much more easily. This system is kind of like that: It has distinct markers," said Ogilvie, professor of physics, biophysics, and macromolecular science and engineering

Previously, heliobacteria were difficult to understand because its reaction center structure was unknown. The structure of membrane proteins like reaction centers are notoriously difficult to determine, but Ogilvie's co-author, Arizona State University biochemist Kevin Redding, developed a way to resolve the crystal structure of these reaction centers.

To probe reaction centers in heliobacteria, Ogilvie's team uses a type of ultrafast spectroscopy called multidimensional electronic spectroscopy, implemented in Ogilvie's lab by lead author and postdoctoral fellow Yin Song. The team aims a sequence of carefully timed, very [short laser pulses](#) at a sample of bacteria. The shorter the laser pulse, the broader light spectrum it can excite.

Each time the laser pulse hits the sample, the light excites the reaction centers within. The researchers vary the time delay between the pulses, and then record how each of those pulses interacts with the sample.

When pulses hit the sample, its electrons are excited to a higher energy level. The pigments in the sample absorb specific wavelengths of light from the laser—specific colors—and the colors that are absorbed give the researchers information about the energy level structure of the system and how energy flows through it.

"That's an important role of spectroscopy: When we just look at the structure of something, it's not always obvious how it works.

Spectroscopy allows us to follow a structure as it's functioning, as the energy is being absorbed and making its way through those first energy conversion steps," Ogilvie said. "Because the energies are quite distinct in this type of reaction center, we can really get an unambiguous look at where the energy is going."

Getting a clearer picture of this [energy](#) transport and charge separation allows the researchers to develop more accurate theories about how the process works in other reaction centers.

"In plants and bacteria, it's thought that the charge separation mechanism is different," Ogilvie said. "The dream is to be able to take a structure and, if our theories are good enough, we should be able to predict how it works and what will happen in other structures—and rule out mechanisms that are incorrect."

**More information:** Yin Song et al. Excitonic structure and charge separation in the heliobacterial reaction center probed by multispectral multidimensional spectroscopy, *Nature Communications* (2021). [DOI: 10.1038/s41467-021-23060-9](https://doi.org/10.1038/s41467-021-23060-9)

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