Understanding the Mechanisms of Self-cleaning Surfaces
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Contamination of surfaces by solids and liquids is prevalent but undesirable. Contaminants are detrimental to health: around 45% of hospital-contracted infections are linked to medical devices that were contaminated by biofilms. Contaminants also hinder technological performance: the accumulation of dust on solar panels causes a significant reduction in their efficiency (by up to 35% for 20 g/m^2 of dust). Yet, decontaminating surfaces requires time, energy, water, and chemicals. Interestingly, nature offers attractive solutions to this problem. Numerous plants (e.g., lotus, pitcher plants) and insects (e.g., cicadas) have evolved with a natural ability to remain free of solid and liquid contaminants. Liquid droplets readily roll off their so-called self-cleaning surfaces while also capturing and removing contaminant particles [1]. Self-cleaning surfaces have wide-ranging applications, from preventing biofilm formation on medical devices and dust build-up on solar panels to realising anti-icing and anti-fogging properties relevant for the automotive, aerospace and photographic industries.

In this project, we will use a combination of computer simulations [2] and experiments [3] to probe the detailed mechanisms of particle (contaminant) removal from two types of self-cleaning surfaces, the so-called superhydrophobic (SHS) and liquid infused (LIS) surfaces, for the first time. Both SHS and LIS consist of a rough solid substrate. Compared to regular surfaces, SHS have a reduced contact area with drops and particles due to the presence of air pockets between the solid roughness. The reduced contact area leads to low adhesion and friction between the surface and the drop/particle. Similarly, LIS also have low friction, but instead of containing air pockets, the substrate is infused with a slippery lubricant. Figure 1 illustrates the complex flow mechanisms involved during particle removal on LIS. Understanding these mechanisms is a highly interdisciplinary challenge that will give the PhD student a unique opportunity to develop expertise in several fields, including wetting, surface science and fluid dynamics.

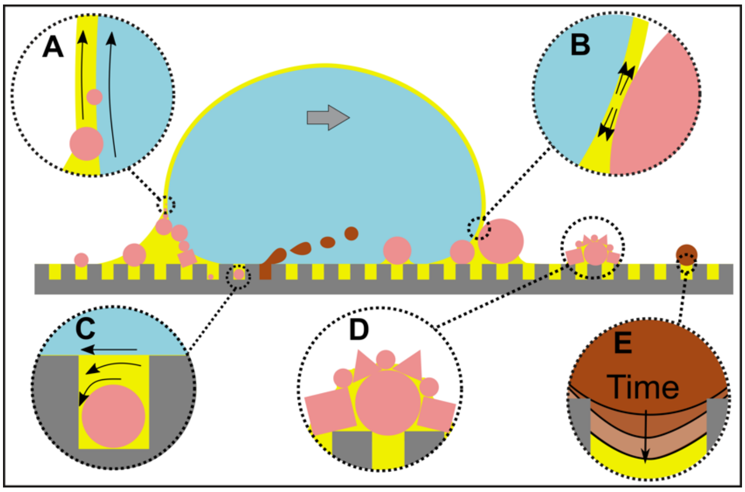

Figure 1. Lubricant-cloaked drop moving on a LIS contaminated with rigid particles (pink) and soft (brown) contaminants. The highlighted regions shows some of the physical phenomena involved, including (A) flow of particles in the lubricant cloak, (B) thin film drainage, (C) flow over trapped particles, (D) capillary imbibition of lubricant by particle aggregates, and (E) deformation of a soft contaminant over time.

References:

[1] F. Geyer et al., Science Advances **6**, eaaw9727 (2020)
[2] M. Sadullah et al., Communications Physics **3**, 166 (2020)
[3] S. Hardt and G. McHale, Annual Review Fluid Mechanics **54**, 83 (2022)