Measuring the water adhesion on structures of biological air-retaining surfaces

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Introduction:

Superhydrophobic technical surfaces are of high scientific and economic interest because of their remarkable properties. However, in plants (e.g. Lotus) and animals highly efficient surfaces have been evolved [1,2]. Up to now the most attention was given to superhydrophobicity and self-cleaning properties. Nevertheless, air-retaining properties under water are of great technological, economic and ecological interest, e.g. for low friction fluid transport and drag reducing ship coatings [3].

Technical surfaces developed so far, mimicking the Lotus surface lack of their limited persistence of air retention [4]. In case of the water fern *Salvinia* we found a paradox that offers a novel mechanism to stabilize the air-layer: hydrophilic tips on otherwise superhydrophobic hairs [5]. In order to understand this stabilization effect one has to measure the water adhesion of those structures. However, those surfaces are chemically heterogeneous and topographically structured. Hence, it is demanding to determine their surface energy, i.e. the water adhesion. Here we show a novel method to determine the water adhesion on those surfaces.

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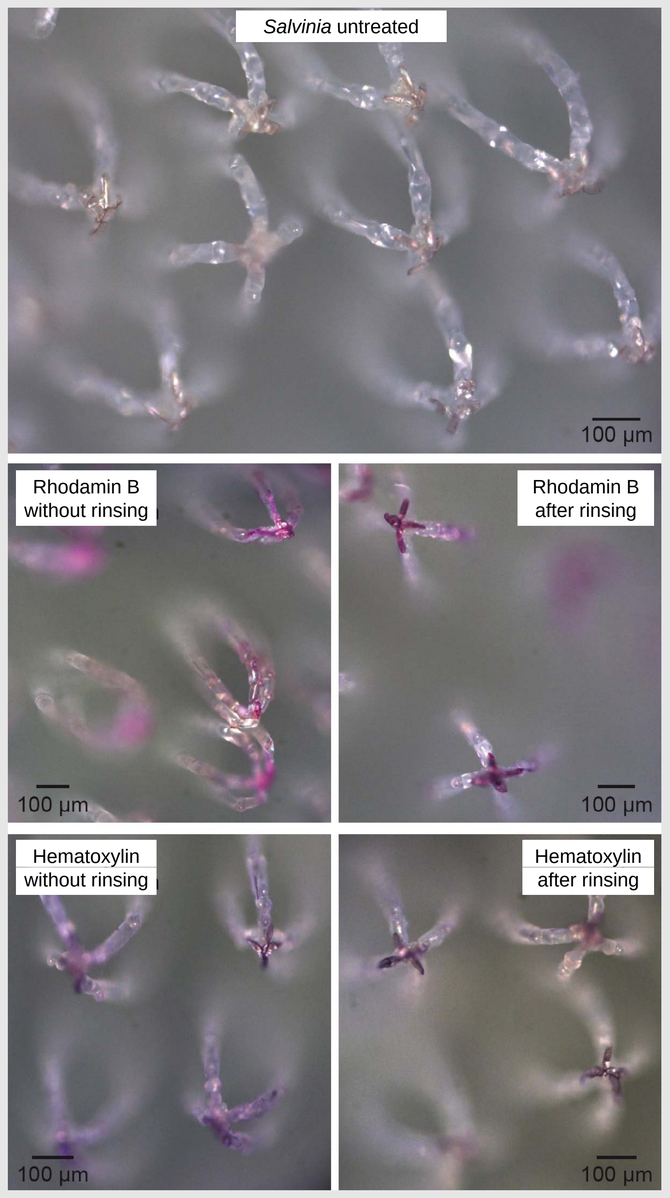
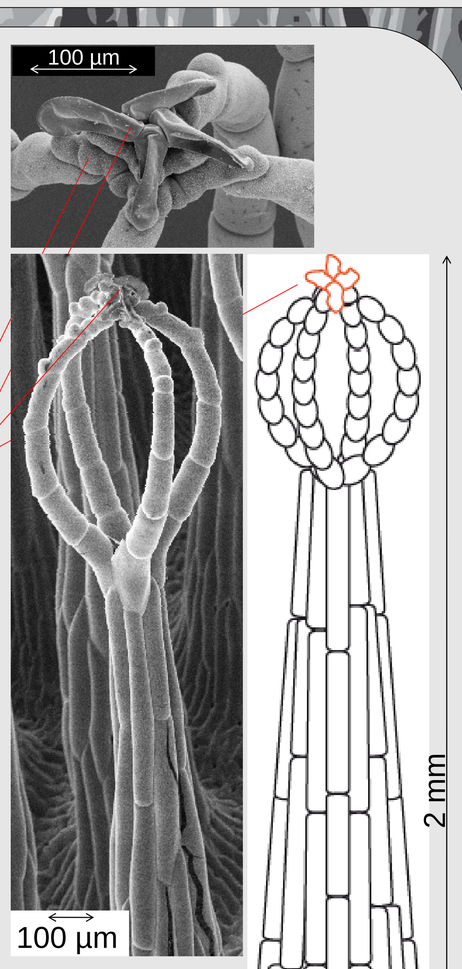
Dyeing method



- One method to distinguish between hydrophilic tips and super-hydrophobic rest is to use dyes
- For this, the leaf is dipped in dyed water and imaged afterwards
- The areas that stay in contact with the water become dyed, here parts of the branches and the tips
- In a second step we rinsed the dyed leaf with clear water and imaged it again
- While some patches of the braches are dyed before the rinsing too, only the tips stayed dyed after the rinsing

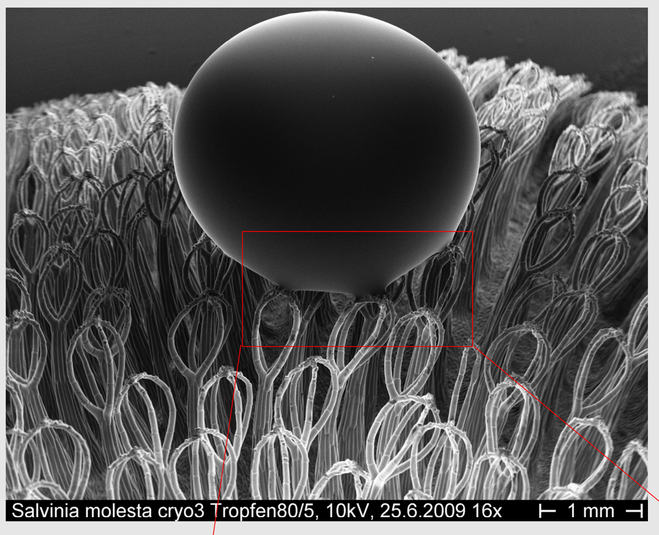
Hierarchically structured surface of *Salvinia molesta*

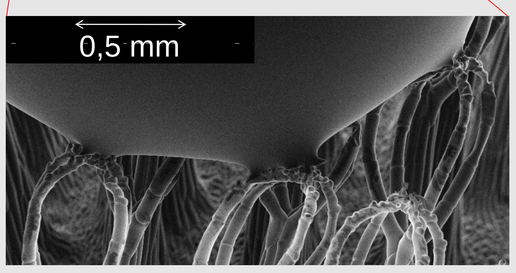
- Upper side of the floating leaves of *Salvinia molesta* is densely covered with complex multicellular hairs
- Hairs branch and form egg-beater like structures with a total height of up to 2 mm
- Super-hydrophobic surface is densely covered with nanostructured wax crystals
- Terminal cells lack wax crystals and therefore show hydrophilic behavior [5]
- Almost identical hair structures in *S. biloba and S. auriculata*



- Schematic of a *Salvinia molesta* leaf

- Low-temperature SEM of a frozen leaf with applied droplet of a water-glycerol solution

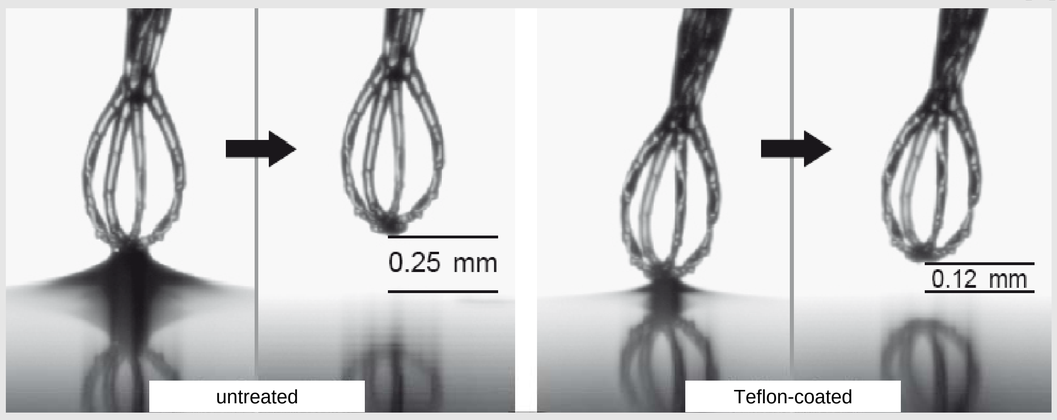




- hydrophilic meniscus between the water-glycerol droplet and the terminal cells

Method for determining the snap-off distance

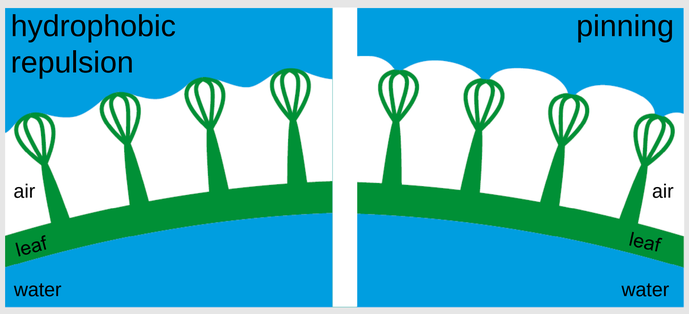
- After the snap-off of the water meniscus the distance between the tip of the specimen and the water surface was measured
- Untreated and Teflon-coated *Salvinia* hairs were dipped in water
- A factor of two was measured between untreated and Teflon-coated hairs [5]



Summary:

- A novel method to determine water adhesion of topographically structured and chemically heterogeneous structures has been established
- Hydrophilic tips lead to a pinning of the air-water-interface, hence stabilize the air-water interface
- A novel effect was found explaining air-retention under water [5]:

  the Salvinia Effect



- Schematic of the air retention by a submerged *Salvinia* leaf