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Researchers find new ways to understand bacteria's 'thinking'

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It's not thinking in the way humans, dogs or even birds think, but new findings from researchers at the University of Tennessee, Knoxville, show that bacteria are more capable of complex decision-making than previously known.

The discovery sets a landmark in research to understand the way bacteria are able to respond and adapt to changes in their environment, a trait shared by nearly all living things, and it could lead to innovations in fields from medicine to agriculture.

In the long-term, the researchers think that scientists will be able to take the findings, published online this week in the Proceedings of the National Academy of Sciences, and use them to tailor medicines in new ways to fight harmful bacteria or to find enhanced ways to use bacteria in agricultural or other applications.

Biology typically looks at the common bacteria Escherichia coli as the model for bacteria's ability to move actively and independently, but Gladys Alexandre, an associate professor of biochemistry, cellular and molecular biology at UT Knoxville, decided to look at the more complex soil bacterium, Azospirillum brasilense.

"As bacteria's ability to make decisions goes, E. coli is kind of dumb, which makes it easy for researchers to study sensing and information processing -- essentially, decision making -- in this bacterium," says Alexandre.

It helps to understand the way that bacteria "think". Their cells contain a number of receptors, and each one affects a certain behavior or trait in the bacteria, for example where to move, how to function, even whether to become virulent. The advent of genetic sequencing means we know more about how many receptors bacteria have, and the more receptors, the more ways a bacterium has to sense its surroundings.

E. coli has only five receptors that direct its decision-making process about movement, while Azospirillum brasilense has 48, making it comparatively much "smarter" in its ability to detect changes in its environments and as a result, to make complex decisions regarding where to move.

What scientists have not known and have been unable to study until now is how the individual receptors, by sensing their environment, directly affect the bacteria's behavior and ability to adapt to their environment. Alexandre's study is one of the first to isolate and study a receptor in this way.

She and her colleagues focused on a receptor they suspected was related to the way bacteria convert nitrogen gas from the atmosphere into a form -- ammonium -- that can be used by all organisms. This ability is called nitrogen fixation and while it is uniquely found in bacteria, it is critically important to all living organisms, as it is the only way nitrogen can eventually be incorporated into building blocks of cells.

The process is carried out by an enzyme which is damaged in the presence of high concentrations of oxygen, which presents a dilemma for the bacterium, as the energy needed for the process is usually acquired in the presence of oxygen.

When Alexandre and her team created mutant versions of the bacteria without the receptor, the mutant bacteria were unable to detect where the right position in oxygen concentration was, affecting the nitrogen fixation reaction. In other words, the mutant bacteria were somewhat "blind" and could not detect the right position, showing them their hunch was correct about the receptor's purpose. But their curiosity expanded: if they were able to uncover the receptor's purpose, would they be able to figure out exactly how it functioned?

For that, they enlisted the help of UT-Oak Ridge National Laboratory distinguished scientist Igor Jouline, an expert in carrying out complex computations of biological systems, such as the one governing the receptor at the heart of Alexandre's research. Working with Alexandre's data, Jouline was able to generate a model of the receptor's structure and compare it to other structures on a nearly atom-by-atom basis.

This enabled them to predict which one of the more than 100 amino acids in the sensory part of the receptor is responsible for sensing the precise oxygen concentration that this bacterium needs for nitrogen fixation. It's a process that, using normal genetic techniques, would have taken a substantial commitment of hours and resources, but was made simpler and less labor-intensive by using computing.

Alexandre hopes that other scientists and researchers can use a similar technique to look at receptor sites on other bacteria of interest. She noted that the ability to work with Jouline and with the resources available through UT Knoxville's partnership with ORNL was key to her discovery.

"Partnering with Igor provided us great insight," said Alexandre. "We would not have been able to fully understand how this receptor works without him."

Alexandre says there's good long-term potential for the knowledge gained in the study.

"We see now that bacteria are, in their way, big thinkers, and by knowing how they 'feel' about the environment around them, we can look at new and different ways to work with them."

More information: The paper, titled "A PAS-domain containing chemoreceptor couples dynamic changes in metabolism and chemotaxis," is published online this week in the Proceedings of the National Academy of Sciences.

Provided by University of Tennessee at Knoxville