PRESS RELEASE

Self-propulsion or slow diffusion: how bacteria, cells, and colloids respond to stimuli

One enables them to quickly leave an environment; the other helps them move toward where they are needed. In microorganisms, as well as in artificial structures, these are the movements triggered in response to incoming and outgoing signals. This is the finding of a new SISSA study published in *Physical Review Letters*.

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What physical processes govern the movement of microscopic structures capable of interacting with their environment? The answer lies in two mechanisms: self-propulsion, to escape unfavorable locations, and slow diffusion, to move toward more advantageous ones. This is the finding of scientists Jacopo Romano and Andrea Gambassi from SISSA-Scuola Internazionale Superiore di Studi Avanzanti in their new study published in Physical Review Letters.
In their work, the researchers combined computer simulations with mathematical calculations, taking inspiration from nature. It is well known that feedback-driven motion underlies the behavior of various microorganisms, which analyze

incoming and outgoing signals and adapt their direction of movement accordingly.
The study reproduces the physical behavior of natural and synthetic agents in two distinct scenarios: when a specific destination must be avoided based on signals, and when it must instead be reached. The researchers found that in the first case, a process of “superdiffusion” occurs, with accelerated motion, while in the second case a subdiffusive process takes place, with much slower movement. These findings provide important insights for the design of “smart” particles capable of moving at the microscale, with potential applications in medicine, particularly for more efficient drug delivery.

Bacteria, cells, and artificial particles: a shared challenge

“Bacteria, cells, and artificial particles, known as colloids, may seem very different, yet they share a fundamental challenge: finding efficient ways to explore and occupy space. This is why looking at nature is so valuable, as it helps us understand underlying mechanisms and transfer them into advanced microtechnologies,” explain the authors Jacopo Romano and Andrea Gambassi.
Bacteria and other microorganisms, for example, have developed particularly elegant strategies. “By releasing and sensing chemical signals, they leave behind traces that allow them to ‘record’ where they have already been. This enables them to occupy favorable regions and avoid less suitable ones. A similar mechanism also applies to tumor cells and their spread. Our goal was to understand, from a physical perspective, what happens in the movements driven by these interactions,” the researchers add.

Simulations and calculations to explain the physics of motion

By translating these mechanisms into a synthetic context and using computer simulations and mathematical models, the scientists studied the behavior of moving agents. The traces left behind act like road signs: they can attract micro-agents toward a specific destination or, conversely, push them away.
The researchers explain: “We found that agents avoiding their own chemical trails move in a surprisingly unusual way: instead of being slowed down by friction, they experience negative resistance that accelerates their motion, leading to a form of self-propulsion. The resulting dynamics spread faster than normal random motion, a phenomenon known as superdiffusion. By contrast, agents attracted to their own trails tend to remain near their point of origin, producing a much slower, subdiffusive dynamic.”

Smart particles for improved drug delivery

“Overall, these results show how self-generated chemical signals can profoundly influence motion, offering new insights into biological systems and potentially inspiring the design of smart, self-guiding particles,” Romano and Gambassi conclude.
“In the long term, the idea is to design engineered agents that, thanks to their chemical structure, can interact with their environment. These particles could act as ‘cargo,’ transporting specific molecules, such as drugs, to their targets. This could improve the efficiency of therapies, allowing them to remain longer in targeted areas of the body.”

USEFUL LINKS
The original paper

IMAGE
Crediti: Luke Besley on Unsplash

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