

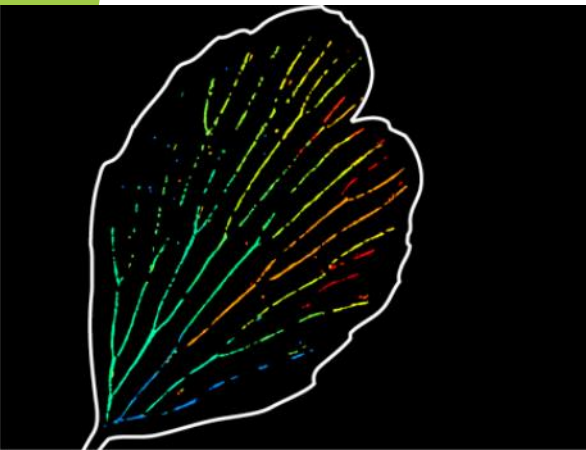
Biomimetic leaves to study embolism

Complex Day
7th February 2023

**F.X. Gauci^a, L. Keiser^a, C. Cohen^a, A. Vigna-Brummer^a,
B. Dollet^b, P. Marmottant^b and X. Noblin^a**

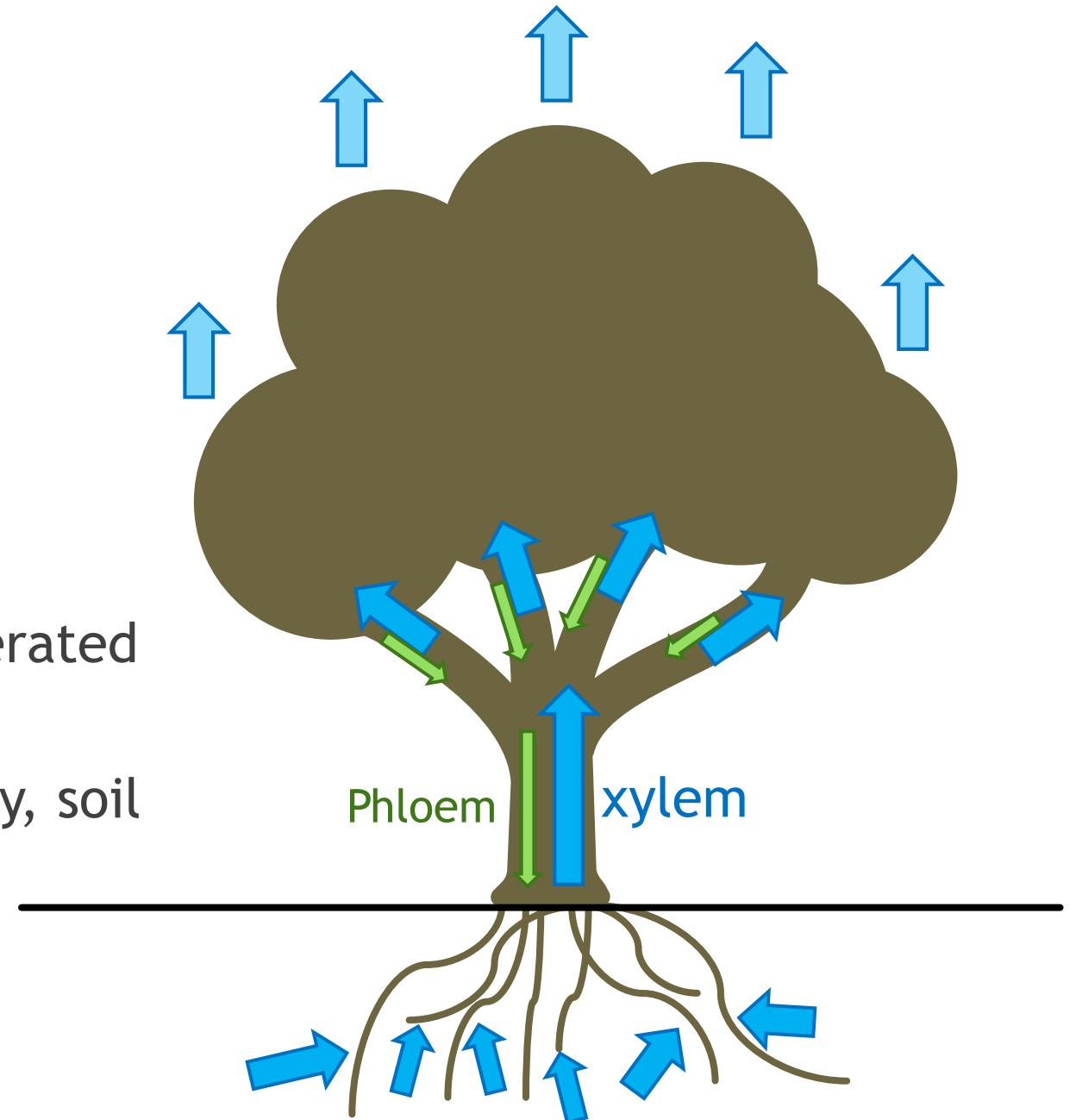
^a Université Côte d'Azur, CNRS UMR 7010, Institut de Physique de Nice (INPHYNI).

^b Université Grenoble Alpes, CNRS UMR 5588, Laboratoire Interdisciplinaire de Physique (LIPHY).



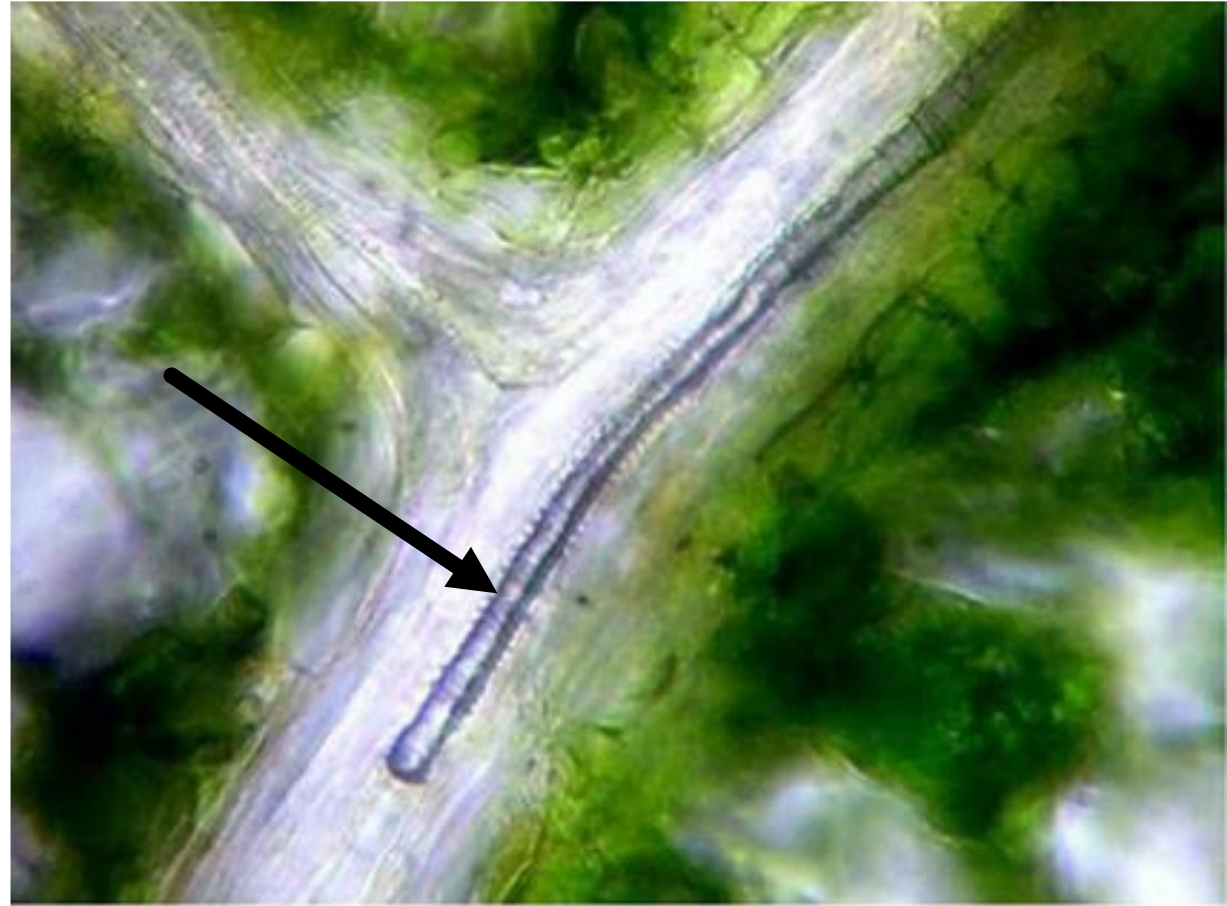
How does the sap climb from roots to leaves?

- ▶ The roots absorb water in soil
- ▶ Water is pulled to leaves by evapotranspiration
- ▶ An ascending water column is generated in the xylem
- ▶ Negative pressure (gravity, viscosity, soil effect)



Embolism in plants

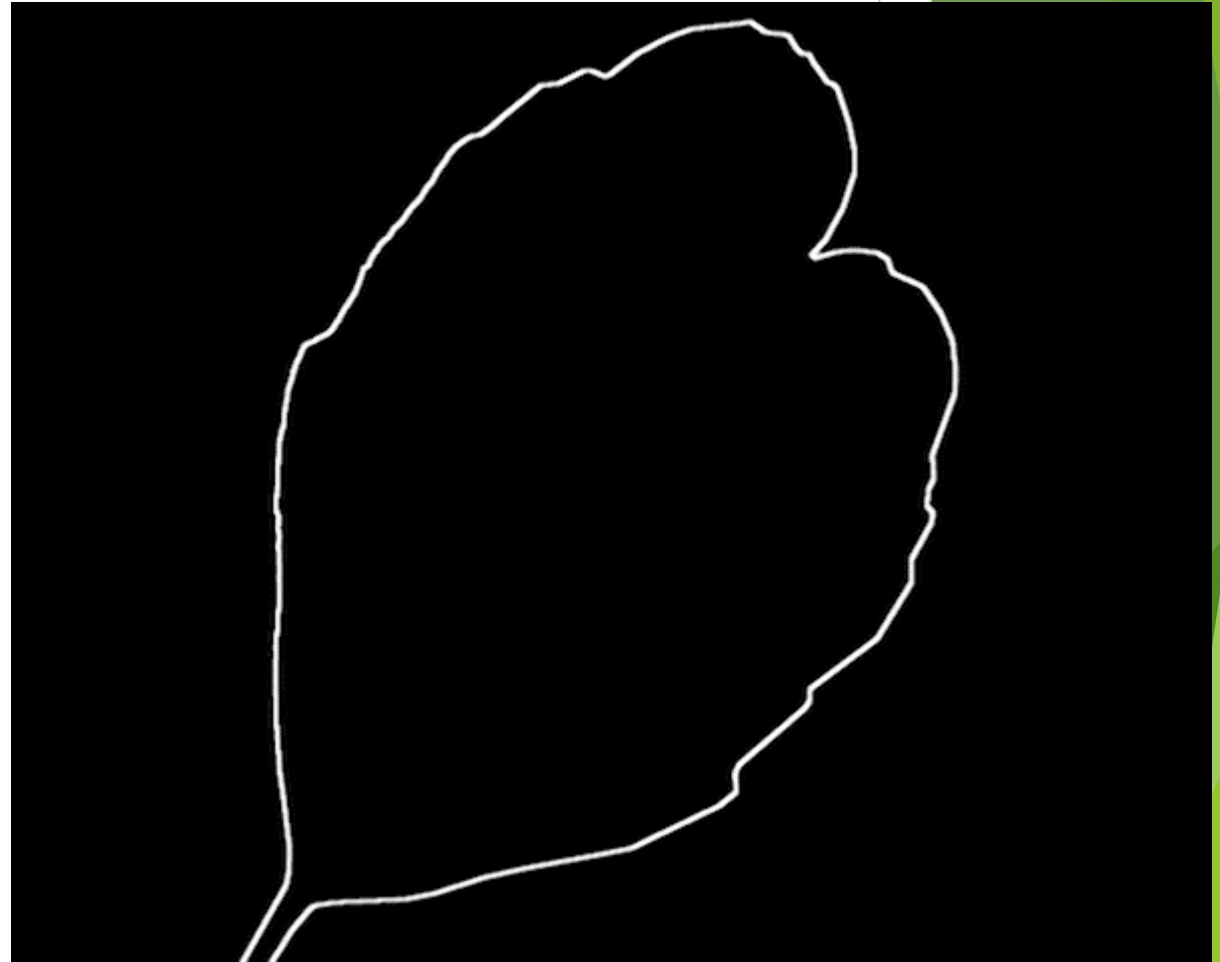
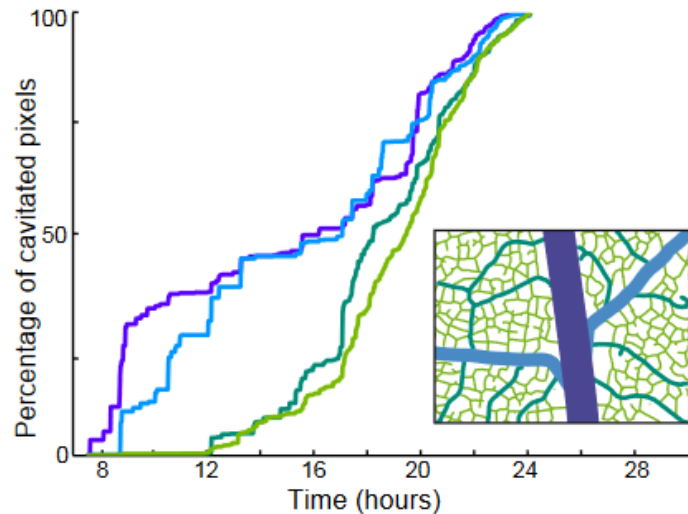
- ▶ Bubble generated by cavitation or air-seeding



H. Cochard, INRAE, PIAF

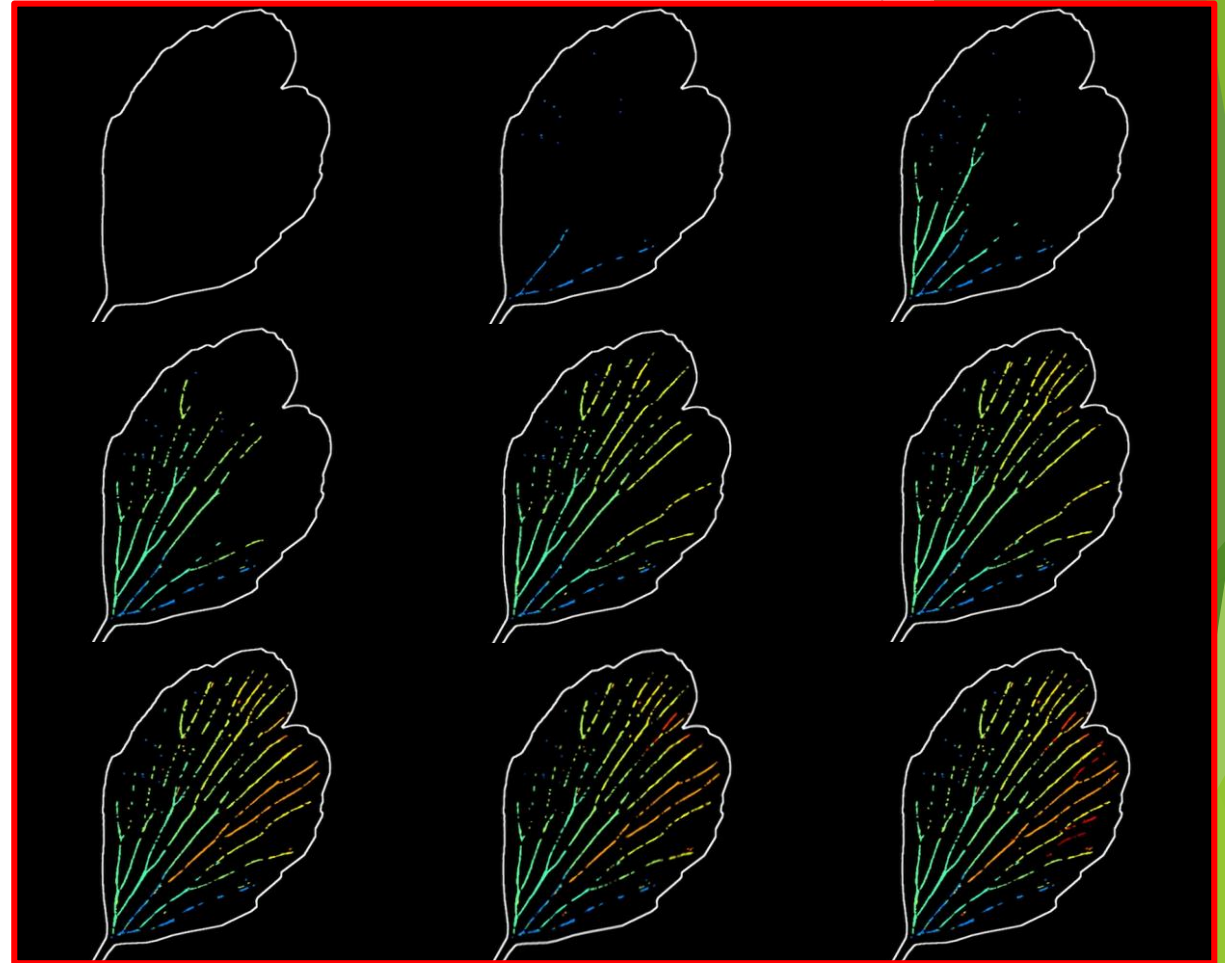
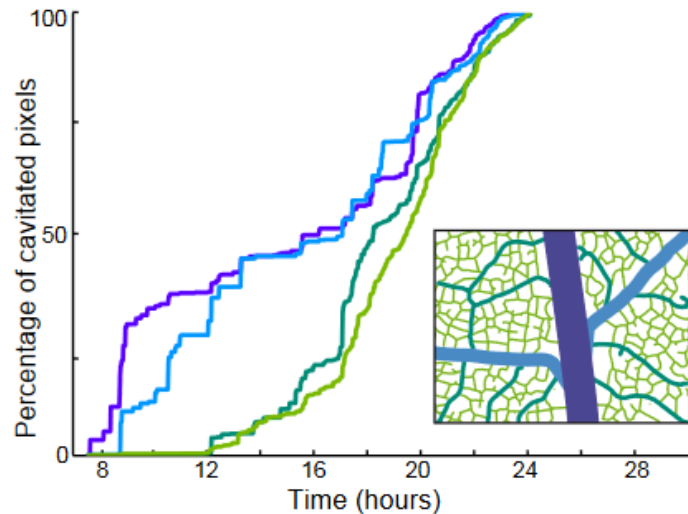
What do we observe in real leaves?

- ▶ Progression of embolism in an *Adiantum*, from image analysis
 - ▶ Jerky dynamics
 - ▶ Hierarchical

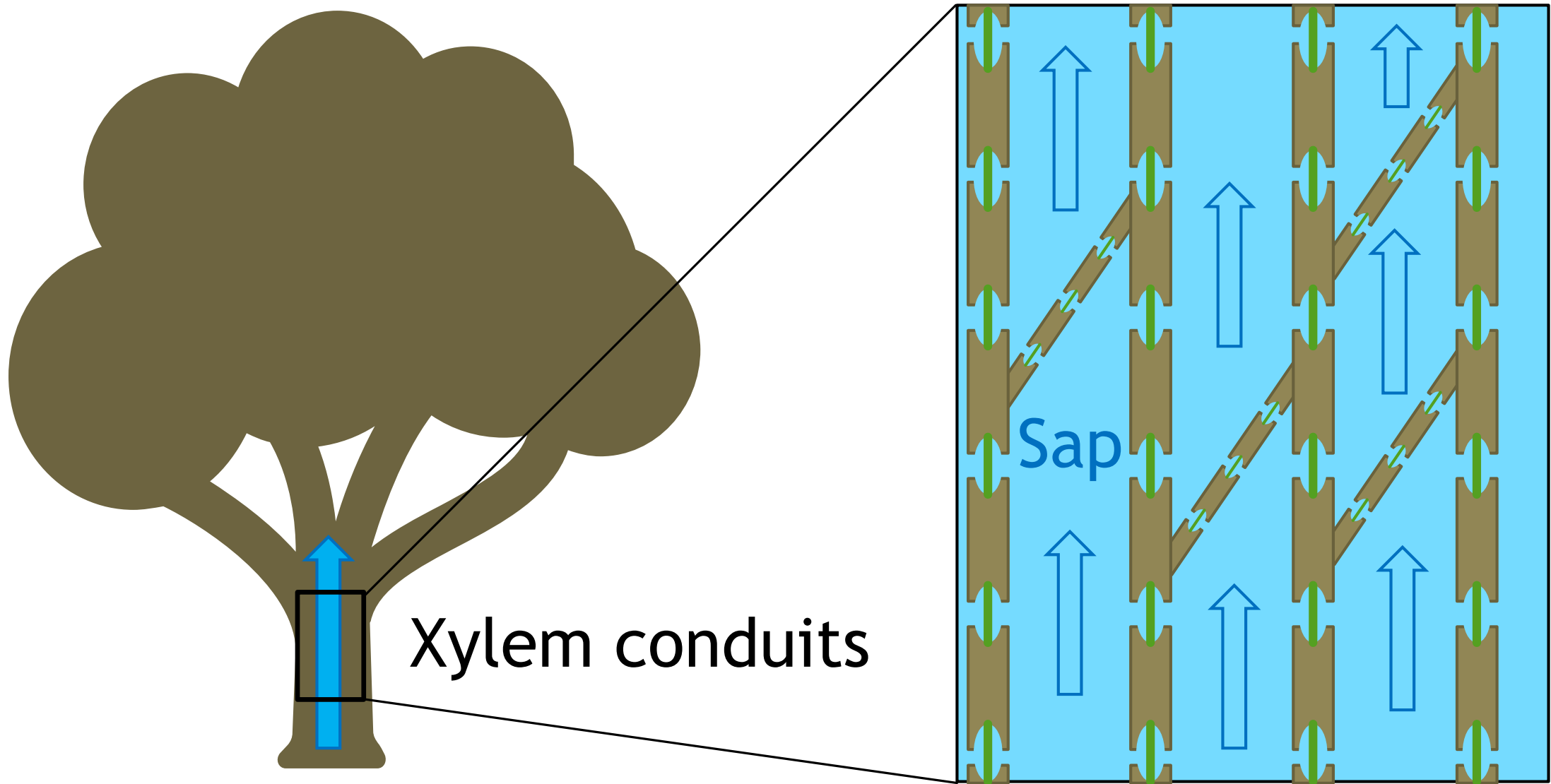


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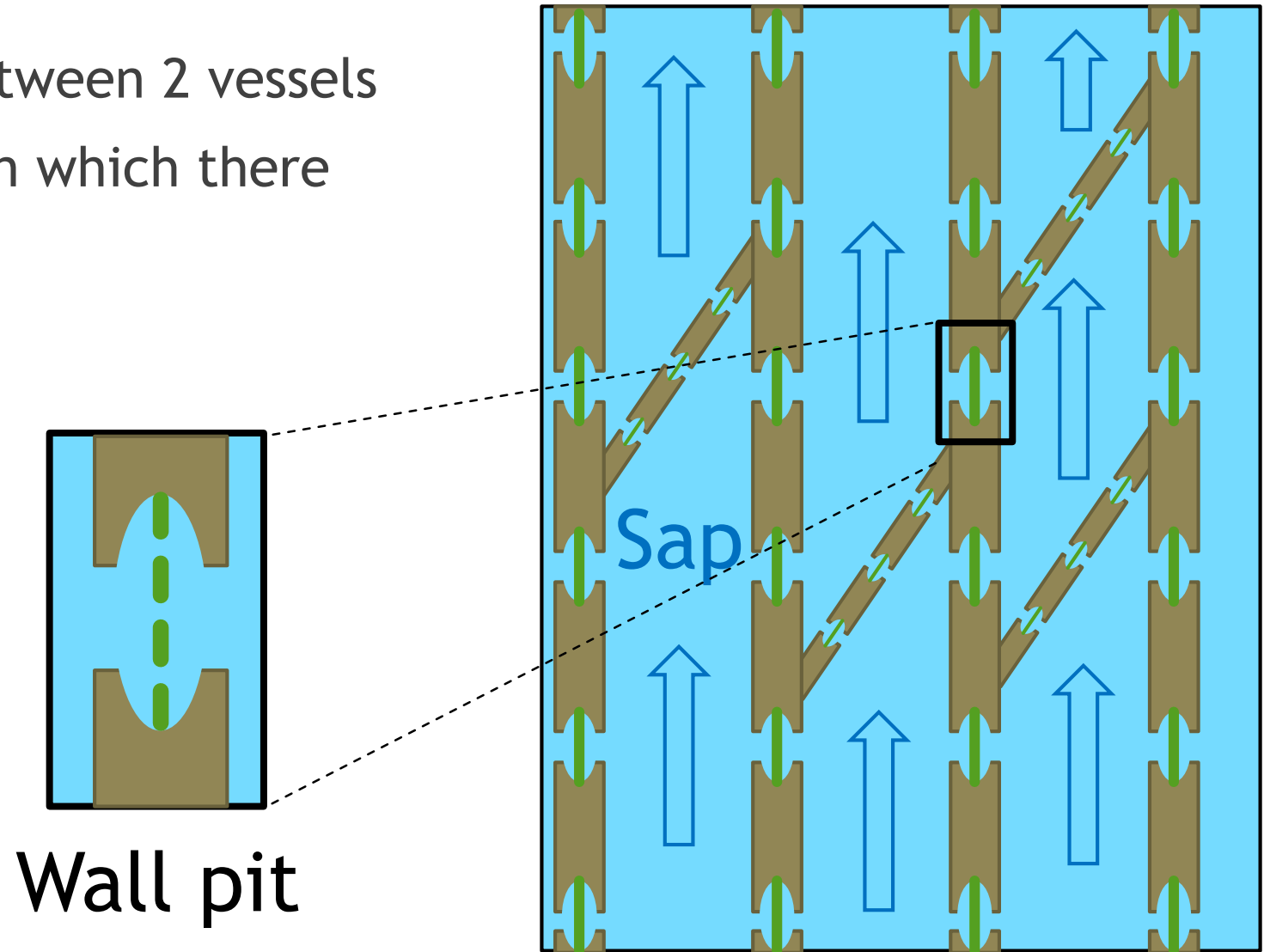


Zoom in the xylem venation network



Zoom in the xylem venation network

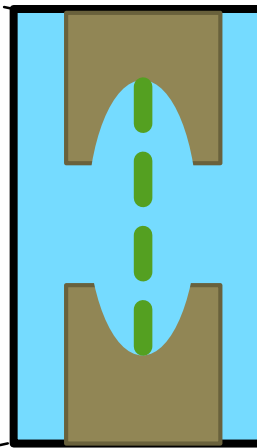
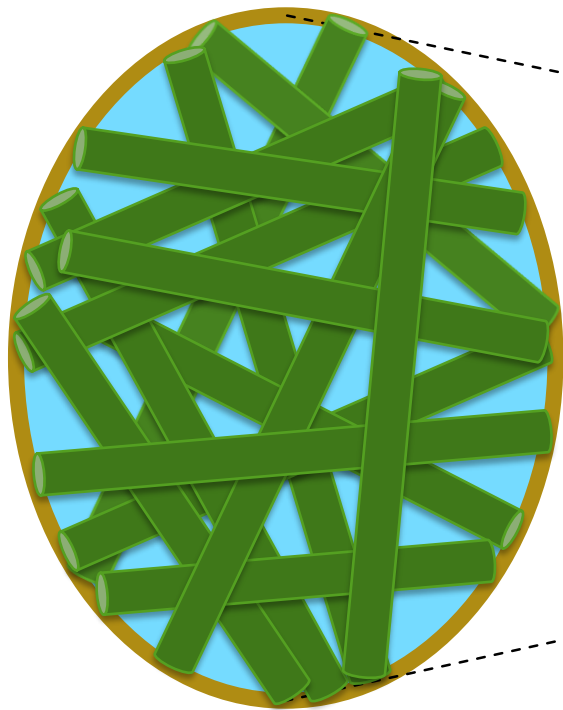
- ▶ Wall pit : cross-connection between 2 vessels
- ▶ Containing a cellulosic mesh in which there are nanoholes



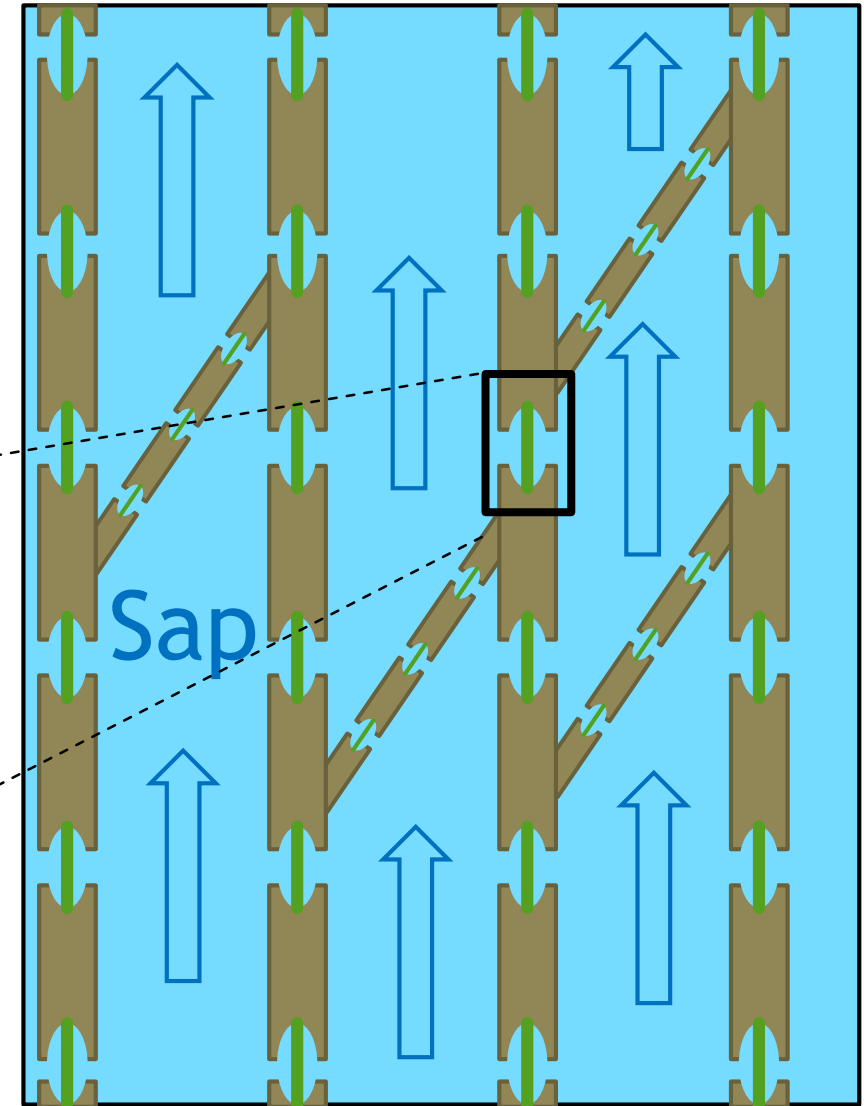
Wall pit

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- ▶ Wall pit : cross-connection between 2 vessels
- ▶ Containing a cellulosic mesh in which there are nanoholes

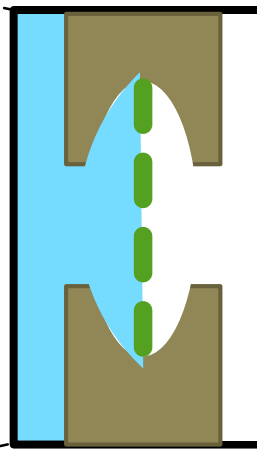
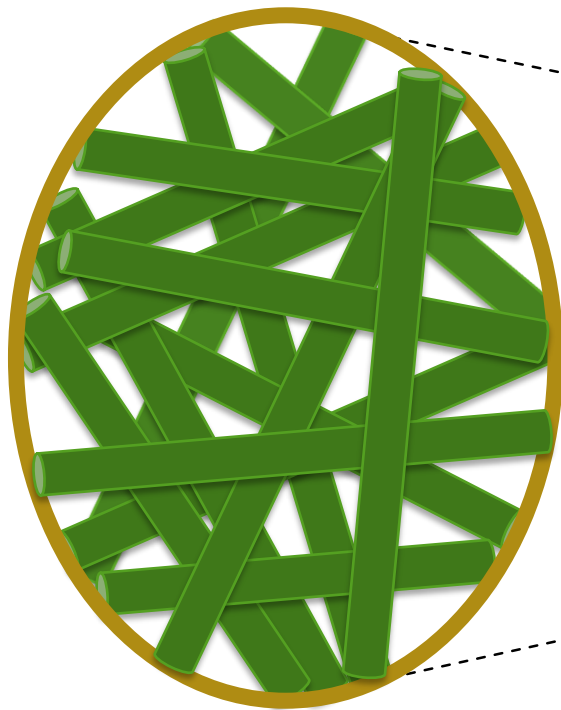


Wall pit

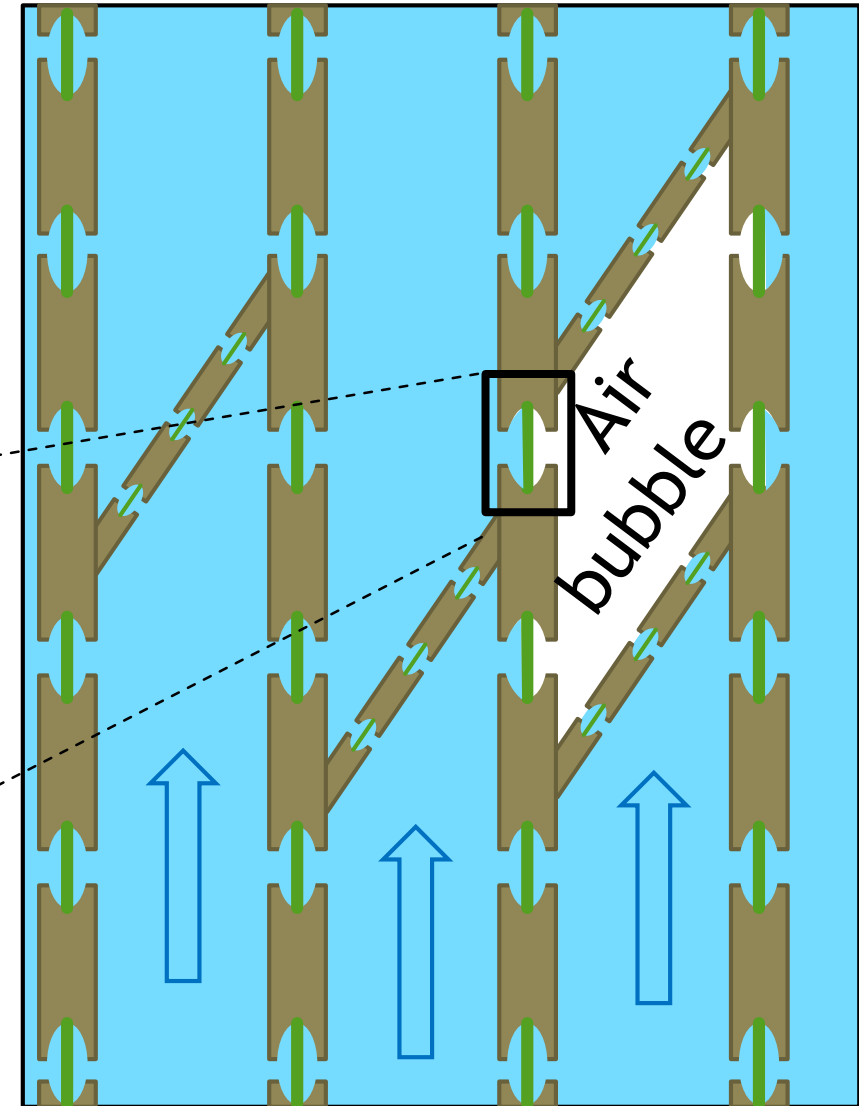


Zoom in the xylem venation network

- ▶ Wall pit : cross-connection between 2 vessels
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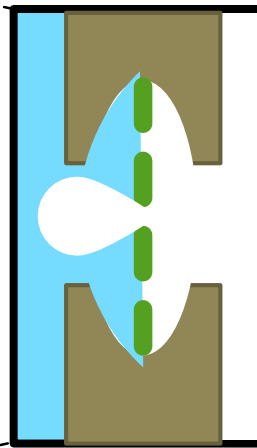
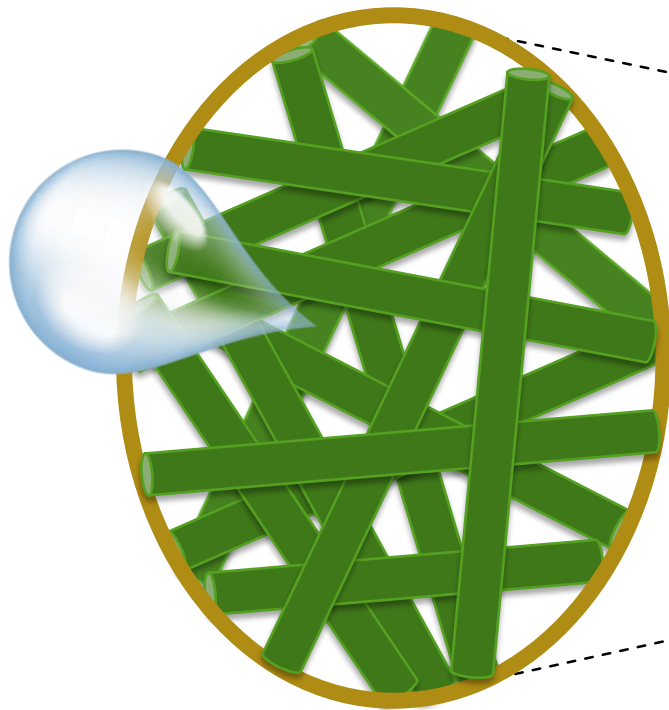


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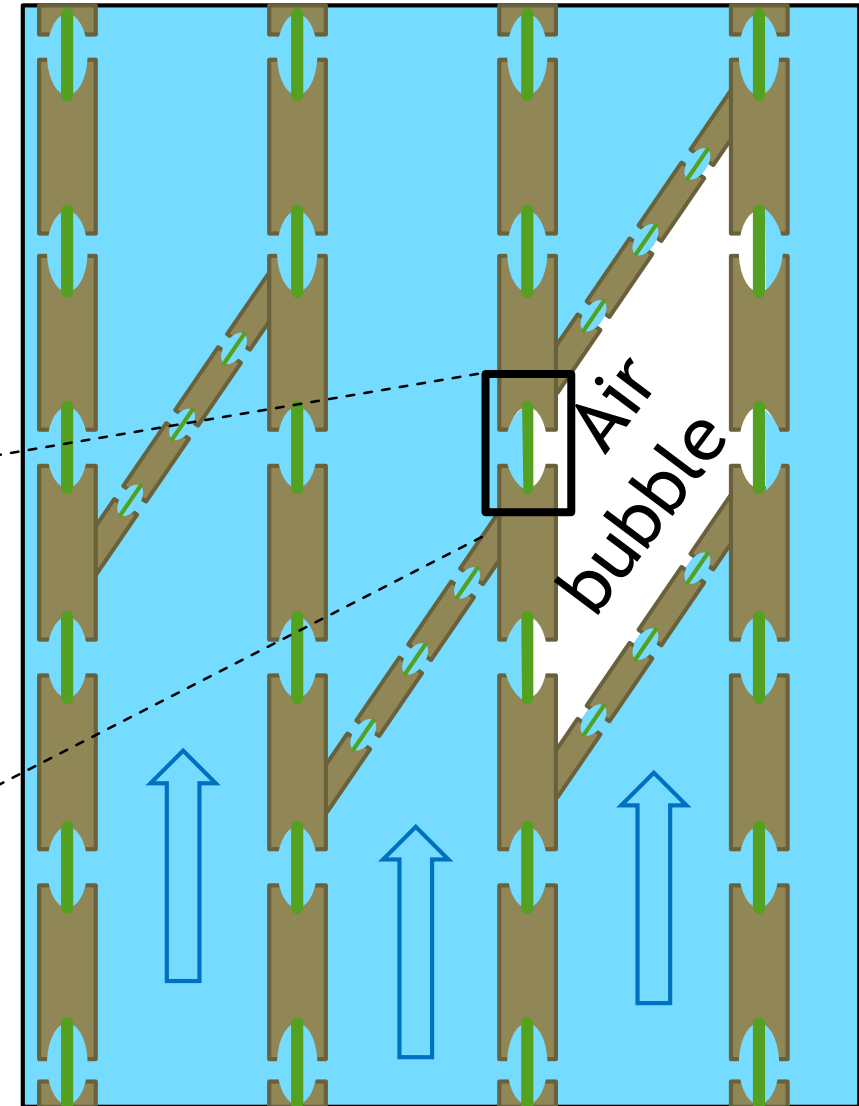


Zoom in the xylem venation network

- ▶ The bubble needs to reach the Laplace pressure

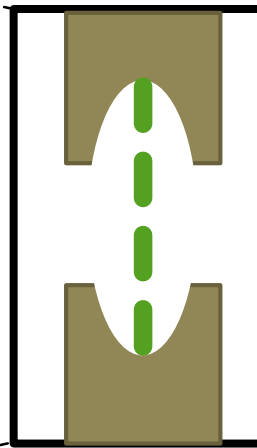
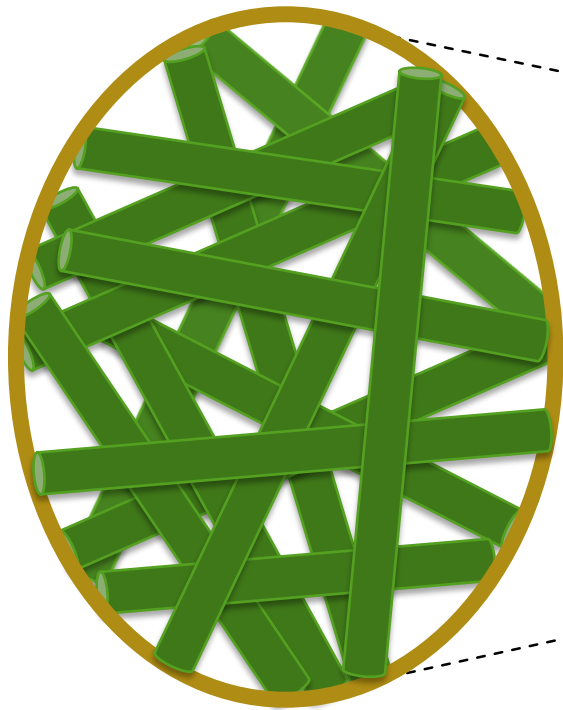


Wall pit

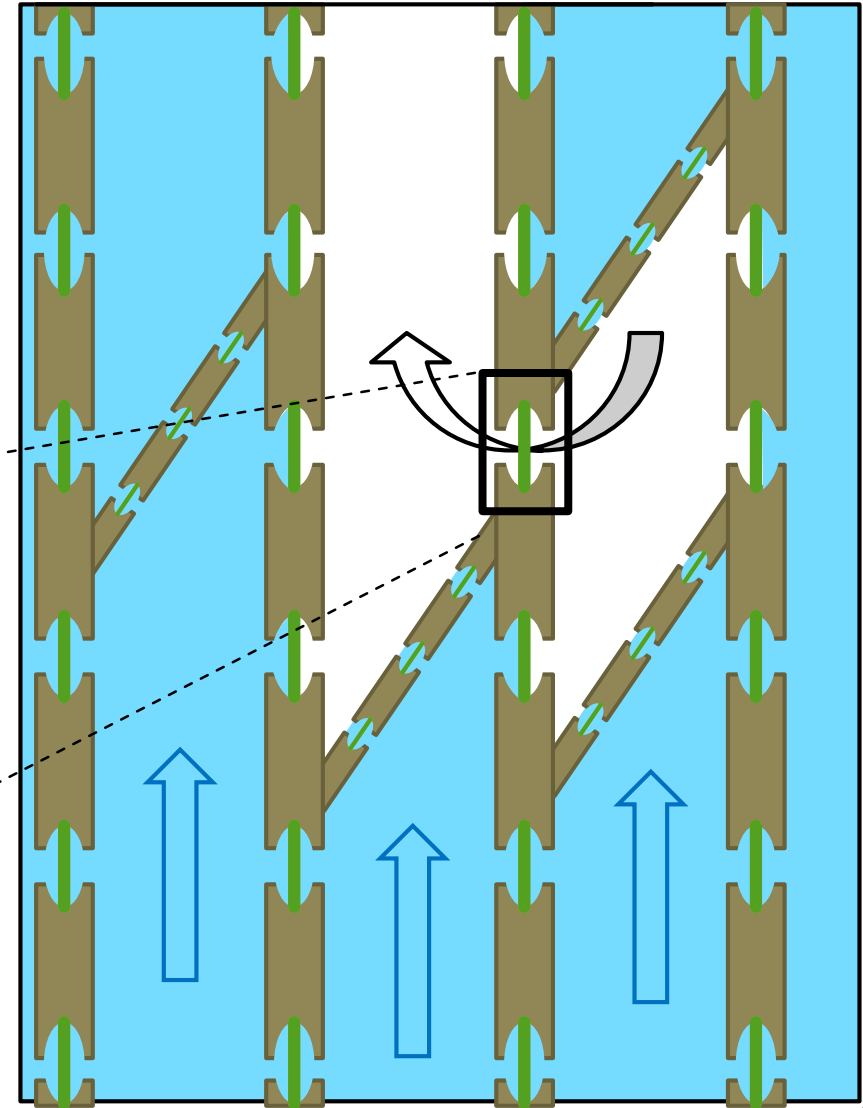


Zoom in the xylem venation network

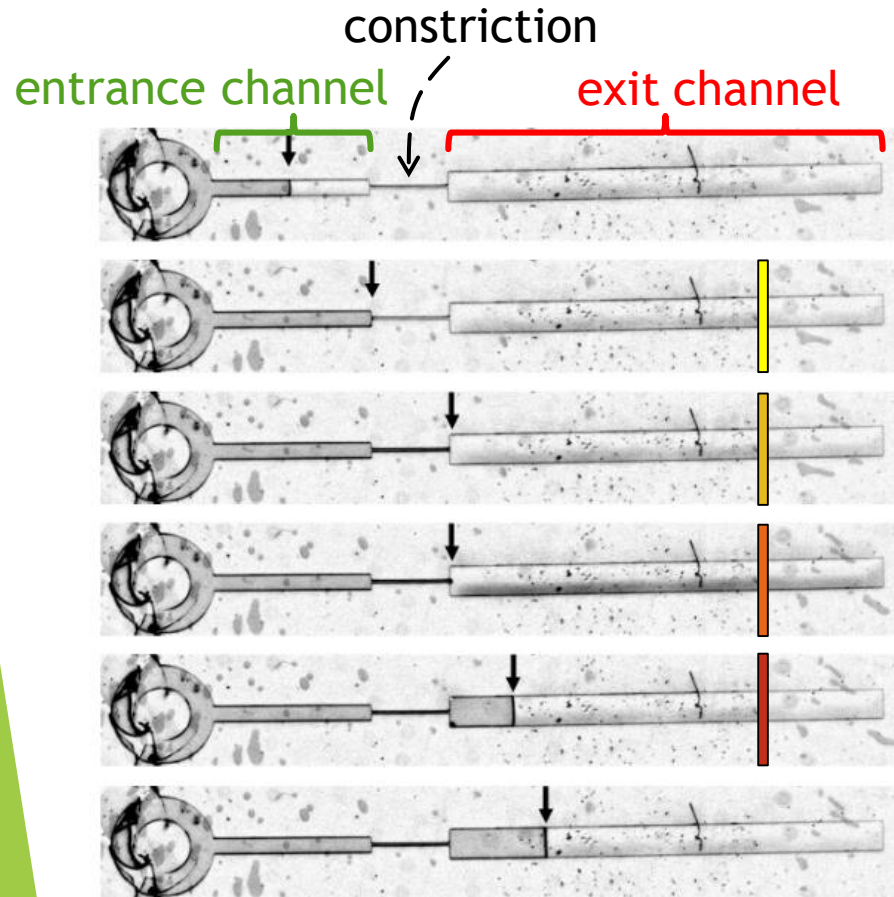
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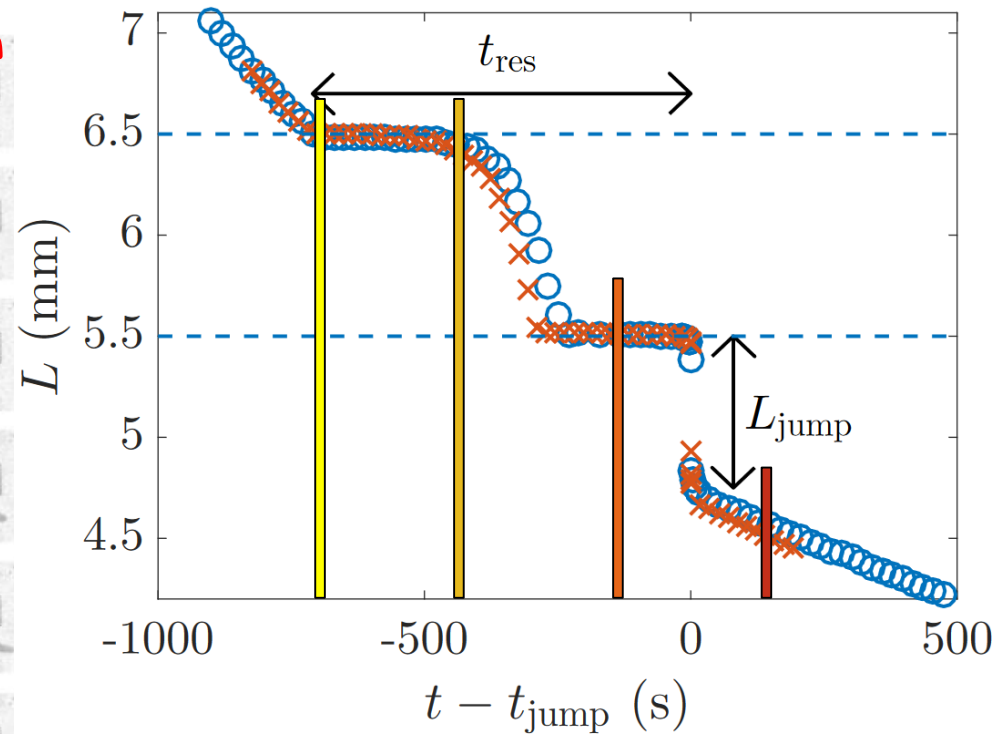
Wall pit



The key role of constrictions

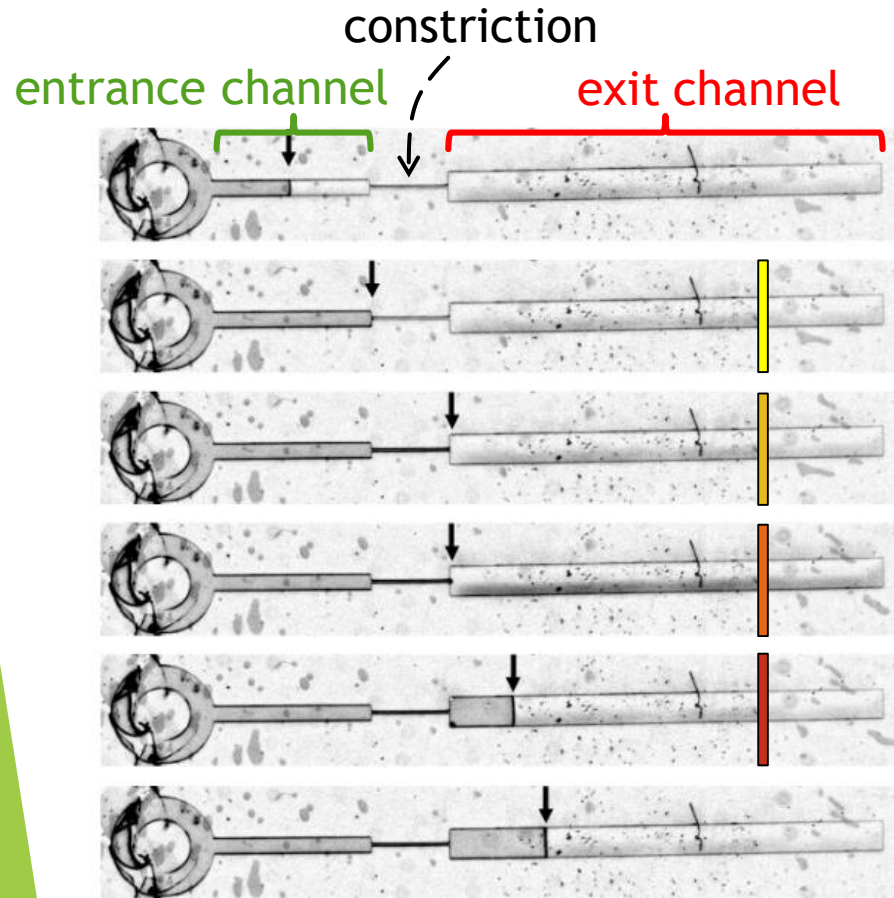


Meniscus dynamics
through a constriction

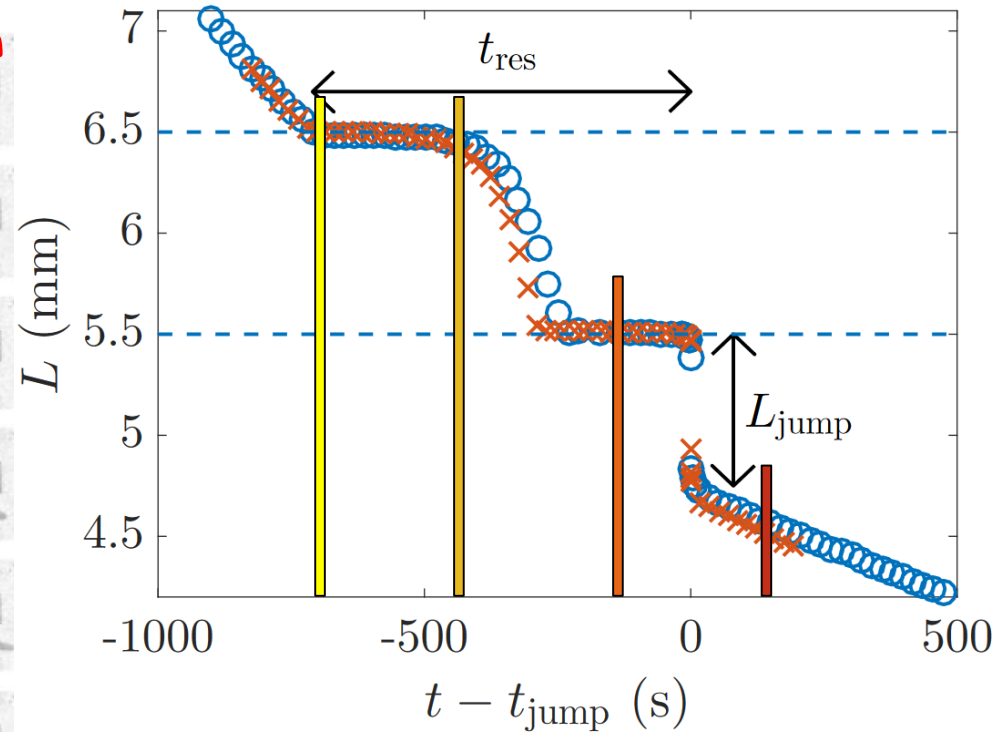


Length of the water column
while evaporation

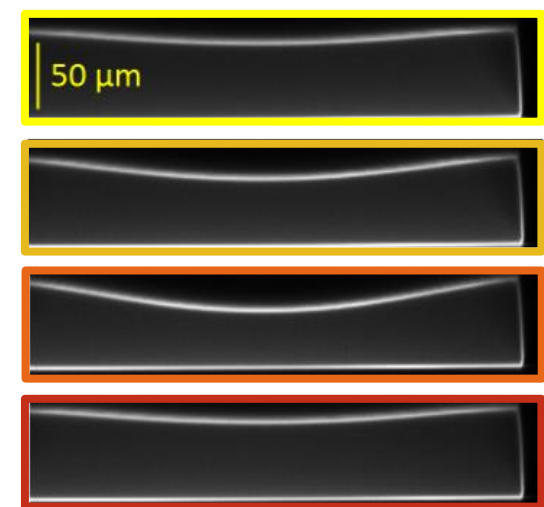
The key role of constrictions



Meniscus dynamics
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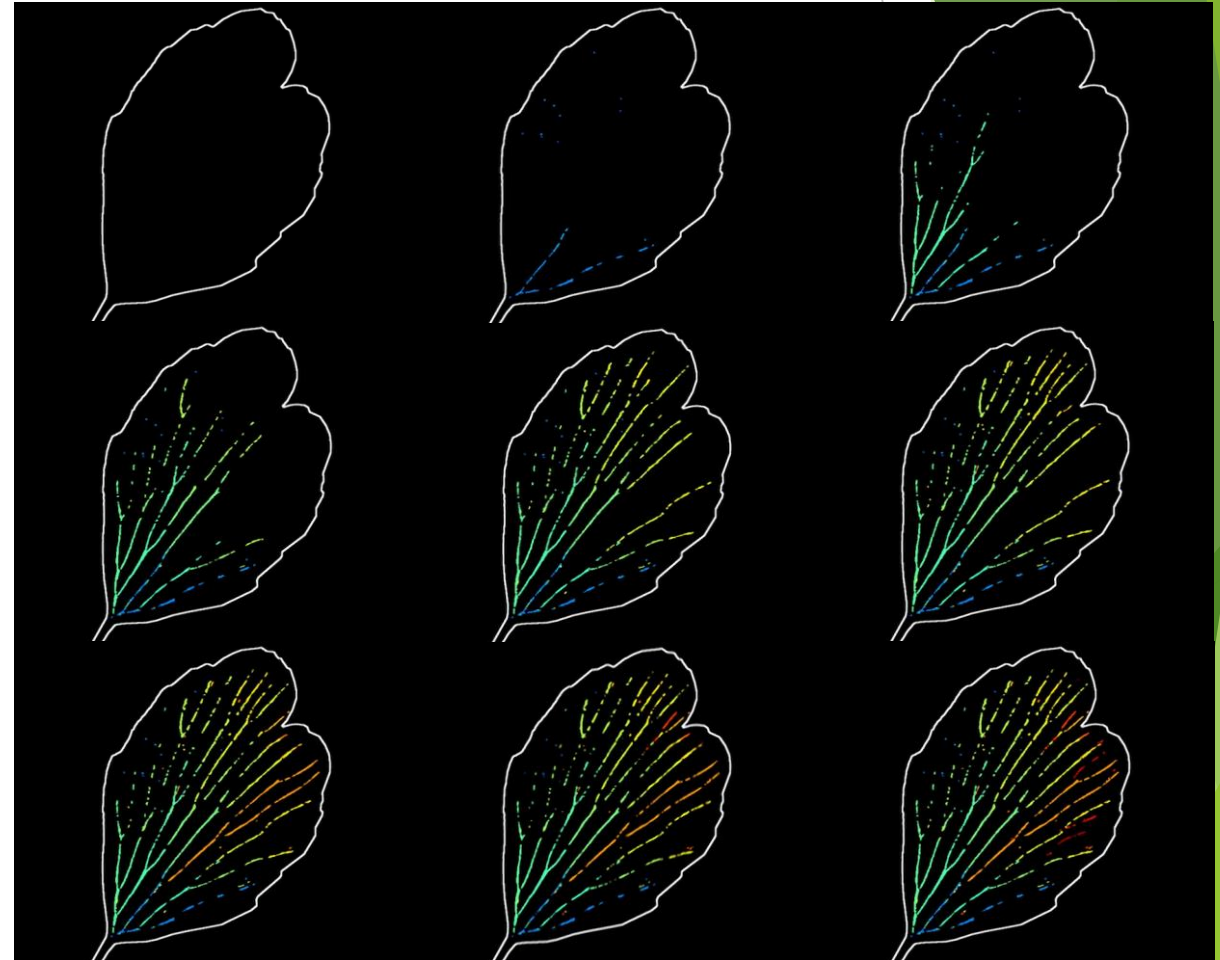
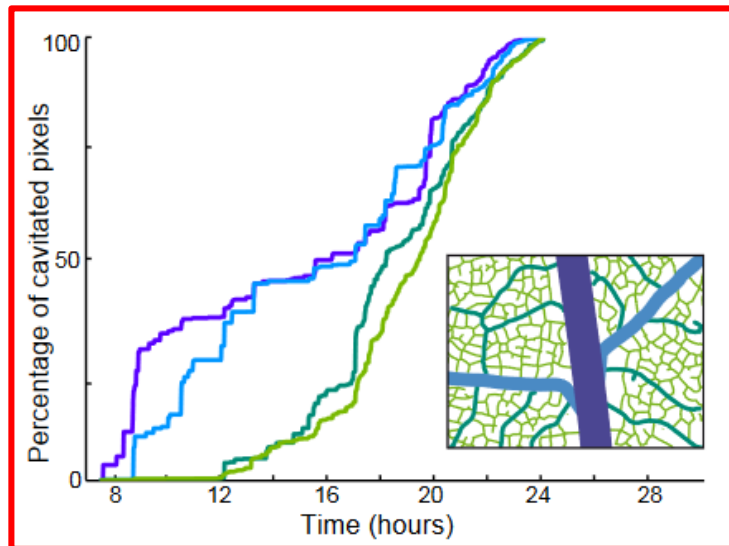
Length of the water column
while evaporation



Exit channel deformation
Cross-section (confocal
imaging)

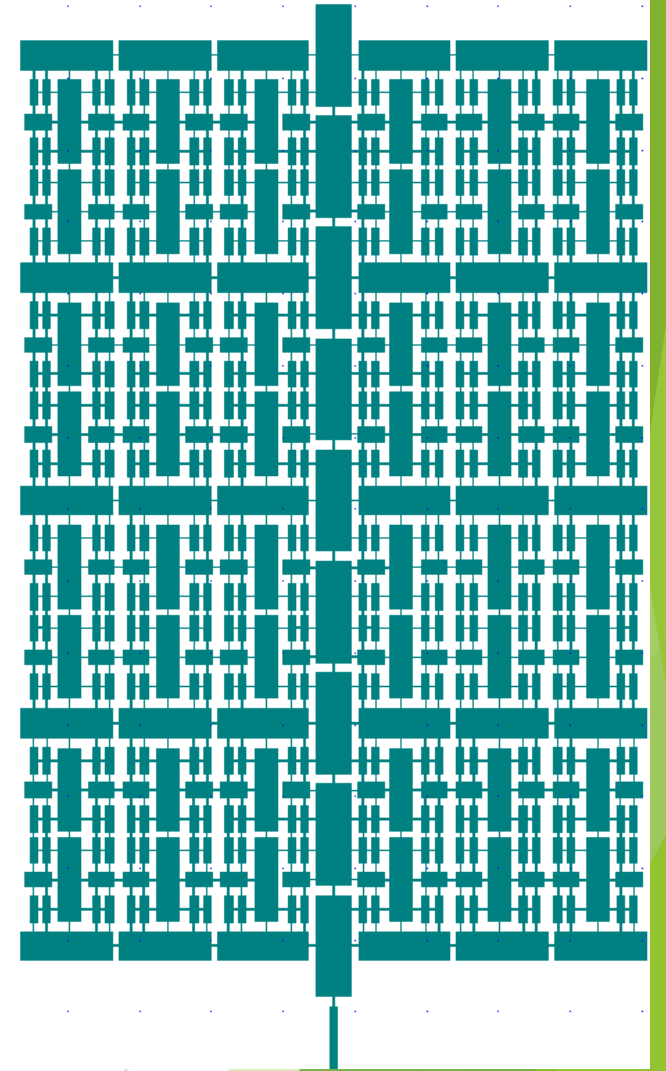
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More complex systems

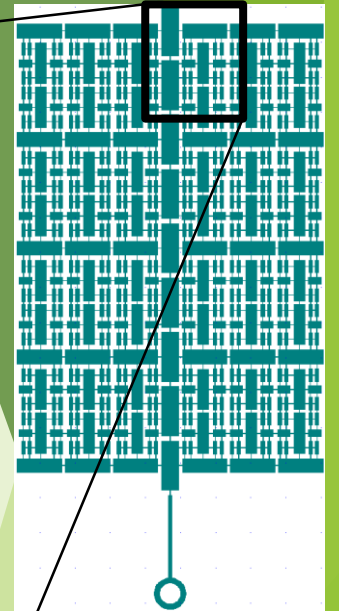
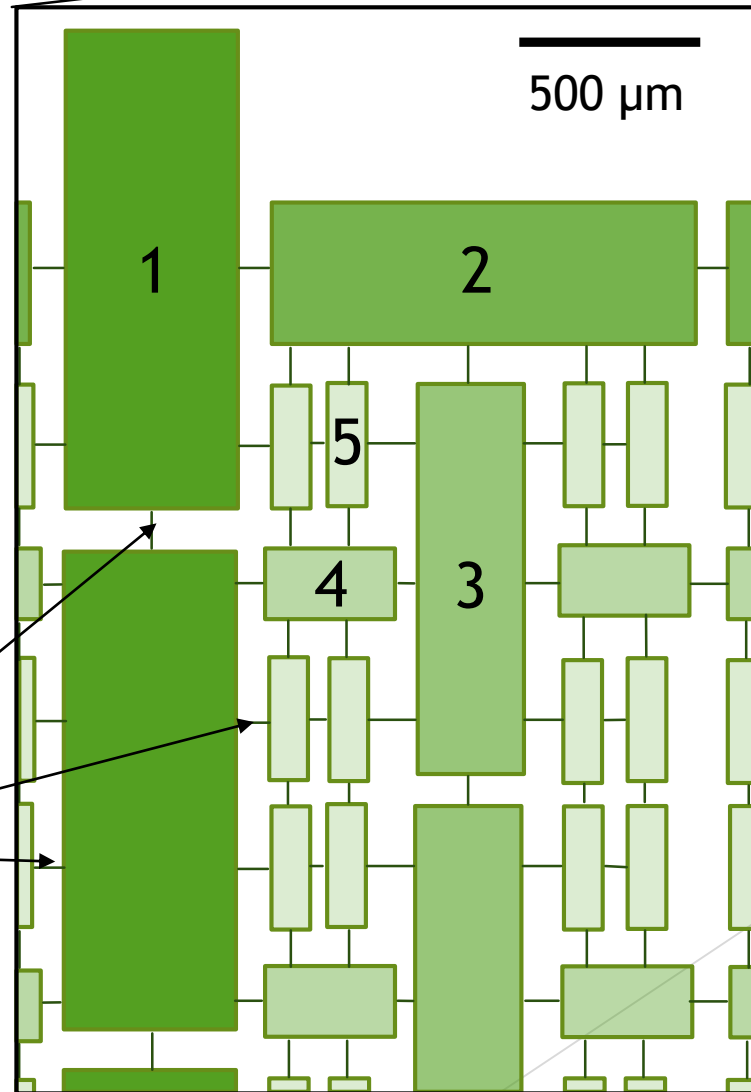
- ▶ Closer to a real leaf venation network
- ▶ 5 order-network of decreasing width



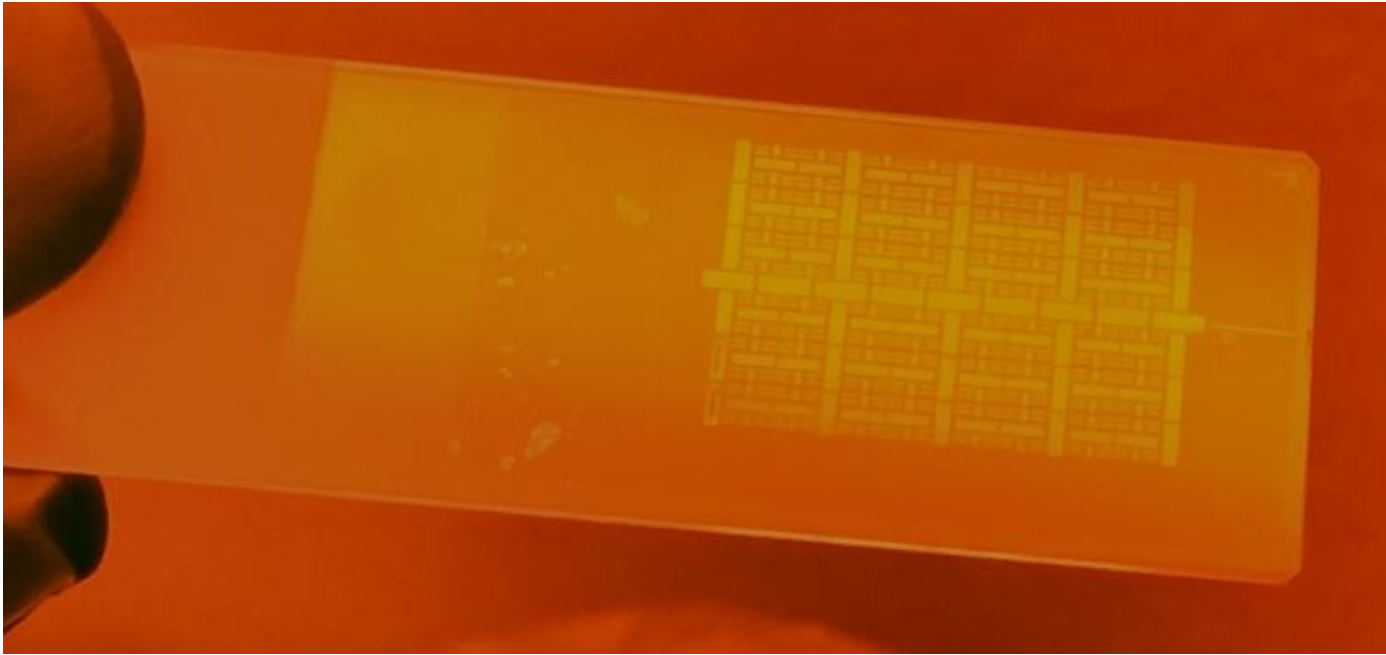
More complex systems

- ▶ Closer to a real leaf venation network
- ▶ 5 order-network of decreasing width (1, 2, 3...)
- ▶ 10 μm -width constrictions

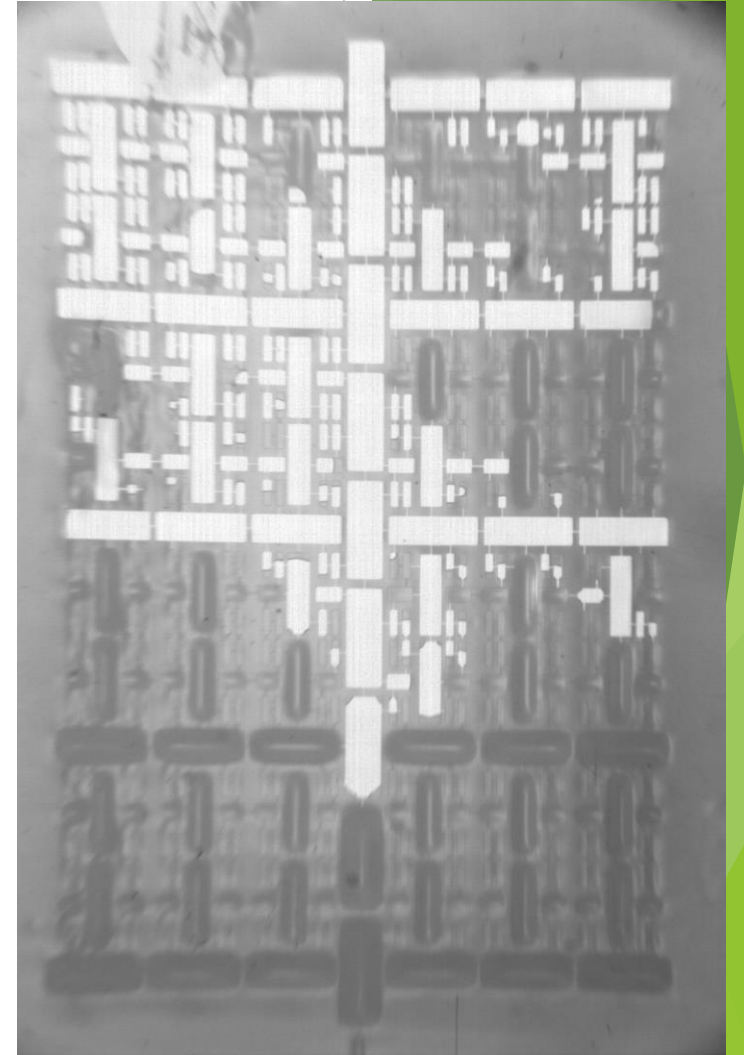
Constrictions



Embolism in the artificial leaf

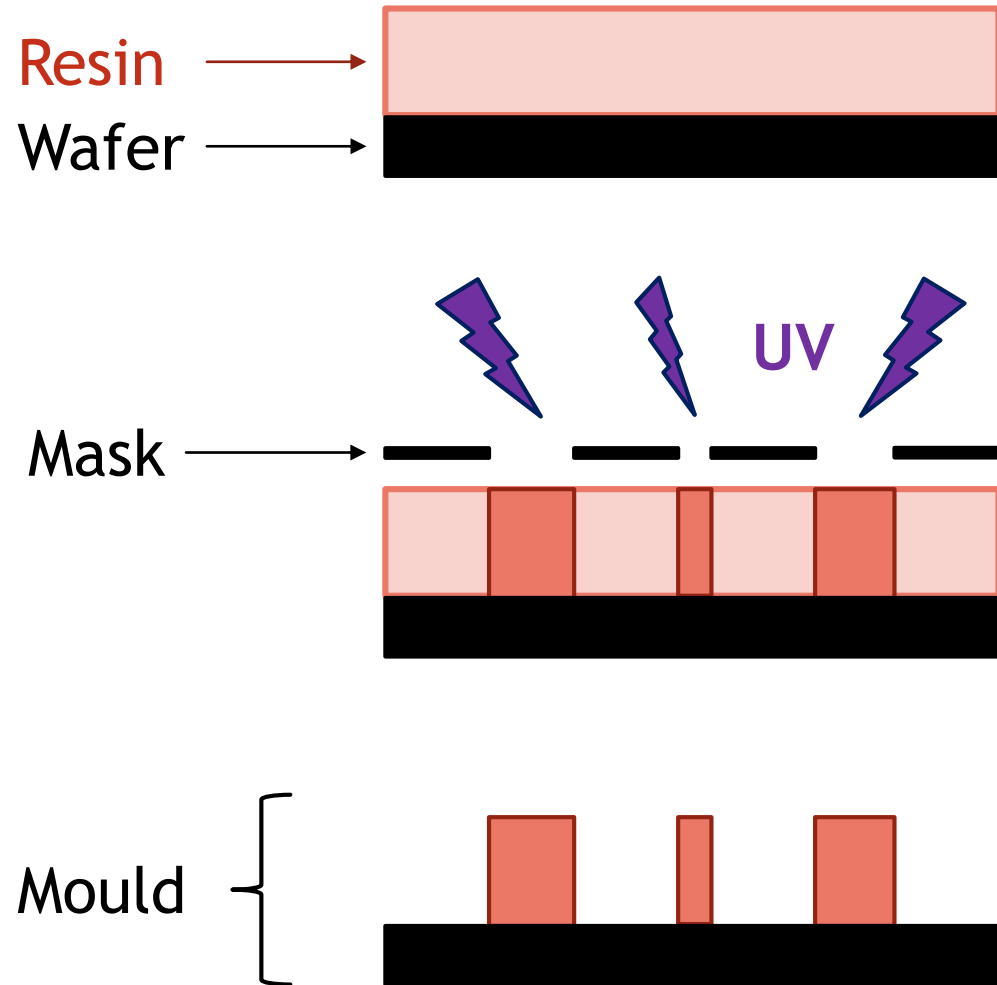


PDMS membrane

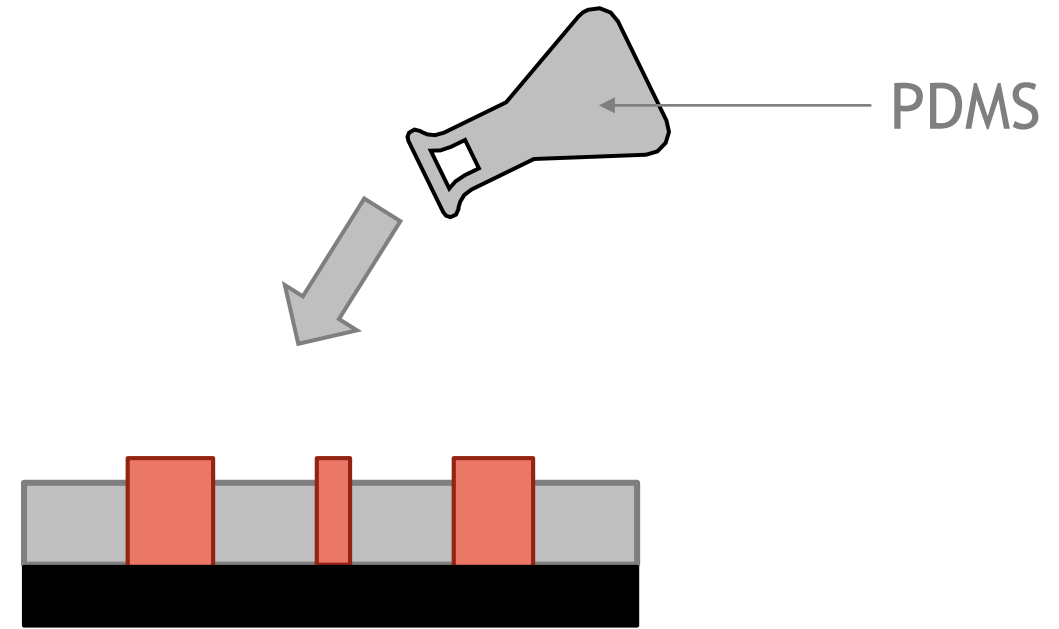
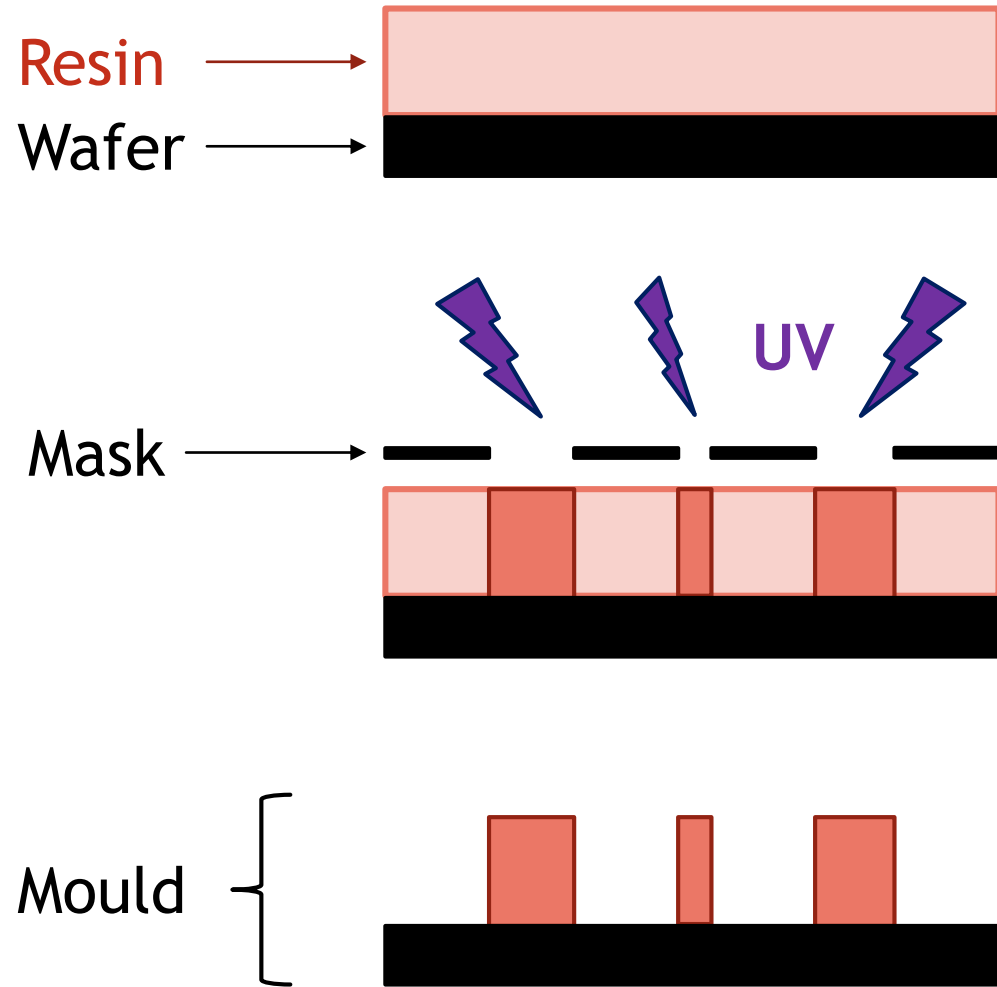


Artificial leaf drying

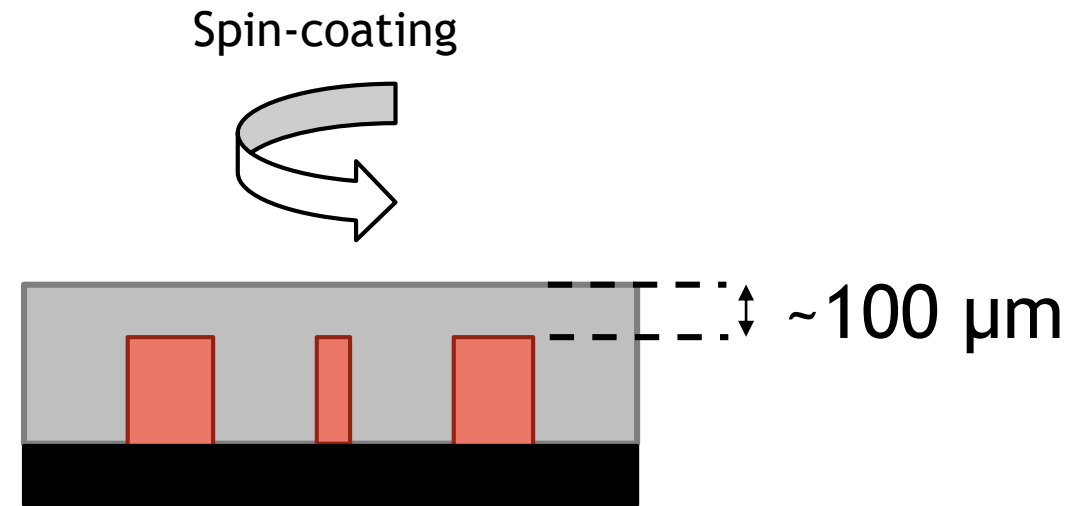
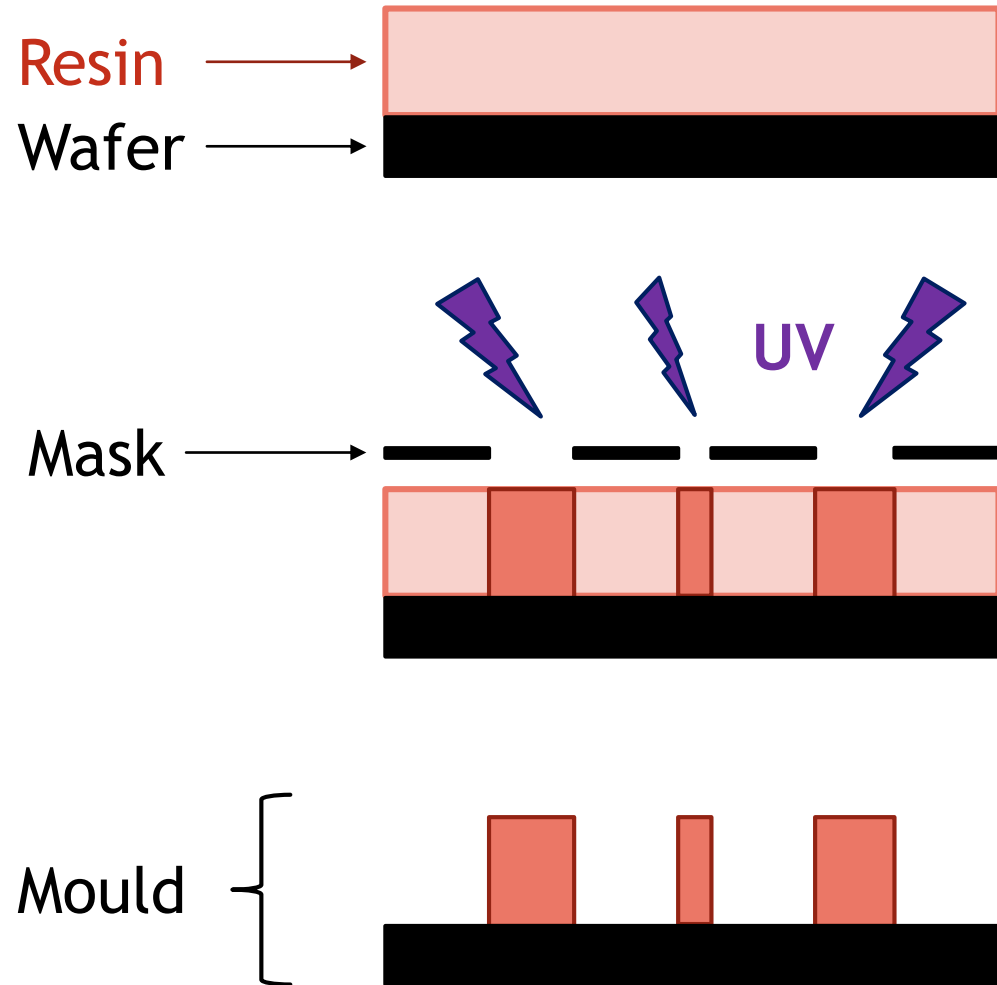
Photolithography for microfluidics



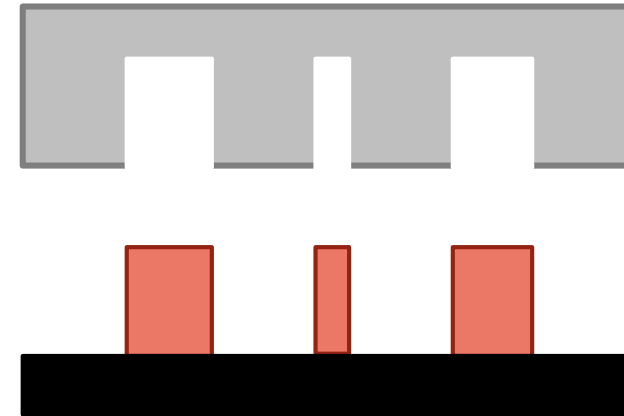
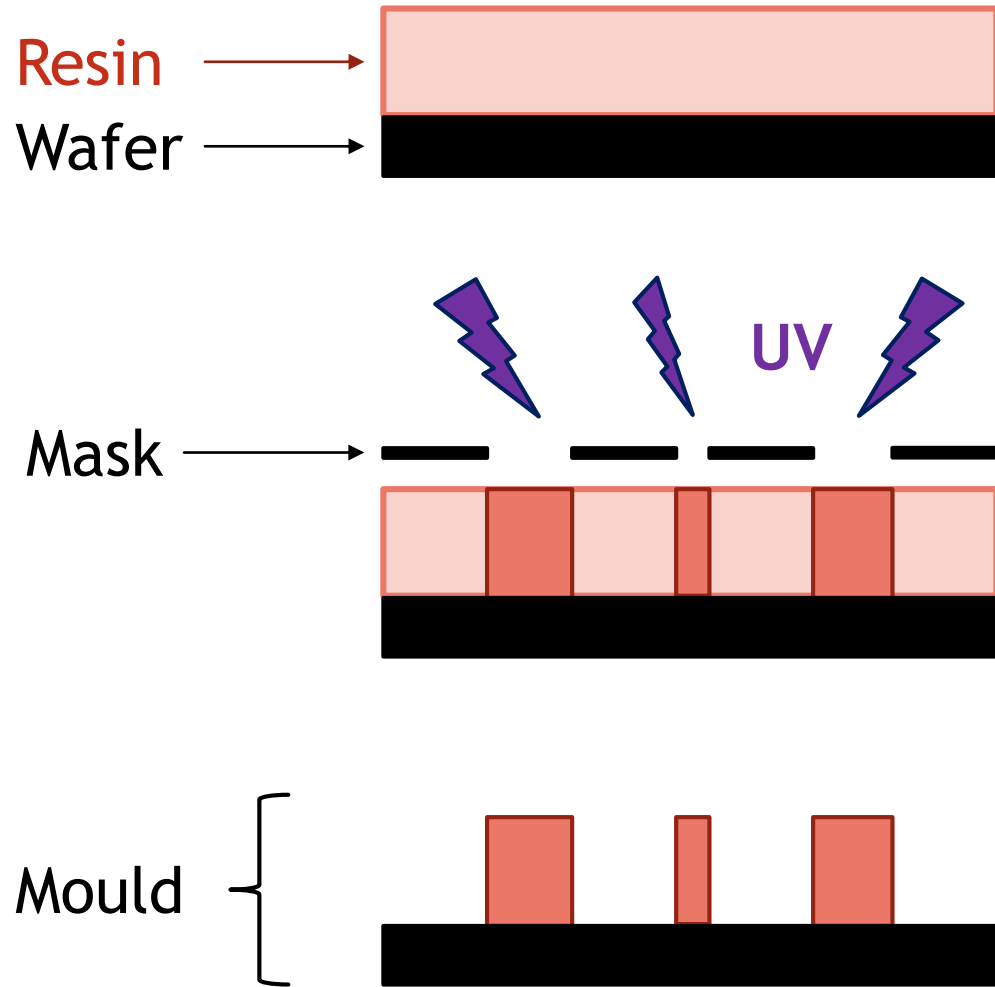
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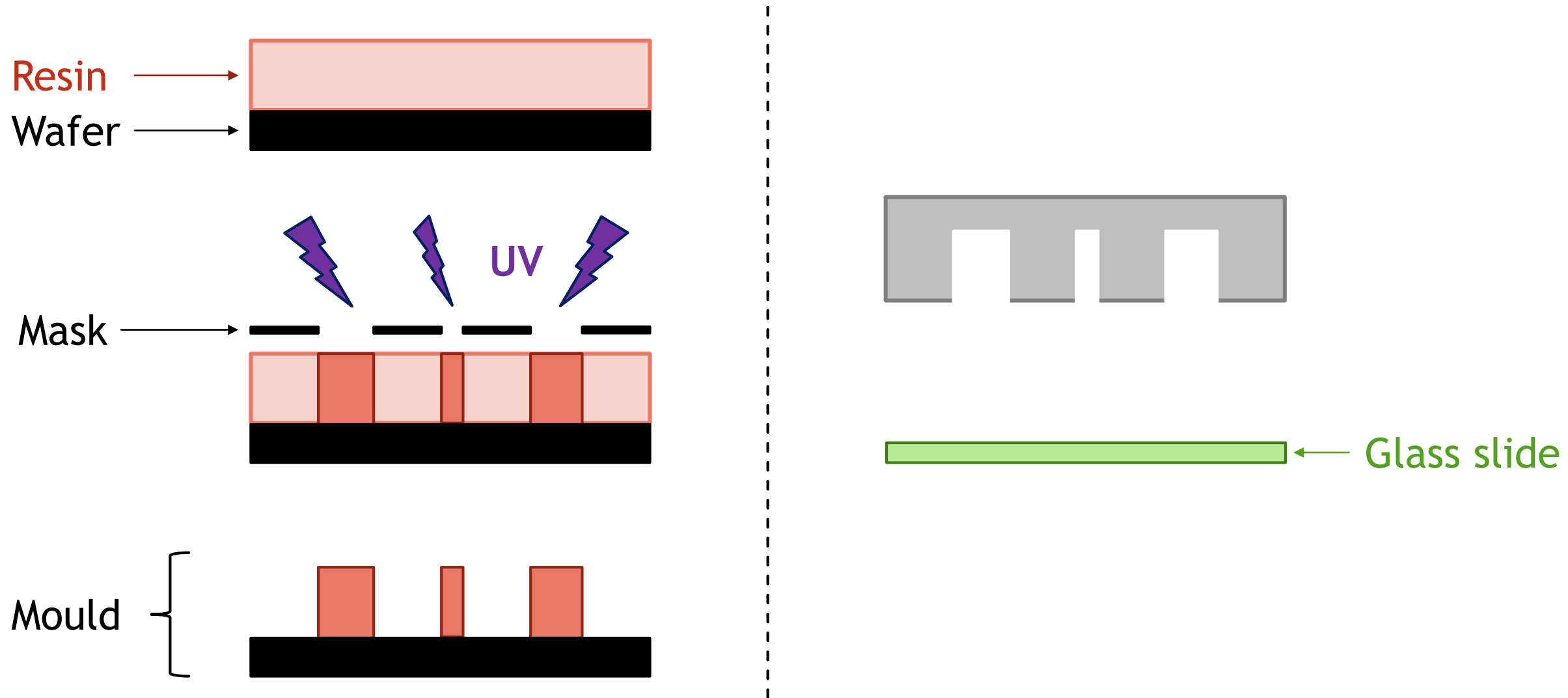
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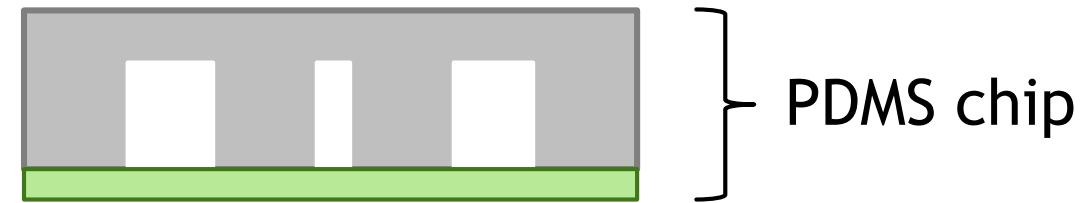
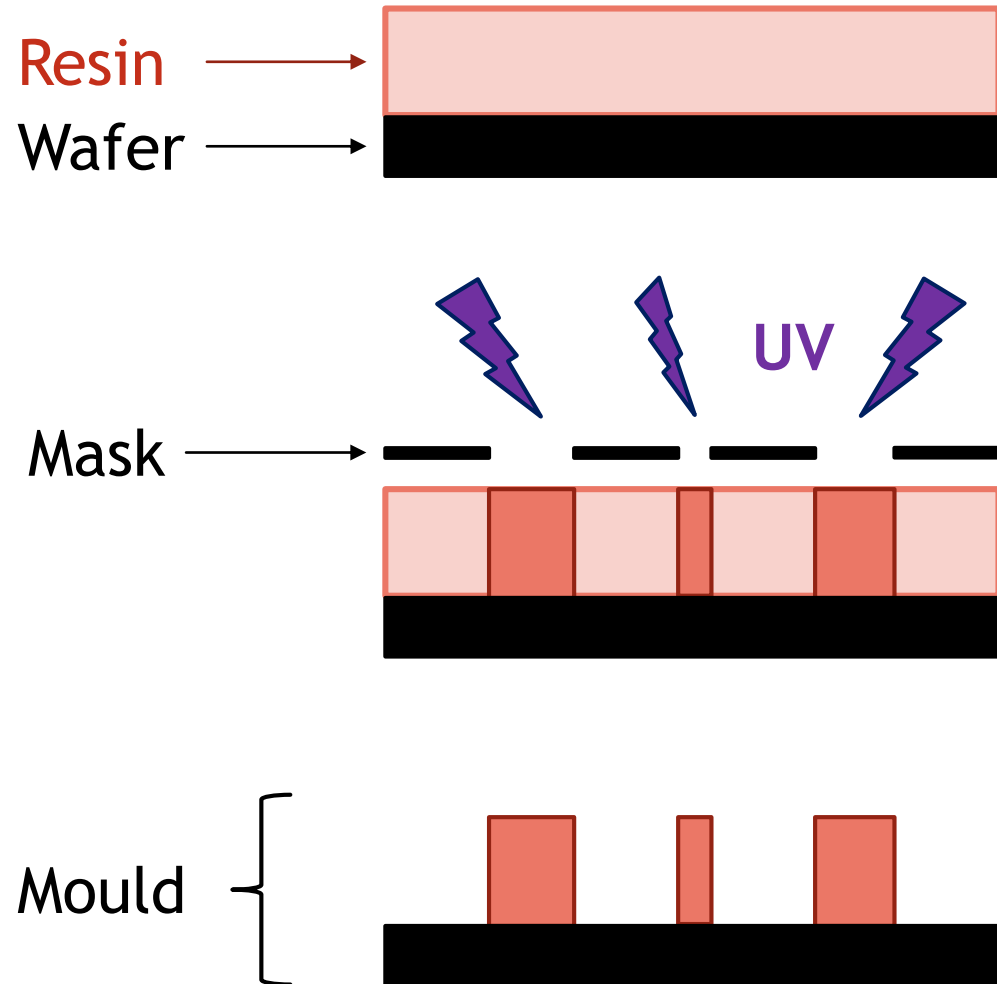
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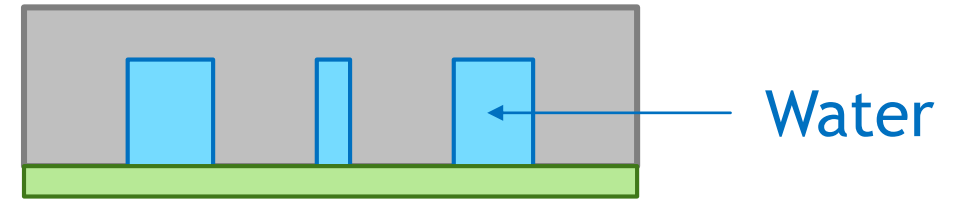
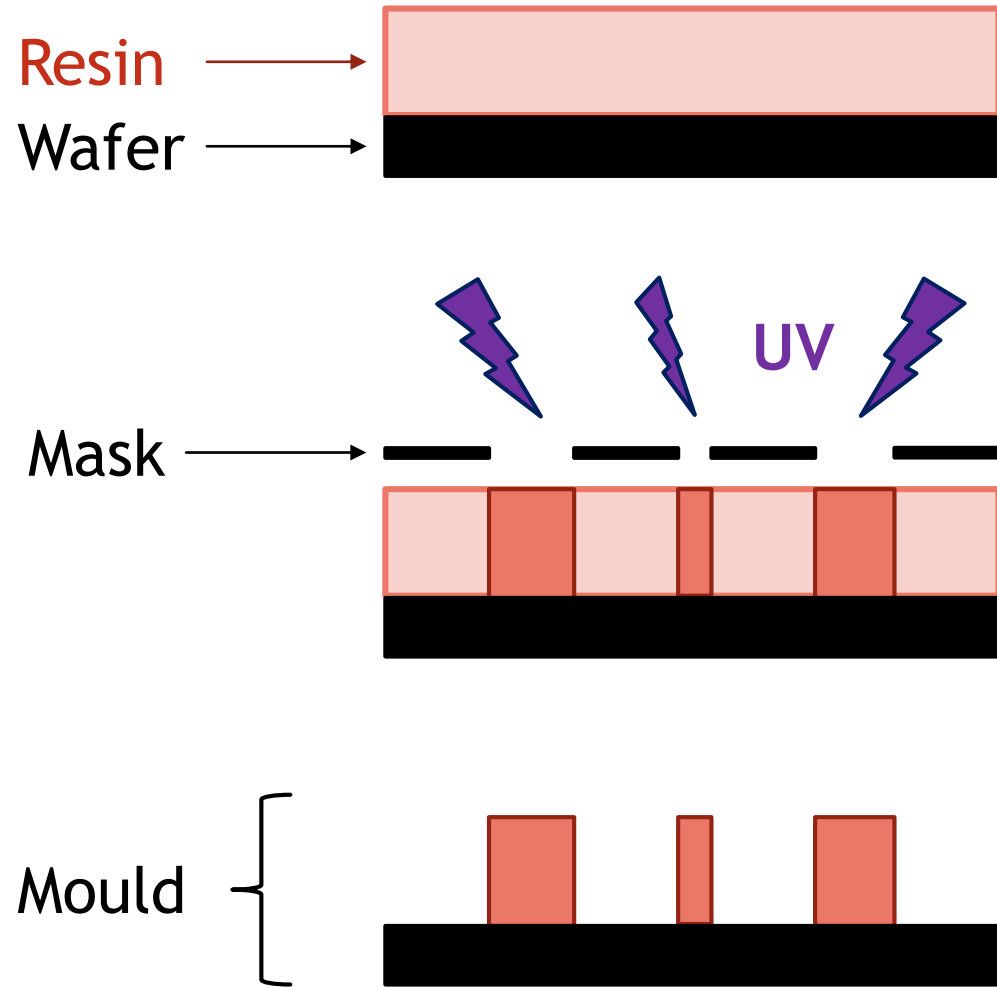
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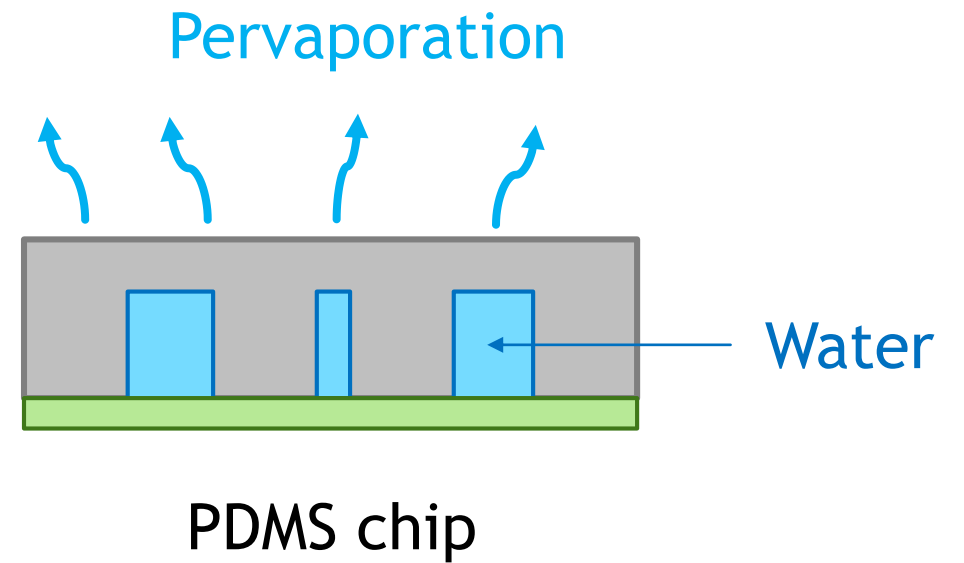
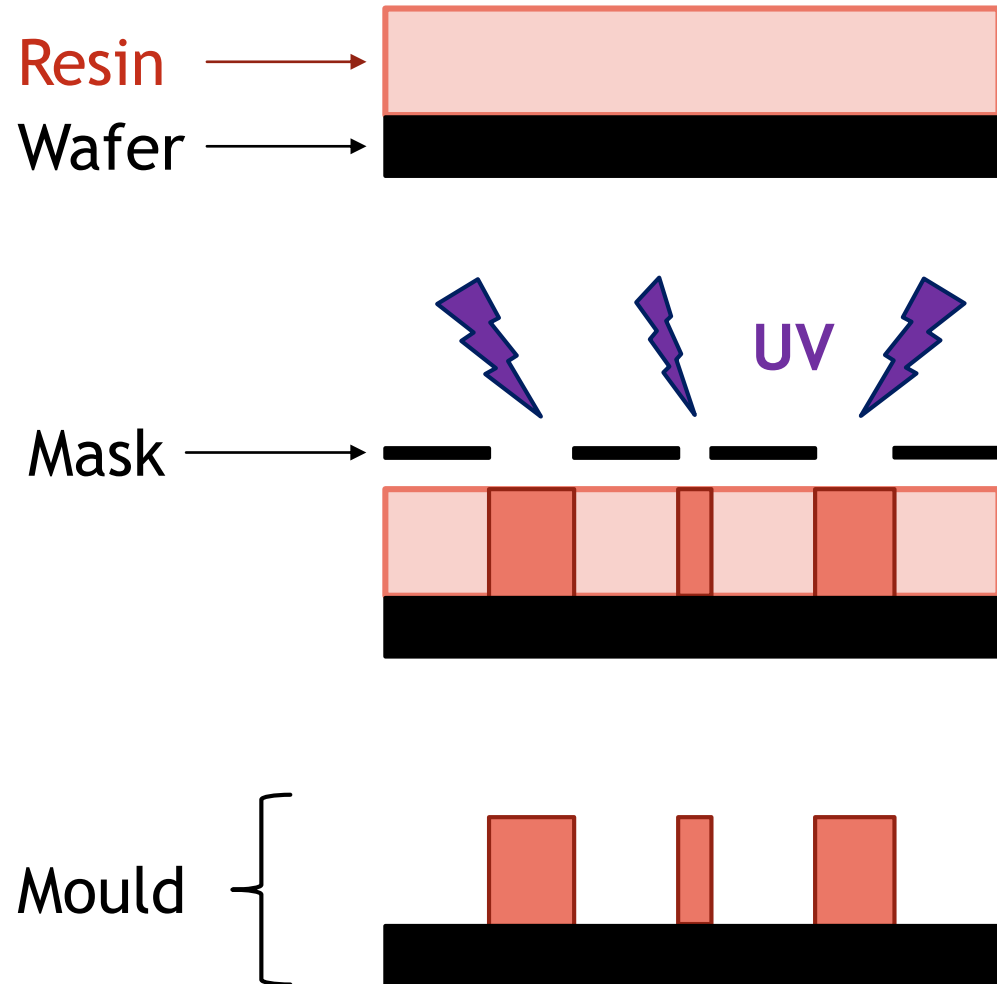


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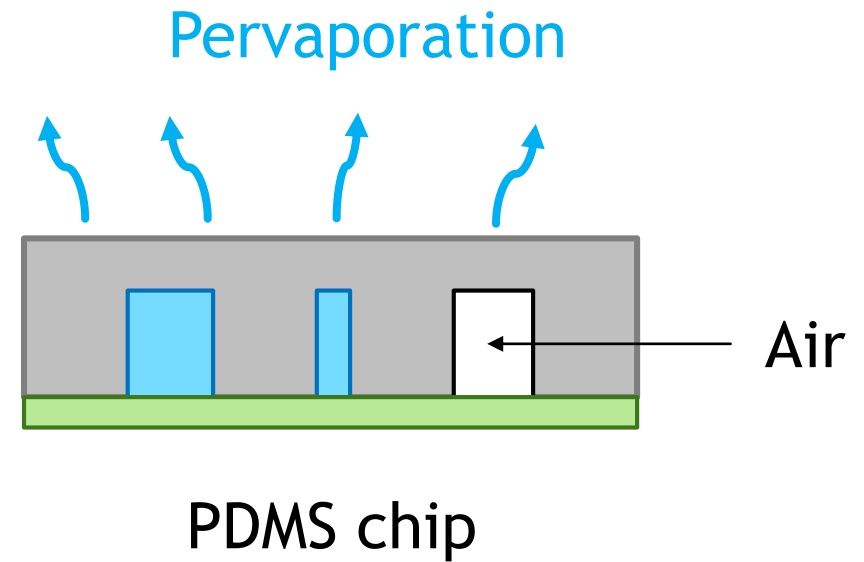
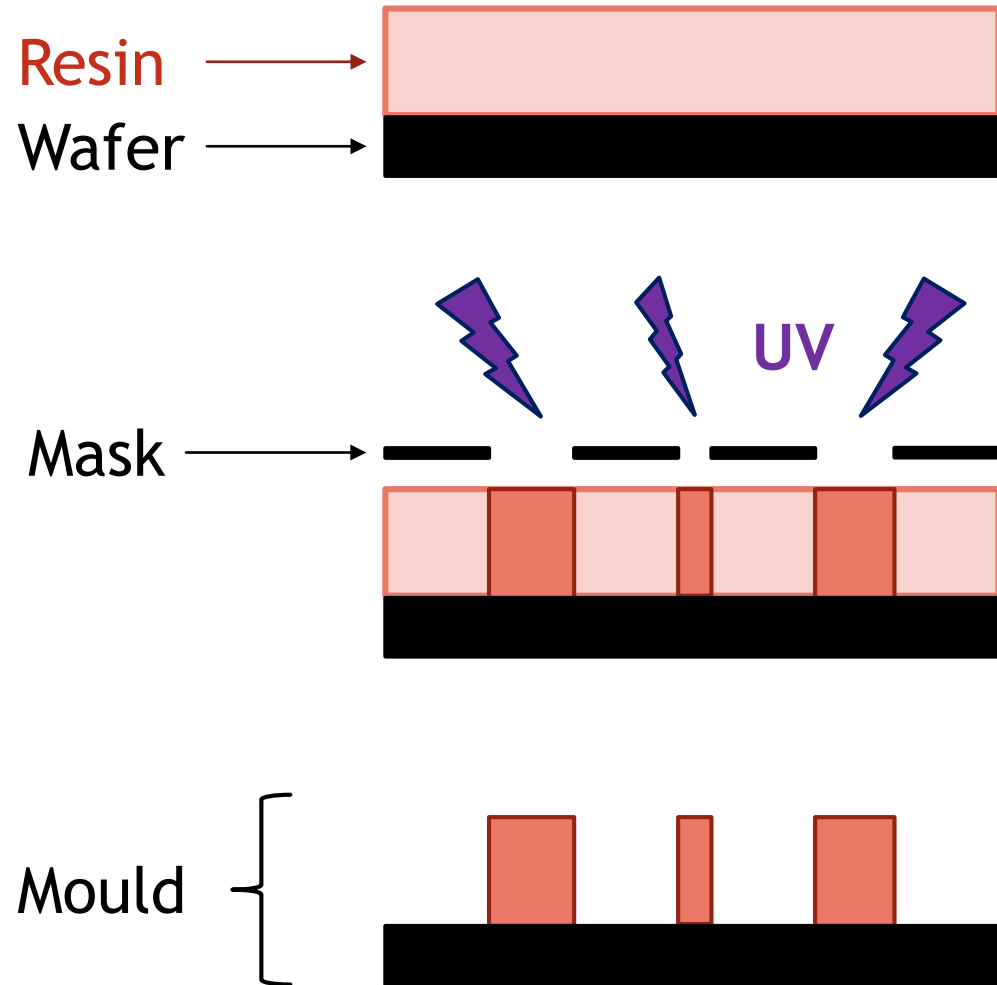


PDMS chip

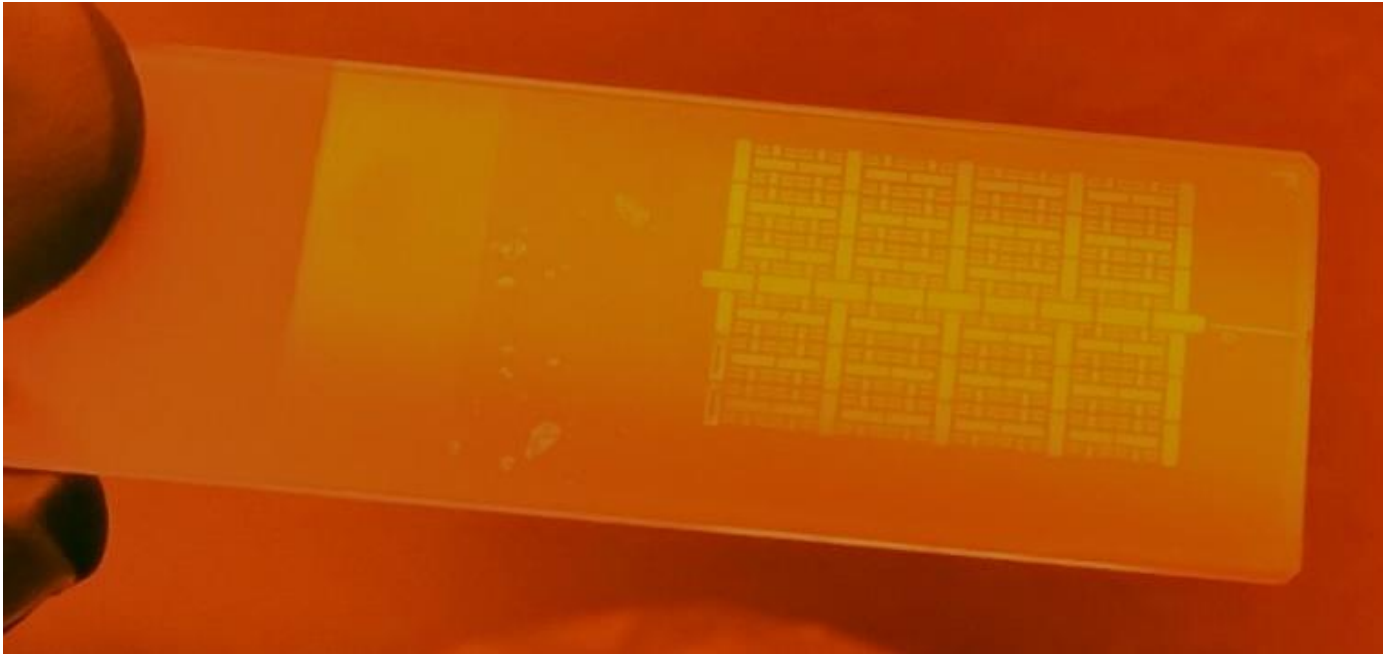
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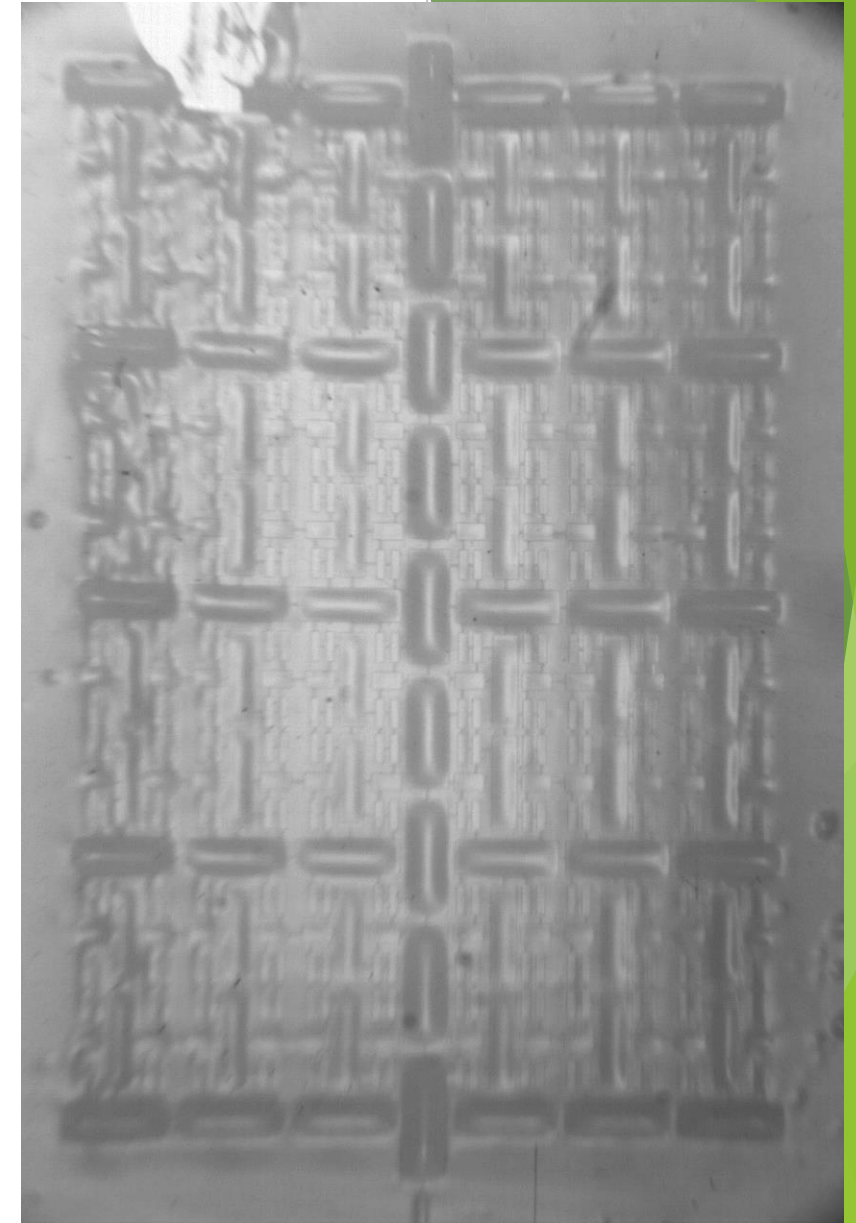
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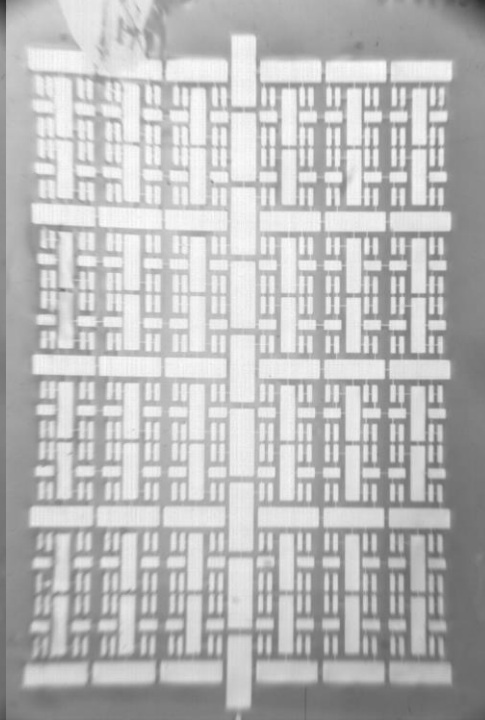
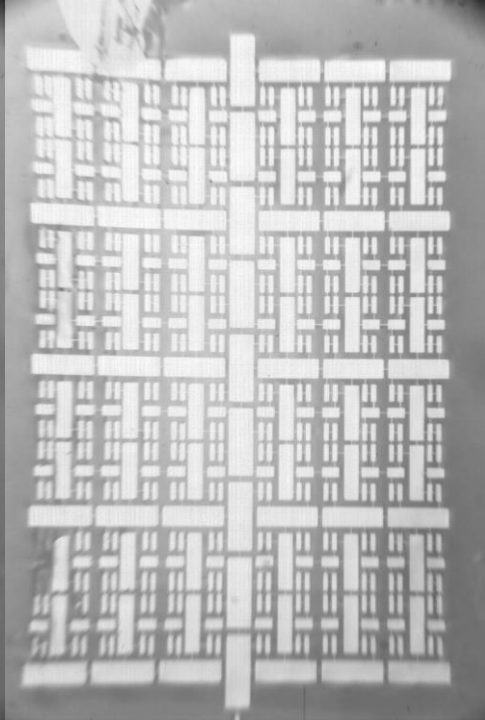
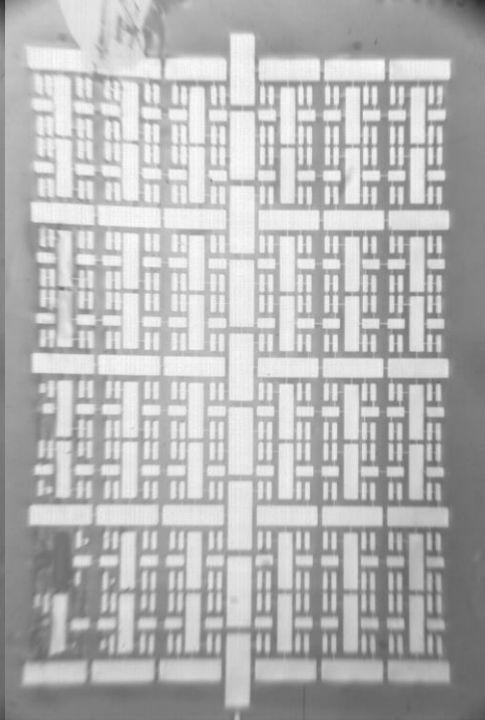
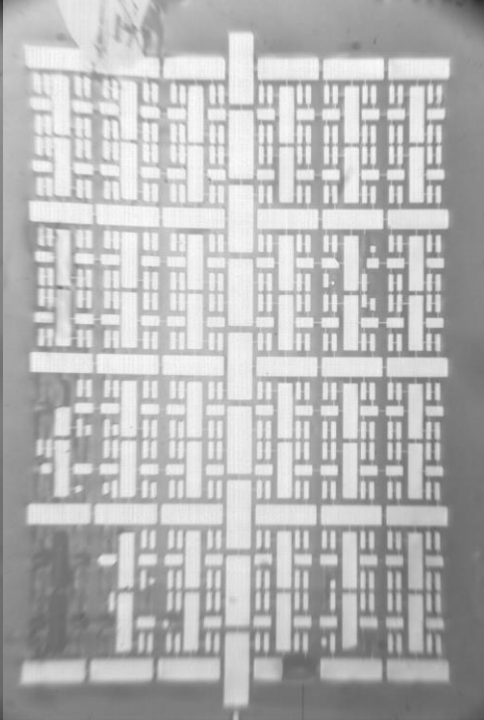
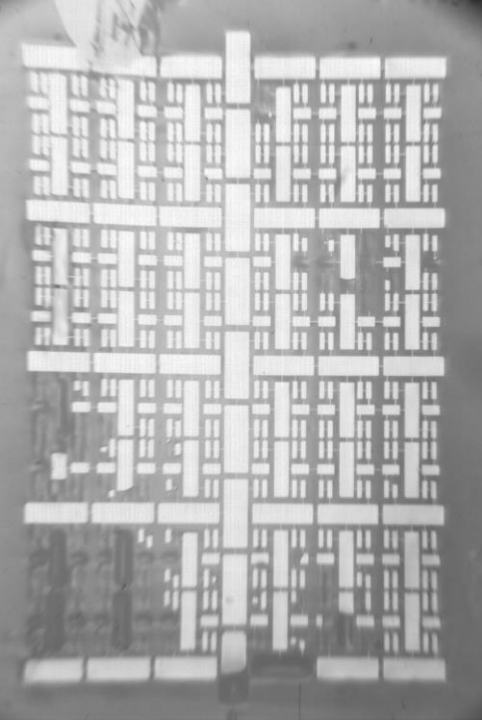
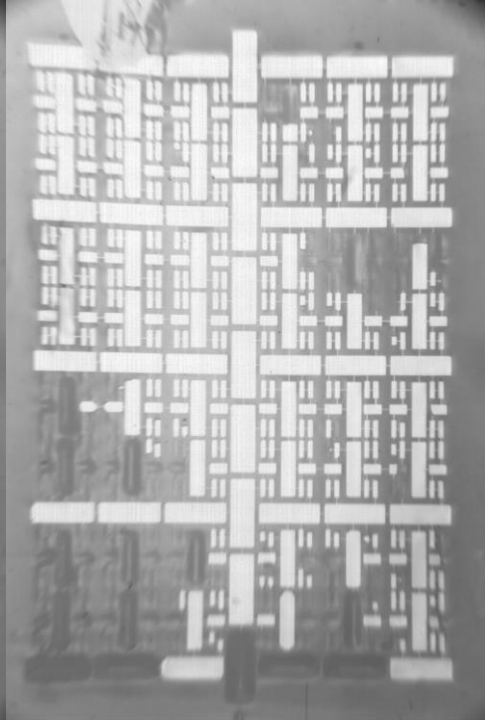
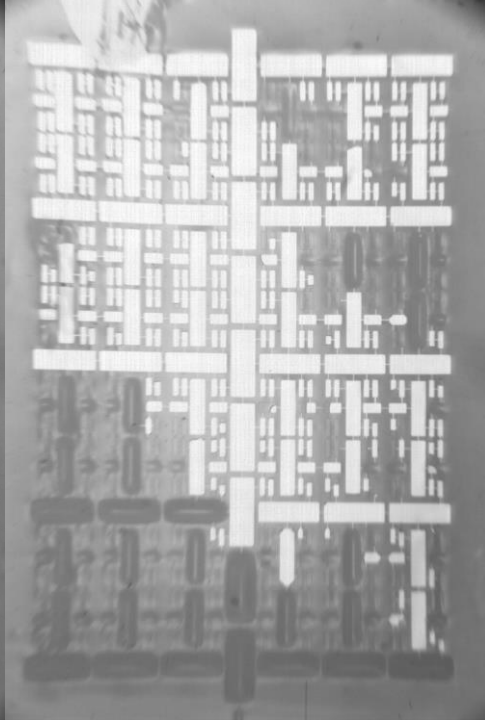
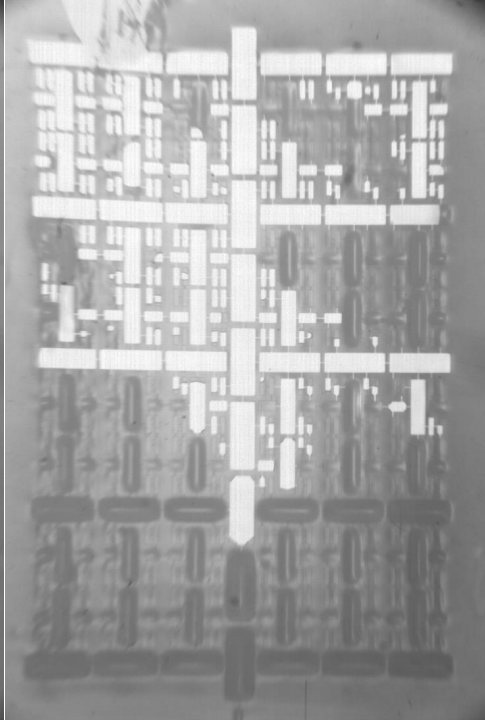
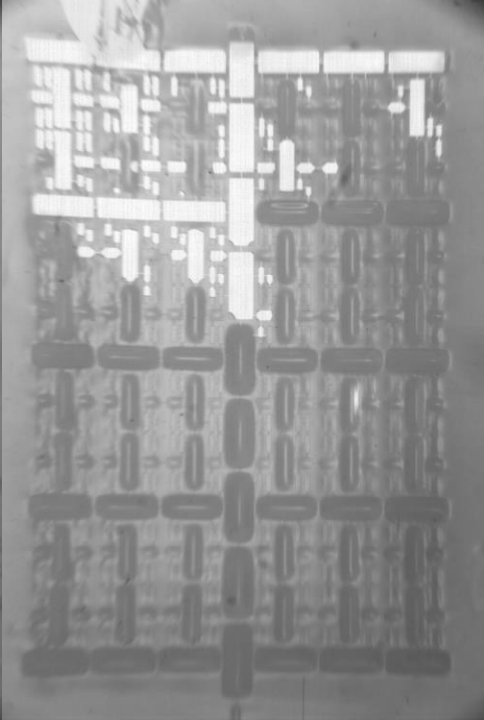
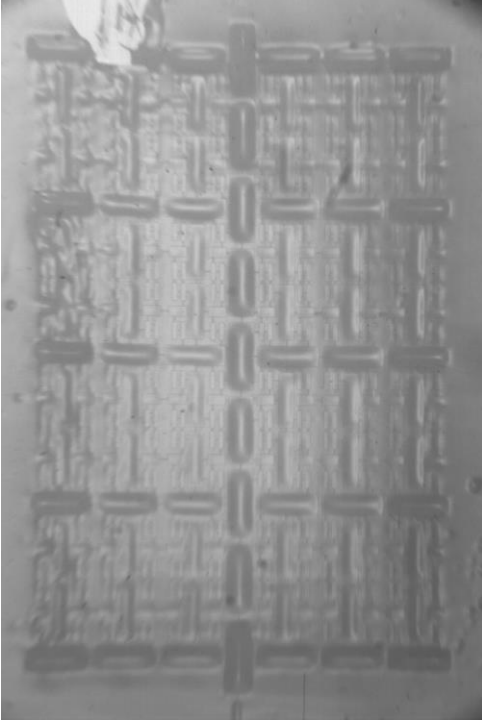
Embolism in the artificial leaf



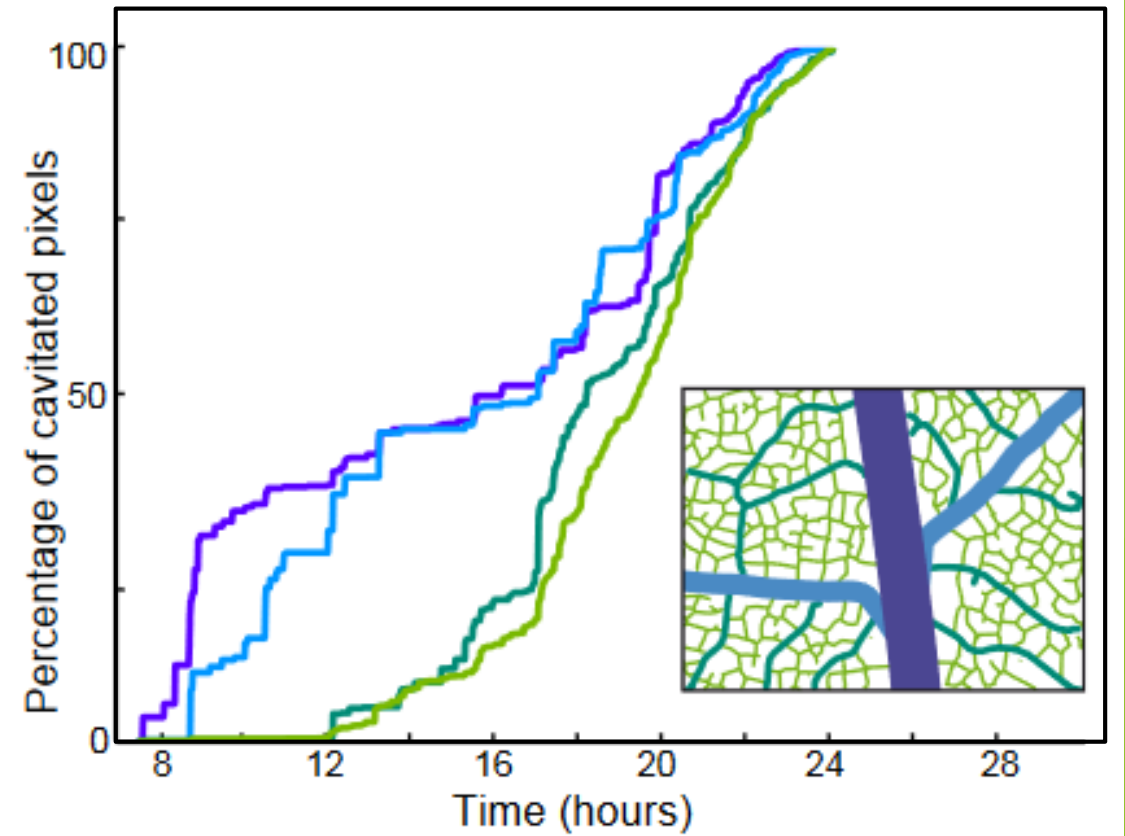
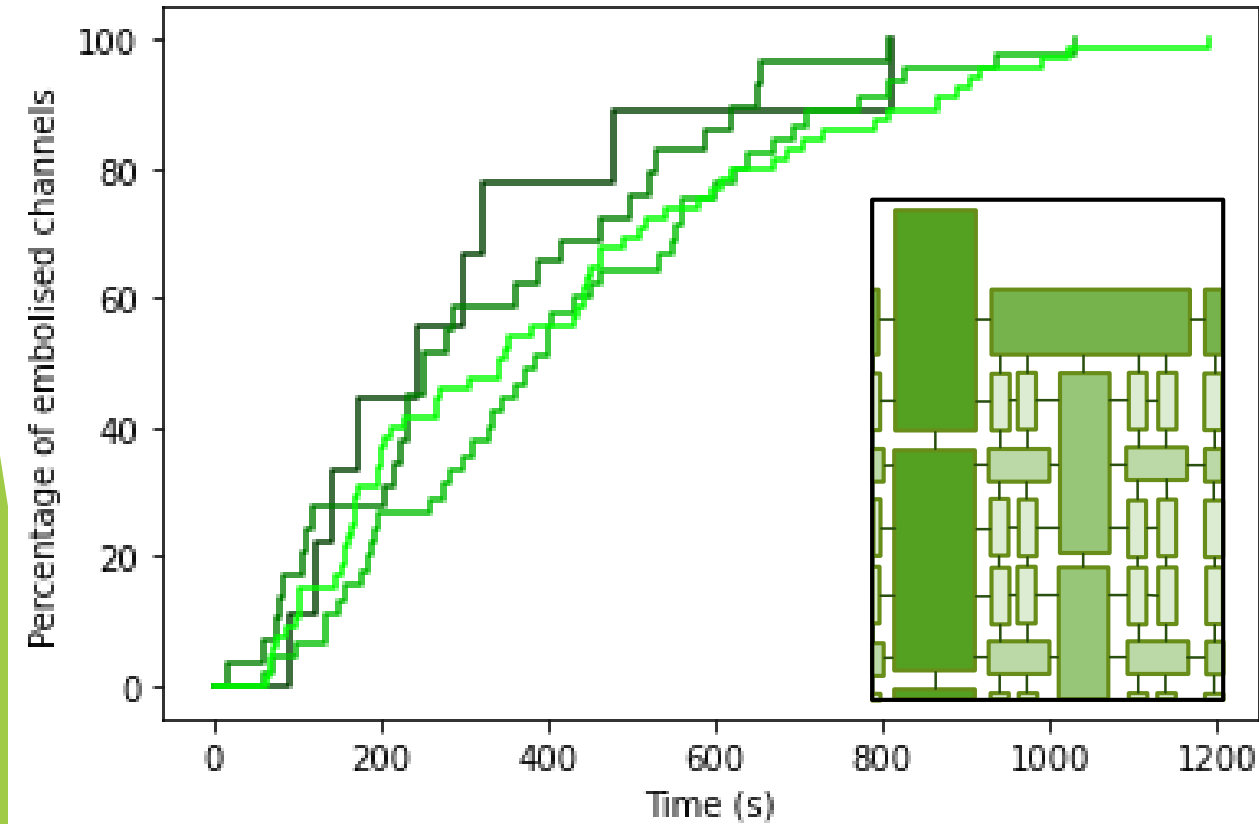
PDMS membrane made in clean room



5 hours of drying



Hierarchy recovered



T.J. Brodrigg, D. Bienaimé and P. Marmottant, PNAS, 2016

Perspectives

- ▶ Quantify more precisely
- ▶ Material to experimentally reach negative pressure (hydrogel)
- ▶ Work on real leaf and different species (INRAe Clermont-Ferrand)
- ▶ Refilling post drought

Physics of sap ascent : mechanism and biomimeticism - PHYSAP



Céline Cohen
François-Xavier Gauci
Ludovic Keiser
Xavier Noblin



Philippe Marmottant
Benjamin Dollet



Eric Badel
Hervé Cochard
Virgile Thievenaz
José Torres-Ruiz

Thank you for your attention