ELECTRIC SIGNALS HELP IMMUNE CELLS FIND THEIR WAY

NEW PURDUE RESEARCH CO-LED BY SCHOLARS IN VETERINARY MEDICINE AND BIOLOGICAL SCIENCES UNCOVERS CLUES TO IMMUNE CELL NAVIGATION

By Alisha Willett

The body's immune system is constantly on patrol, deploying billions of specialized cells to detect and destroy harmful invaders. Among the first to respond are neutrophils — fast-moving white blood cells that rush to sites of infection or injury. But how do these tiny first responders know where to go?

A new study led by Purdue University researchers reveals that electrical signals across a cell's membrane — a form of bioelectricity — play a critical role in how immune cells navigate. The team discovered that an ion channel called Kir7.1 acts as a gatekeeper, controlling the flow of potassium ions and allowing neutrophils to sense direction and move efficiently toward chemical cues in their environment. The research, published under the title "Inwardly rectifying potassium channels promote directional sensing during neutrophil chemotaxis," was co-led by Qing Deng, professor of biological sciences, and GuangJun Zhang, John T. and Winifred M. Hayward Professor of Genetic Research, Genetic Epidemiology and Comparative Medicine. Their laboratories are based in Purdue's College of Science and College of Veterinary Medicine, respectively.

A collaborative discovery

The project brought together expertise from across Purdue, including:

- Qing Deng, Department of Biological Sciences – co–senior author who co-led the project and oversaw experiments on neutrophil migration.
- GuangJun Zhang, Department of Comparative Pathobiology – co–senior author who co-initiated the study and co-supervised the research.
- Krishna Jayant, Weldon School of Biomedical Engineering and Purdue Institute for Integrative Neuroscience – contributed to membrane voltage quantification.
- Chongli Yuan, Davidson School of Chemical Engineering – contributed to quantitative membrane voltage analyses.
- Alexander Chubykin, Department of Biological Sciences and Purdue Autism Research Center – provided expertise in neural bioelectricity and electrophysiology.
- Christopher J. Staiger, Departments of Biological Sciences and Botany and Plant Pathology – developed the photoactivation techniques used in the study.

Together, these groups combined cell biology, engineering, and neuroscience to uncover how electrical activity within immune cells drives their movement — a discovery made possible through Purdue's highly collaborative research environment.

The electric compass inside immune cells

Every cell in the body maintains a voltage difference across its outer membrane, caused by the uneven distribution of charged particles like potassium and sodium. This voltage — known as the membrane potential — acts like an internal electric field that can influence how a cell behaves.

In neurons, for example, electrical impulses control communication and reflexes. The Purdue team found that neutrophils, although not nerve cells, use a similar electrical system to guide their movement.

"When a neutrophil is at rest, its membrane voltage is suppressed," Deng explained. "But when the immune system calls it into action, the voltage changes — the front of the cell becomes more excited while the back becomes more inhibited. That electrical difference helps the cell know which direction to move."

In other words, Kir7.1 helps keep the cell in a "ready but restrained" state. When a signal from damaged tissue or a pathogen appears, this electrical balance shifts, allowing the cell to form a leading edge and move toward the target.

Seeing electricity in motion

Using advanced imaging and photoactivation techniques developed in the Staiger Lab, researchers were able to visualize and manipulate the electrical potential across individual immune cells. When they artificially changed the voltage in specific regions of a cell, they could direct where new protrusions formed — effectively steering the cell with light. "It s like watching an immune cell think." said Zhang. "By controlling its electrical state, we could actually influence the direction it chose to move."

The researchers also demonstrated that when the cells were made too electrically quiet — overly hyperpolarized — they stalled, unable to move at all. These findings show that maintaining a precise electrical balance is essential for effective immune response.