Internship proposal 2025

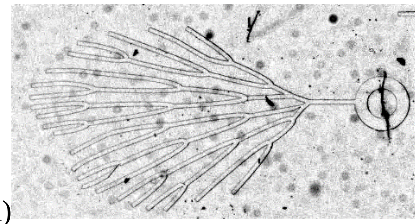
Physics of plants: Solving the mystery of embolism repair in plants after a period of drought

The context If plants do not have a heart to pump water from the soil, they have the ability to strongly decrease their internal water pressure in the leaves. There, evaporation results in very reduced pressures, down to -190 bars during dry weather! However, under those negative pressures, water can produce cavitation with the sudden nucleation of bubbles. The growth of those bubbles induces a gaseous *embolism*, progressively filling the hydraulic networks with air. This stops the water circulation and eventually leads to the death of trees.

It is not really understood how a plant can recover after such an event [1], some studies calling for a "miracle" [2], and other some studies suggesting its impossibility and the need for the growth of new tissue [3]. An emerging hypothesis focuses on solutes (salts, sugars) to trigger the nucleation and growth of new droplets, which will refill the dry parts of the hydraulic circuit.

Objectives The main objective of the internship is to understand the physics of the refilling when solutes are present. Our approach will be to manufacture biomimetic leaves made of a thin layer of transparent silicone (PDMS), in which we design microfluidic chip with channels (Fig a) where refilling can be quantified by image analysis [4]. The silicone is indeed porous to water vapour, allowing evaporation or condensation. The internship student will study the dynamics of refilling of dryed channels initially filled with salt/sugar crystals (Fig b). We will consider two strategies: (i) put the chip into a humid environment, (ii) design neighbour channels that are full of water (which occurs in plants, where sap circulates in two distinct networks of channels), and can also bring humidity. This internship is mostly experimental, but also involves modelling of the observed refilling dynamics.

Outcomes We aim at demonstrating that the physical role of solutes is essential to the survival of plants, giving cues to solve the mystery of embolism repair.

(a) 

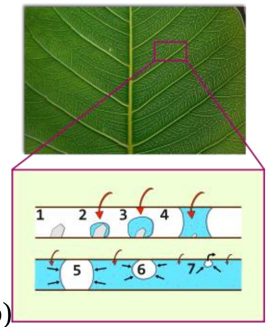
(b) 

Figure:
(a) Artificial biomimetic leaf, with microfluidic channels100 μm wide.
(b) Refilling hypothesis (drawing by L. Stamoulis)

Environnement Laboratoire Interdisciplinaire de Physique is located on the Grenoble campus, France

Supervision The student will work in a team with Philippe Marmottant and Benjamin Dollet. Note that we will collaborate on this topic with a team in Denmark (group of Kaare Jensen, Danish Technical University), specialized in the flows in plants.

[1] Brodersen, C. et al., "Maintenance of Xylem Network Transport Capacity: A Review of Embolism Repair in Vascular Plants", *Frontiers in Plant Science* 4 (2013).
[2] Holbrook, N. M. "Embolism Repair and Xylem Tension: Do We Need a Miracle?" *Plant Physiology* 7-10 (1999).
[3] Choat, B et al. "Non-Invasive Imaging Shows No Evidence of Embolism Repair after Drought in Tree Species of Two Genera" *Tree Physiology* 39, 113-21 (2019).
[4] L. Keiser, B. Dollet, P. Marmottant Embolism propagation in Adiantum leaves and in a biomimetic system with constrictions J. R. Soc. Interface 21:20240103 (2024).

Contact Philippe Marmottant, Mél: philippe.marmottant@univ-grenoble-alpes.fr , page web
Laboratoire Interdisciplinaire de Physique (LIPhy), CNRS/Université Grenoble Alpes, Campus de Grenoble