Dense array of elastic hairs obstructing a fluidic channel

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Dense arrays of soft hair-like structures protruding from surfaces in contact with fluids are ubiquitous in living systems. Fluid flows can easily deform these soft hairs which in turn impacts the flow properties. At the microscale, flows are often confined which exacerbates this feedback loop since the hair deformation has a strong impact on the flow geometry. Here, I investigate experimentally and theoretically pressure driven flows in laminar channels obstructed by a dense array of elastic hairs. I show that the system displays a nonlinear hydraulic resistance that I model by treating the hair bed as a deformable porous media. The porous media height and thus degree of confinement results from the deflection of individual hairs. The resulting fluid-structure interaction model is leveraged to identify the dimensionless drag force $\hat{f}_0$ controlling the elasto-viscous coupling and used to design passive flow control elements for microfluidic networks.

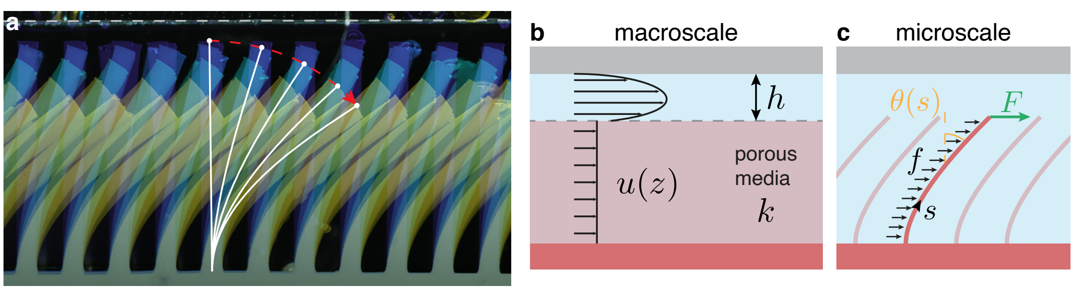

Figure 1. a Superimposition of experimental images of a portion of the channel for different flow rates. The centerline of a hair, its tip movement, and the channel ceiling are drawn for clarity. **(b)** Schematic of flow modeling at the macroscale. **(c)** Schematic of hair mechanics modeling at the microscale.

References

1. E. Jambon-Puillet, Dense array of elastic hairs obstructing a fluidic channel, *arXiv*, 2501.01875 (2025).