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Entomological fluid dynamics[1]

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The world of arthropods (insects and spiders) presents a number of novel fluid mechanics problems on a scale of interest to the microfluidics community. We address a number of such problems, giving particular attention to elucidating and rationalizing natural strategies for water-repellency and fluid transport on a small scale. The rough, hairy integument of water-walking arthropods is well known to be responsible for their water-repellency; we here consider its additional roles in underwater breathing and propulsion along the free surface. When submerged, many arthropods are able to survive by virtue of a thin air bubble trapped along their rough exteriors. The diffusion of dissolved oxygen from the water into the bubble allows it to function as an external lung, and enables certain species to remain underwater indefinitely. By coupling the bubble mechanics and chemistry, we develop criteria for this style of underwater breathing. We further demonstrate that the tilted flexible leg hairs of water-walking arthropods render the leg cuticle directionally anisotropic: contact lines advance most readily towards the leg tips. The dynamical role of the resulting unidirectional adhesion is explored, and yields new insight into the manner in which water-walking arthropods generate thrust, glide and leap from the free surface. Finally, we provide new rationale for the fundamental topological difference in the roughness on plants and insects, and suggest new directions for biomimetic design.

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