EPSRC DTP PhD Research Project

Project Title: Bioinspired micropatterned metamaterials for directional fluid transport

Primary Supervisor details:

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Location: Geoffrey Pope Building, Streatham Campus

PhD Programme: Natural Sciences

Project Description:

Controlling liquid flow on surfaces underpins a diverse range of technologies for critical 21st Century applications that **can help to optimize production processes, save resources, mitigate effects of climate change and transform medical care.** For example, capturing and directing water is essential for fog water harvesting and water-efficient crop irrigation in drought-ridden coastal regions. Engineered surfaces with precisely defined fluid transport properties have the potential to revolutionize these and other applications, such as automated drug delivery or the lubrication of manufacturing tools. Unfortunately, **a lack of scientific understanding of the principal mechanisms of surface fluid transport currently hampers the design and deployment of optimal surfaces for the microscale control of liquid flow.**

Engineers often take inspiration from nature—the natural trapping surfaces of insect-catching *Nepenthes* pitcher plants (**Fig. 1A**) show an extraordinary capacity to transport and direct water.

Within milliseconds, droplets spread against gravity along radial ridges, forming a continuous thin film on which insects "aquaplane" to their death. However, no study to-date has systematically investigated how the complex hierarchical topography (**Fig. 1B**) and the surface chemistry interact to determine wettability and the direction and speed of water spreading. This knowledge is crucial for manufacturing fluid-transporting surfaces with defined transport properties using multiple materials with different surface chemistries.

This project will design and manufacture bioinspired micropatterned surfaces (bio-metasurfaces) for directional fluid transport, optimized for different manufacturing techniques and materials. We will take a three-step approach: 1) – **Characterize the diversity of natural plant surfaces** and quantify their capacity to guide and transport water. 2) – **Develop synthetic surface replicas and artificial surfaces** using inexpensive cleanroom fabrication techniques (**Fig. 1C**). We will prioritise simplified structural design to help us **disentangle the contributions of surface chemistry and topography on wetting and water spreading**. The results will allow us to **identify the functional limits of water transport** on pitcher plant-like surfaces. 3) – **Optimize surface topography for fluid transport** within the constraints of manufacturing techniques and materials. **The culmination of the PhD will be the realisation of bioinspired fluid transporting meta-surfaces and demonstration of liquid-flow control as proof of concept**.

The project is highly interdisciplinary and combines methods from biology, physics and engineering. The successful applicant will be trained in diverse skills including bioimaging, image and video analysis, cleanroom manufacturing—such as lithographic and 3D printing techniques, micro-milling, surface replication, and oxygen plasma processing—characterisation of wettability and water spreading, surface design, and computer-based optimization The student will be based in an enthusiastic and interdisciplinary plant biomechanics research group, and will be supported by a cross-departmental supervisory team of biologists and physicists.

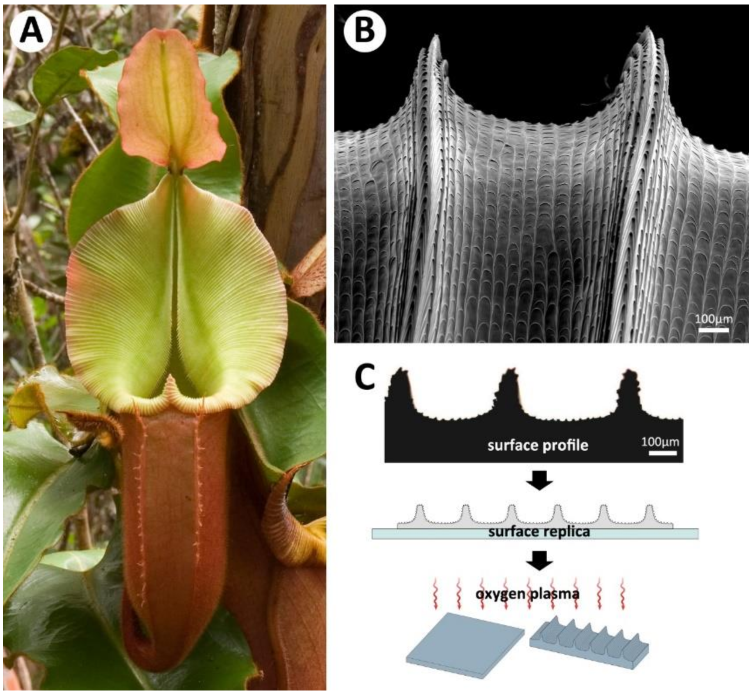

Figure 1. The collar-shaped trap rim of tropical *Nepenthes* pitcher plants (**A**) is exceptionally wettable (superhydrophilic). Guided by a complex hierarchical micro-topography of ridges, grooves and arched overhangs (**B**), water spreads and forms a thin stable film on which

insects slip and fall prey to the plant. (**C**) We will cast accurate replicas of natural surfaces and use oxygen plasma treatment to temporarily render them superhydrophilic. By comparing water spreading on treated replicas with static contact angles on simultaneously treated flat surfaces at multiple time points during the natural decay of the plasma treatment effect, we can tease apart the contributions of chemistry and topography to surface wetting and water spreading.

Project specific entry requirements:

The project suits a student with a strong background in engineering or physics and a solid foundation in quantitative and statistical data analysis. The ideal candidate will have strong computational skills, a creative approach to problem solving, and is passionate about working in an interdisciplinary and collaborative team. Curiosity and enthusiasm for working with biological systems are desirable.

Project specific enquiries:

Interested students should contact Dr Ulrike Bauer, u.bauer@exeter.ac.uk to discuss the project in detail.