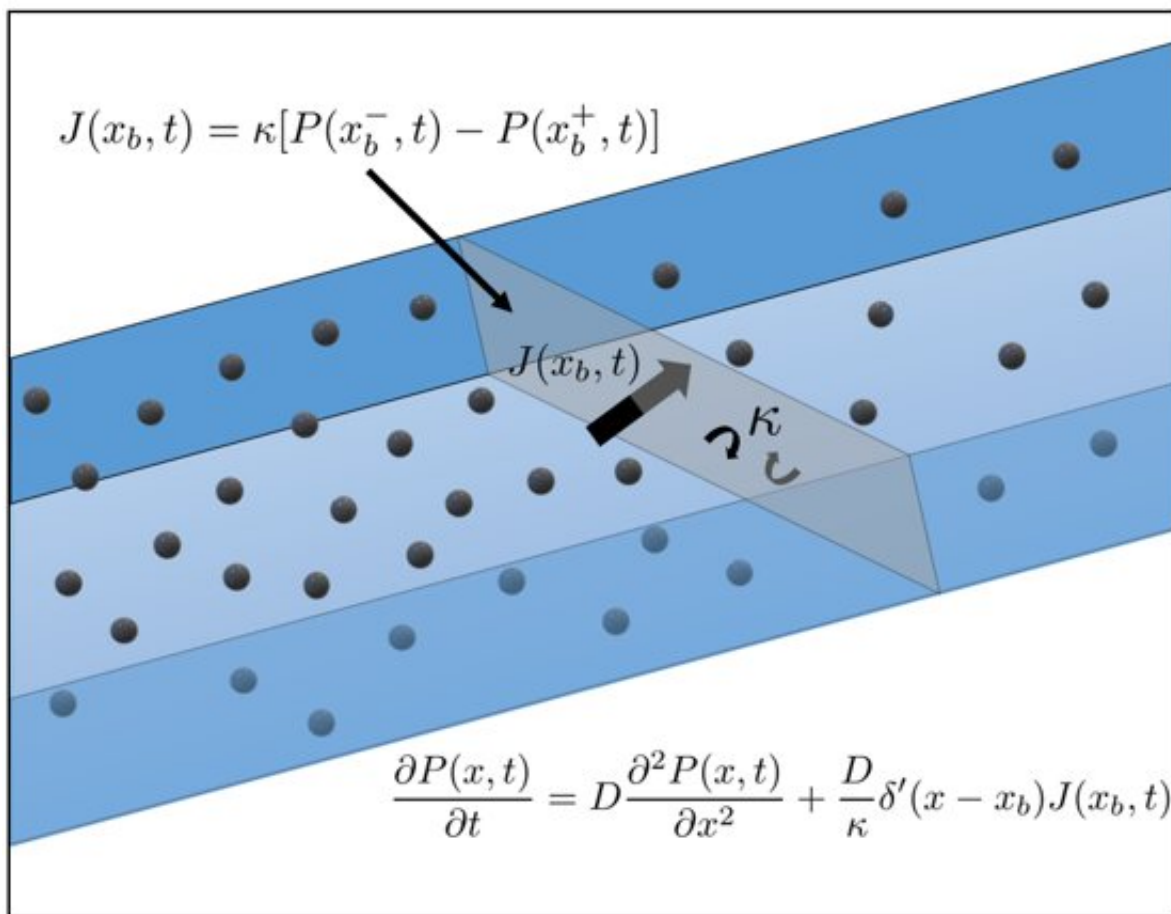# Pioneering mathematical formula paves way for exciting advances in health, energy, and food industry

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A groundbreaking new equation has been developed to model diffusive movement through permeable material exactly for the very first time. Credit: University of Bristol

A groundbreaking mathematical equation that could transform medical procedures, natural gas extraction, and plastic packaging production in the future has been discovered.

The new equation, developed by scientists at the University of Bristol, indicates that diffusive movement through permeable material can be modeled exactly for the very first time. It comes a century after world-leading physicists Albert Einstein and Marian von Smoluchowski derived the first diffusion equation, and marks important progress in representing motion for a wide range of entities from microscopic particles and natural organisms to man-made devices.

Until now, scientists looking at particle motion through porous materials, such as biological tissues, polymers, various rocks and sponges have had to rely on approximations or incomplete perspectives.

The findings, published today in the journal *Physical Review Research*, provide a novel technique that presents exciting opportunities in a diverse range of settings including health, energy, and the food industry.

Lead author Toby Kay, who is completing a Ph.D. in Engineering Mathematics, said, "This marks a fundamental step forward since Einstein and Smoluchowski's studies on diffusion. It revolutionizes the modeling of diffusing entities through complex media of all scales, from cellular components and geological compounds to environmental habitats.

"Previously, mathematical attempts to represent movement through environments scattered with objects that hinder motion, known as permeable barriers, have been limited. By solving this problem, we are paving the way for exciting advances in many different sectors because permeable barriers are routinely encountered by animals, cellular organisms and humans."

Creativity in mathematics takes different forms and one of these is the connection between different levels of description of a phenomenon. In this instance, by representing random motion in a microscopic fashion and then subsequently zooming out to describe the process macroscopically, it was possible to find the new equation.

Further research is needed to apply this mathematical tool to experimental applications, which could improve products and services. For example, being able to model accurately the diffusion of water molecules through biological tissue will advance the interpretation of diffusion-weighted MRI (Magnetic Resonance Imaging) readings. It could also offer more accurate representation of air spreading through food packaging materials, helping to determine shelf life and contamination risk. In addition, quantifying the behavior of foraging animals interacting with macroscopic barriers, such as fences and roads, could provide better predictions on the consequence of climate change for conservation purposes.

The use of geolocators, mobile phones, and other sensors has seen the tracking revolution generate movement data of ever-increasing quantity and quality over the past 20 years. This has highlighted the need for more sophisticated modeling tools to represent the movement of wide-ranging entities in their environment, from natural organisms to man-made devices.

Senior author Dr. Luca Giuggioli, Associate Professor in Complexity Sciences at the University of Bristol, said, "This new fundamental equation is another example of the importance of constructing tools and techniques to represent diffusion when space is heterogeneous; that is, when the underlying environment changes from location to location.

"It builds on another long-awaited resolution in 2020 of a mathematical conundrum to describe random movement in confined space. This latest

discovery is a further significant step forward in improving our understanding of motion in all its shapes and forms—collectively termed the mathematics of movement—which has many exciting potential applications."

More information: Toby Kay and Luca Giuggioli, Diffusion through permeable interfaces: Fundamental equations and their application to first-passage and local time statistics, *Physical Review Research* (2022). journals.aps.org/prresearch/ac … 9165d2cc3a57a416bdf4

Provided by University of Bristol