Bacterial locomotion near a surface: tumble or not tumble

Digital Holography enables measurements of 3D locations and displacements of microscopic objects in space. It has revolutionized microscopy recently, especially while studying multi-scale flow-structure interactions in engineering applications (wall shear stress, drag reduction, etc.) and hydrodynamic interactions of micro-organisms near a complex boundary (surface or interface) as well as the impact of flow on these processes, when other techniques such as tomography and PIVs are employed concurrently.

In this talk, I will focus on one of our research area: biophysical processes involved in hydrodynamic interactions, locomotion, migration, and sorption of micro-organisms near a complex boundary. Using novel micro-fabrication techniques, we have developed a suit of microfluidic devices containing novel complex boundaries, which includes textured substrate with heterogeneous micro-posts, chemically textured smooth surfaces, and more recently periodic micro droplets, textured porous substrate, and vertically aligned oil-water interfaces, as well as the 3D layered fluid-fluid interfaces. These devices providing exquisite control over chemical and mechanical environments allows us to conduct kernel studies over key processes governing interactions between micro-organisms and their environments, which are crucial to understand the biofilm formation, pathogenic infections, bio-fouling, and bio-remediation of oil spill. Our 3-D study on *E. coli* bacteria over a solid surface discover that near a surface tumbles are suppressed by 50% and reorientations are largely confined to a surface-parallel directions, preventing escape of bacteria from the wall. A hydrodynamic model indicates that this suppression is due to a surface-induced reduction in the hydrodynamic force responsible for the flagellar unbundling that causes tumbling. Contrarily, near a sheared surface we have found that surface induced suppression in tumble is strongly mitigated and surface normal dispersion has greatly improved with the increase of wall shear. Finally, we will present our latest study on the interactions of bacteria near a straight and curved oil-water interface, which demonstrate the differences of bacterial locomotion and sorption due to the interfacial properties. Additional results on nonlinear interactions will also be discussed. Before concluding, I will present a brief description on several exciting on-going research foci: e.g. (i) Alternative energy systems, (ii) Scalable microfabrication of drag reduction surfaces and their interactions with flows and micro-organisms, (iii) bio-inspired sensor and actuator, and, (iv) Development of several high resolution experimental techniques, etc. In the end, I will discuss briefly the future research directions and resources.