Microfluidic study of chemotactic decision making in swimming microorganisms

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The natural microenvironment of microorganisms is often a heterogeneous landscape of different substrates including nutrient patches and unfavorable chemicals. Motile microorganisms such as bacteria can exploit and migrate toward nutrients or flee from unfavorable environments through a behavior called chemotaxis. Therefore the life of a microbe is a sequence of decisions based on chemical cues in the environment. Much is now known about chemotaxis, yet it remains unclear how variable chemotaxis is within a population and whether certain cells are superior to others in terms of chemotactic abilities.

Borrowing from tools in macro-ecology and exploiting modern microfabrication methods, we have fabricated an iterative microfluidic T-maze in which a population of microorganisms is faced with a series of consecutive decisions, to understand their directional decision performance. We used video microscopy and image analysis to capture the trajectories of thousands of bacteria and monitor their decision performance, where each decision consists in migration up or down the gradient of a chemoattractant at a junction of the T-maze. This microfluidic technique provides detailed statistics at both the single-cell and population levels, while simultaneously sorting cells based on their chemotactic ability. We demonstrate that this microfluidic device allows us to sort the better decision-makers in the population when some subpopulation responds with a different sensitivity level to the chemoattractant through the maze. This approach can be powerful in a broad range of environmental, medical and industrial contexts and is applicable to the design of cell sorters for other types of chemotactic cells such as spermatozoa and phytoplankton.