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Mixing and transport by ciliary carpets YANG DING, University of Southern California, JANNA NAWROTH, California Institute of Technolog, MARGARET MCFALL-NGAI, University of Wisconsin, Madison, EVA KANSO, University of Southern California — Cilia are hair-like micro-structures observed on surfaces of many biological systems such as the human lungs. Cilia usually beat asymmetrically in a coordinate manner and serve for flow generation and sensing. Here, we use a 3D computational model to study the fluid transport and mixing due to the beating of an infinite array of cilia. In accord with recent experiments, we observed two distinct regions: a fluid transport region above the cilia and a fluid mixing region below the cilia tip. We examined the effect of the metachronal wave (due to phase differences between neighboring cilia) on the net flow and mixing rate. We found that the metachronal wave can enhance both transport and mixing rate of the fluid, often simultaneously. Our results suggest that the simultaneous enhancement in fluid transport and mixing is due to the enhancement in shear flow. As the flow above the cilia increases, shear rate in the fluid increases and such shear enhances stretching, which is an essential ingredient for mixing. Estimation of the time scale of the mixing indicates that, compared to diffusion, the mixing due to the cilia beat may be significant or even the dominate way of distributing molecules in some biological systems.

Yang Ding
University of Southern California

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