Taming electrons with bacteria parts

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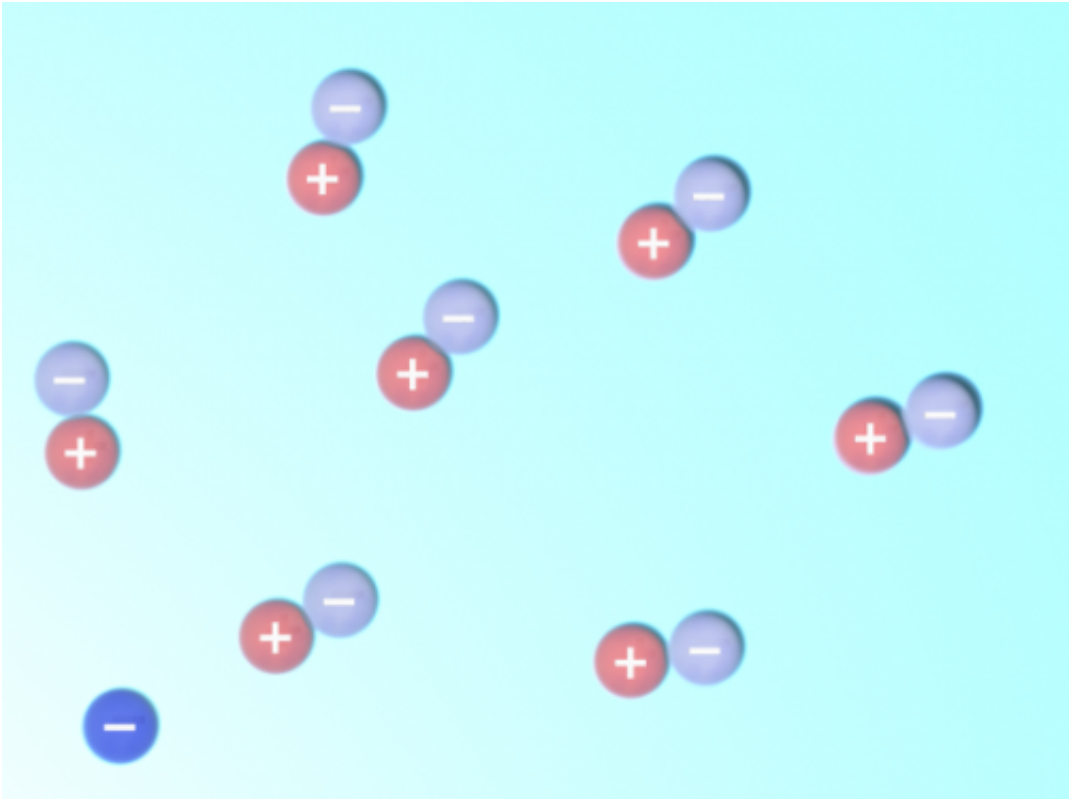

A schematic depiction of virtual electron–positron pairs appearing at random near an electron (at lower left). Credit: RJHall/Wikipedia

Electrons are tough to pin down in biology. Learning how to harness electrons is no fool's errand because, when electrons move, they are the electricity that powers life.

Electrons power the production of fuel and medicine. Electron

movement is behind photosynthesis, our main source of food and combustion. Moving electrons are the definition of an electric current, which is why you can read this story.

In a new study, scientists at the MSU-DOE Plant Research Laboratory report a new synthetic system that could guide electron transfer over long distances. The new system is made up of two components plucked from nature. One is a protein from bacteria and the other a molecule found in our blood.

Nature has figured out how to tame electrons. The trick is to split up their journeys into short pit stops that are easier to manage. Electrons then hop between stops as they are guided towards some final destination.

One of these natural pit stops is the heme, a molecule that contains iron. It is what gives our blood its color and it is found in many other biological molecules.

"In nature, multiple hemes have to be closely positioned and angled precisely to allow for fast electron hops. The hemes are fixed in place by attaching to protein structures," said Jingcheng Huang, a former graduate student in the lab of Danny Ducat. "Otherwise, if the distances between hemes become too large, an electron will hop out of control. It is lost."

Since hemes are found in almost all living beings, they can associate with many types of proteins. The science team used the protein BMC-H, from bacteria, to build their artificial electron pit stops.

The team identified four possible locations the heme can dock into. Specifically, the alpha helical region was the most promising host area.

"We didn't have to modify the BMC-H protein much," Huang said.

"With only three amino acid substitutions, we can get a heme binding tightly to it. Because the modification is minimal, the protein's shape and functions remain intact."

The scientists have managed to produce these larger structures with hemes attached to them. Moreover, they can produce them inside of bacteria cells, which saves resources.

"We'd like to optimize this system into a functional nanowire," Huang said. "Someday, it could funnel electrons to power the production of new medicines, or biofuels or electronic devices made of biogoo; the possibilities are endless."

"The exciting part is that we played with what nature has already figured out: We took a protein that self-assembles into large structures but doesn't bind hemes and functionalized it so that it hosts them," Huang said. "Otherwise, if we had created a system from scratch, we would have added extra layers of difficulty. That's the essence of synthetic biology, taking natural ingredients and re-configuring them in new, unseen ways."

The study is published in *Frontiers in Bioengineering and Biotechnology*.

More information: Jingcheng Huang et al. Functionalization of Bacterial Microcompartment Shell Proteins With Covalently Attached Heme, *Frontiers in Bioengineering and Biotechnology* (2020). DOI: 10.3389/fbioe.2019.00432

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