



Hydraulic Signals induced by bending in artificial and natural branches: link with plant mechanoperception and long-distance signaling in trees

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Jean-François Louf, Geoffroy Guéna, Olivier Pouliquen, Yoël Forterre, Hervé H. Cochard, et al.. Hydraulic Signals induced by bending in artificial and natural branches: link with plant mechanoperception and long-distance signaling in trees. SEB Annual Meeting, Jul 2014, Manchester, United Kingdom. , 1 p., 2014, Stem bending induces hydraulic pulse in vascular system: a physic. hal-01268589

HAL Id: hal-01268589

<https://hal.science/hal-01268589>

Submitted on 3 Jun 2020

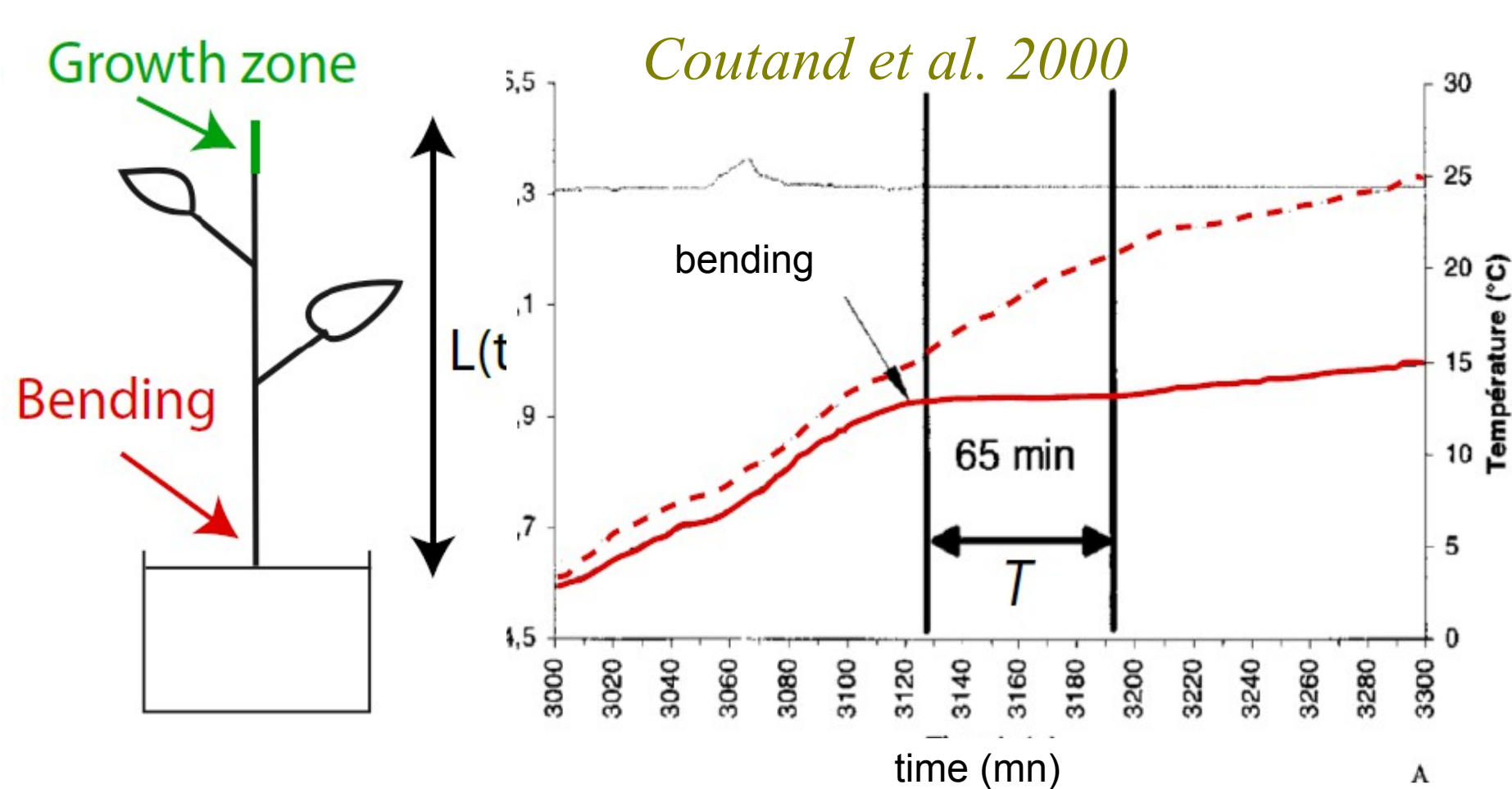
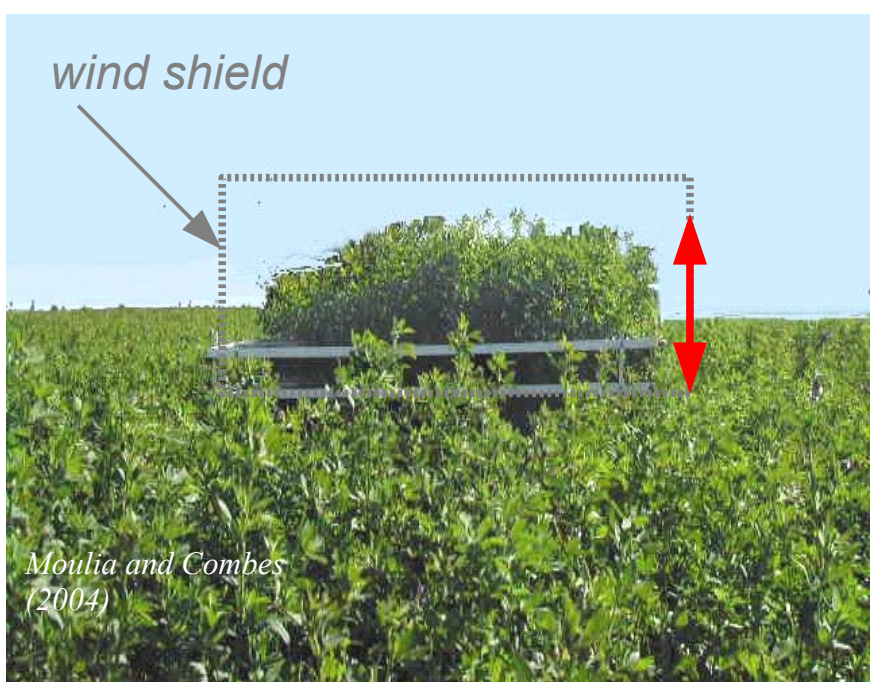
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Hydraulic signals induced by bending in artificial and natural branches : link with plant mechanoperception and long-distance signaling in trees

Growth response to mechanical stimuli (Thigmo-morphogenesis)

Mouliat and Combes 2004

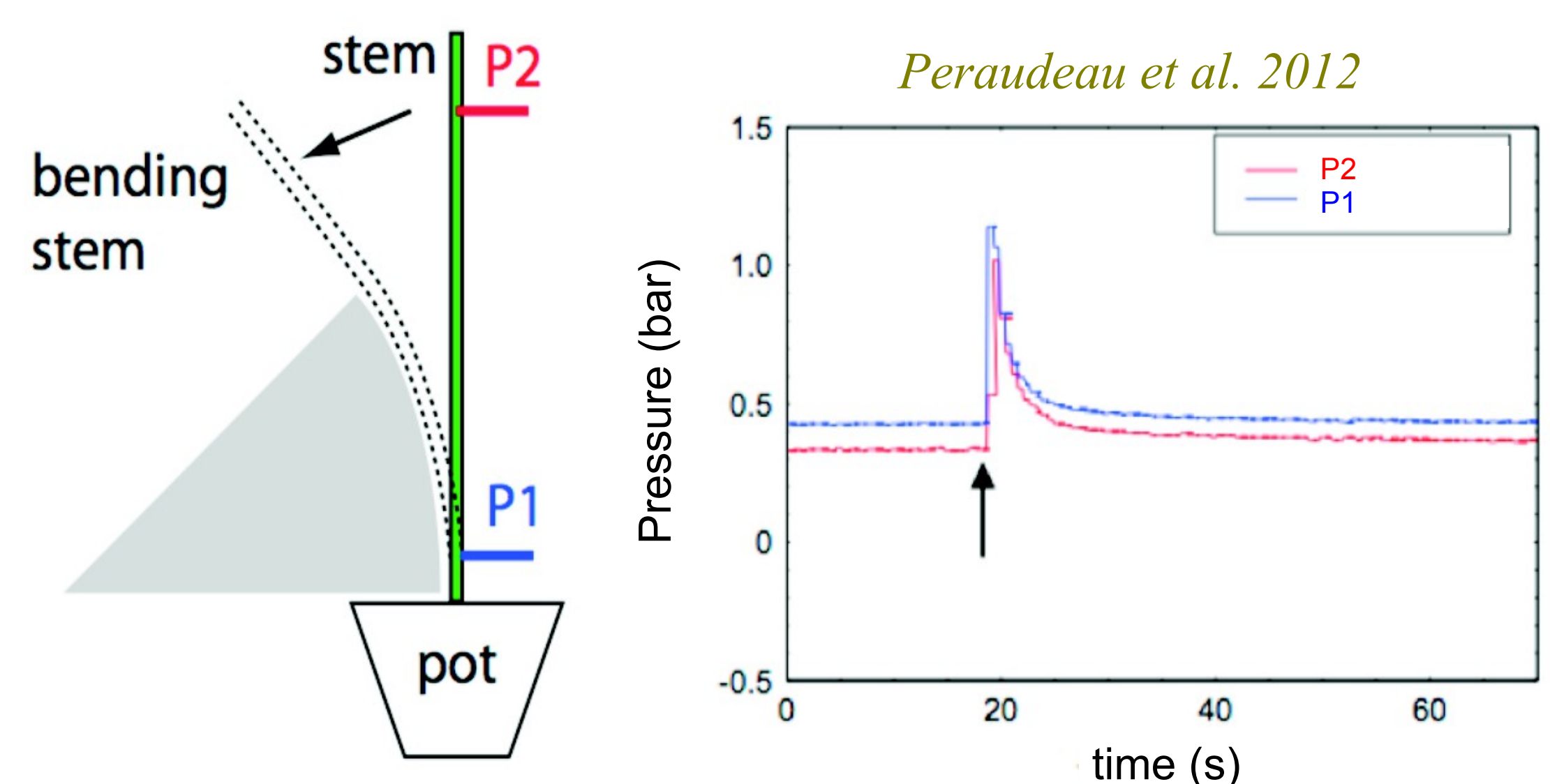


→ Origin of the long distance signaling?
Pressure pulse hypothesis?

Julien 1993, Malone 1994

Recent evidence of hydro/mechanical coupling in plants

É. Badel, H. Cochard, B. Mouliat (PIAF)

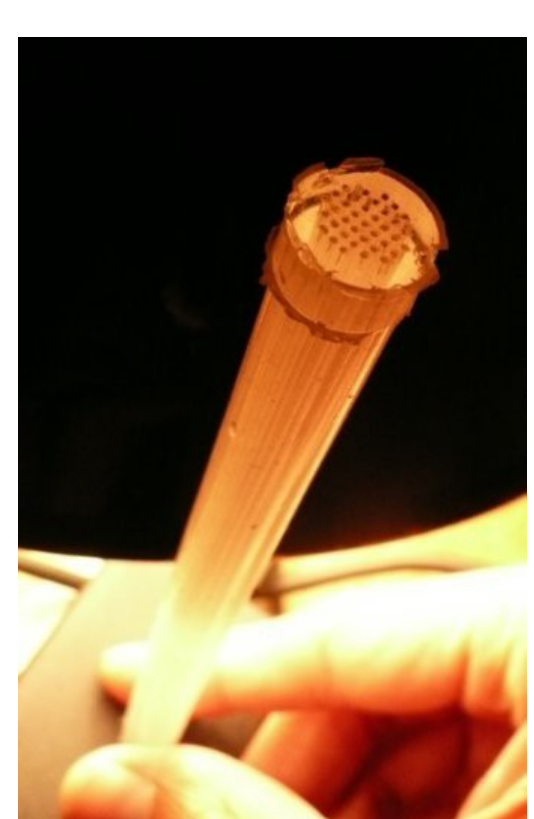


→ Physical mechanisms? (amplitude, speed, damping)

Our approach : study of the poroelastic reponse of artificial and natural branches

Artificial branches : physical modelling

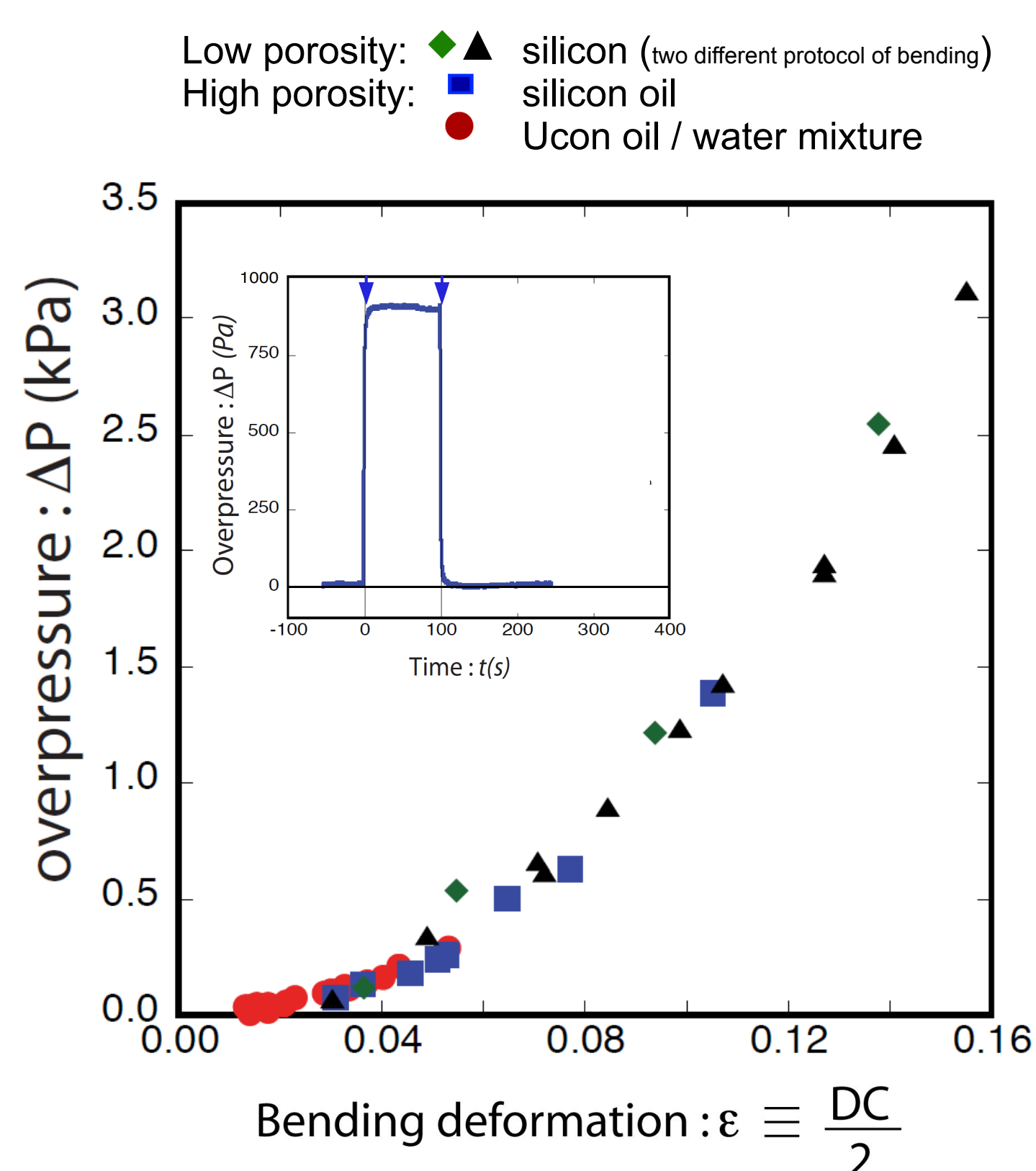
Original 3D microfluidic device:
elastomeric PDMS beam drilled with μ -channels



Experimental set-up

Porosity ~3-10 %

Artificial (PDMS) branches
Young modulus E
2. MPa
diameter of the channels
500 μ m
Permeability
200-700 μ m ²

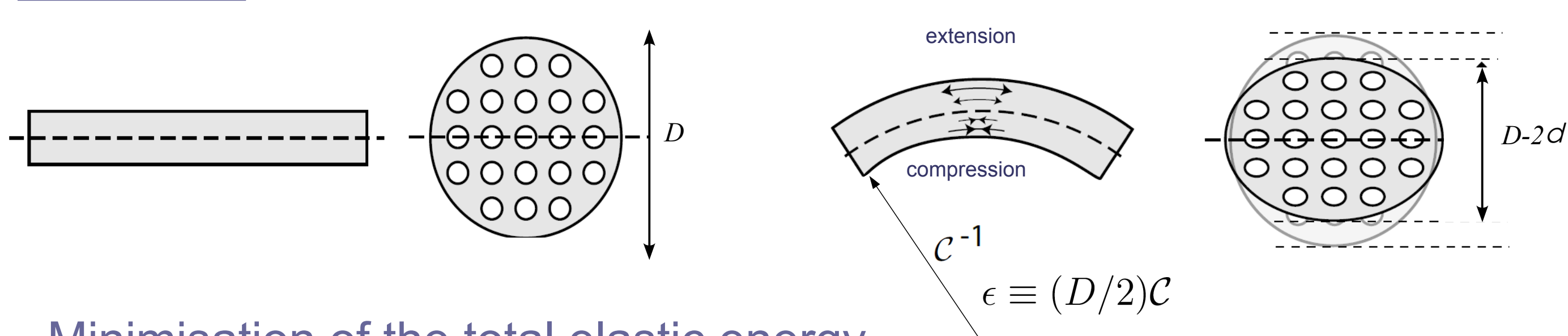


→ Pressure response to bending is non-linear:

$$\Delta P \sim \epsilon^2$$

Physical explanation and key parameters

Model : bending a porous beam induces a squeezing of the cross-section
initial state



Minimisation of the total elastic energy

$$\left. \begin{aligned} U_{bend}(\delta) &\approx \frac{EV}{32} (D - 2\delta)^2 C^2 \\ U_{squeeze}(\delta) &\approx \frac{EV}{2} \left(\frac{2\delta}{D} \right)^2 \end{aligned} \right\} \frac{2\delta}{D} \propto \epsilon^2 \Rightarrow \frac{\Delta V_c}{V_c} = -(1 - \nu_{2D}) \frac{2\delta}{D} \propto \epsilon^2$$

Relation pressure / volume: bulk modulus B

$$\Delta P = B \frac{\Delta V_c}{V_c} \Rightarrow$$

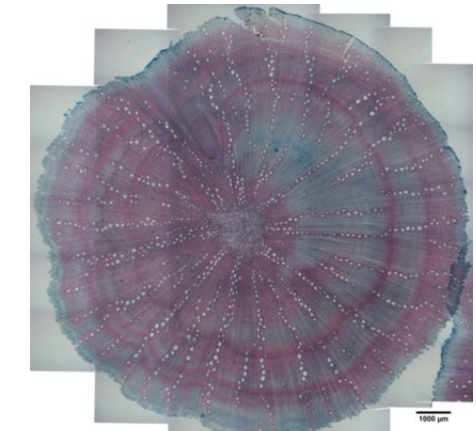
$$\Delta P \sim B \epsilon^2$$

Quantitative measurements on natural branches

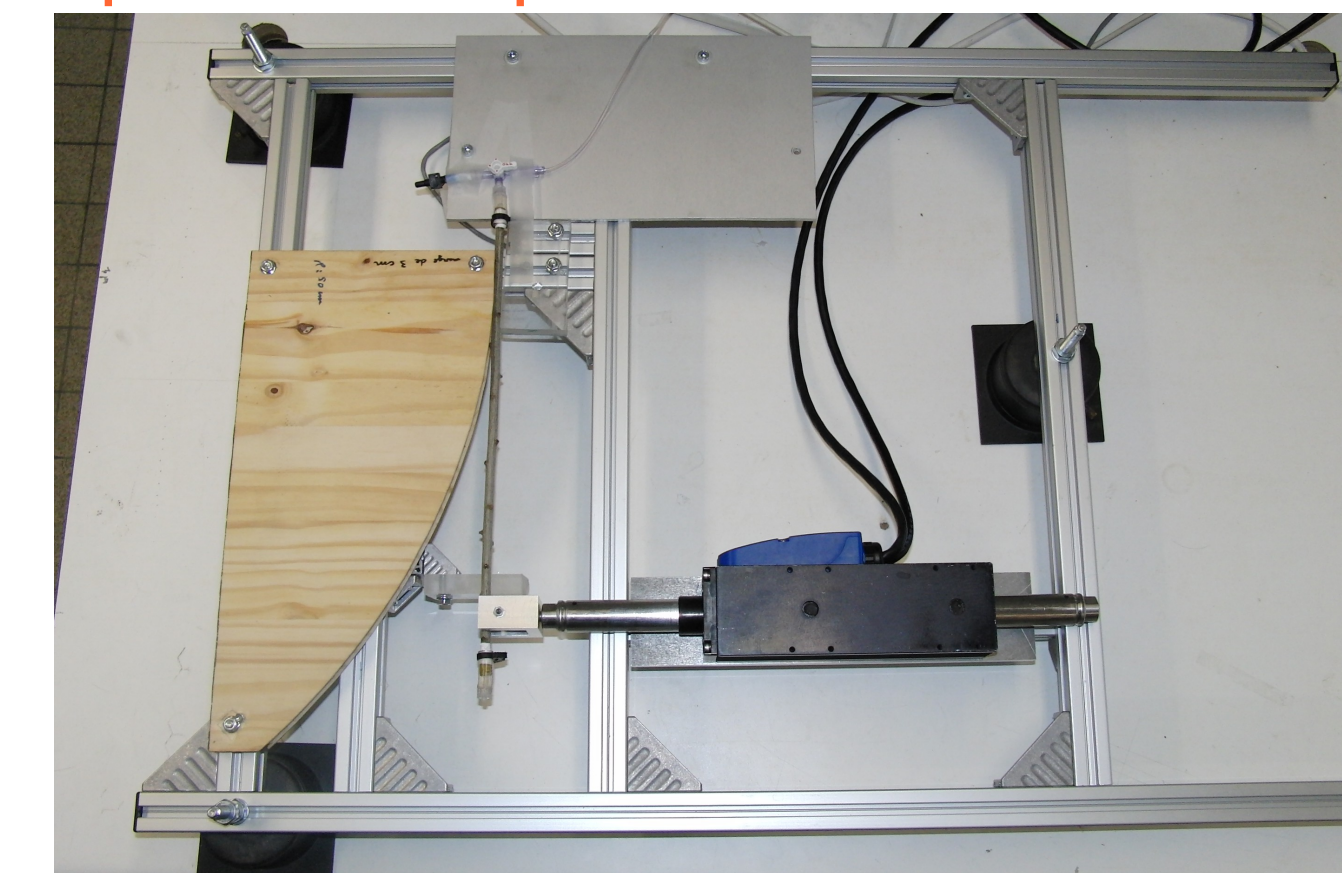
Natural branches properties

Length L ~ 20cm, Diameter D ~ 1cm
Porosity ~ 1-20 %

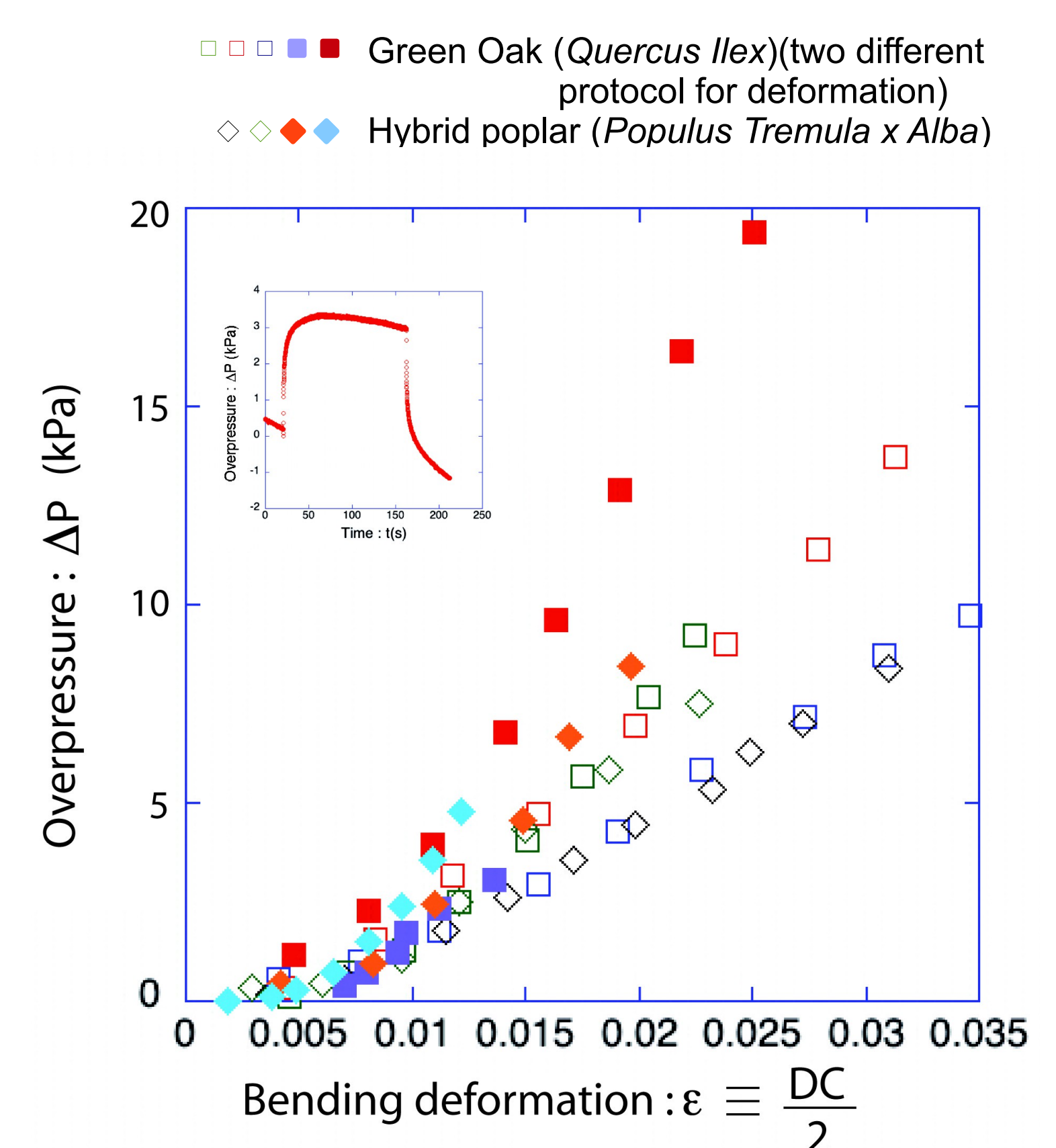
Cytological section



Experimental set-up

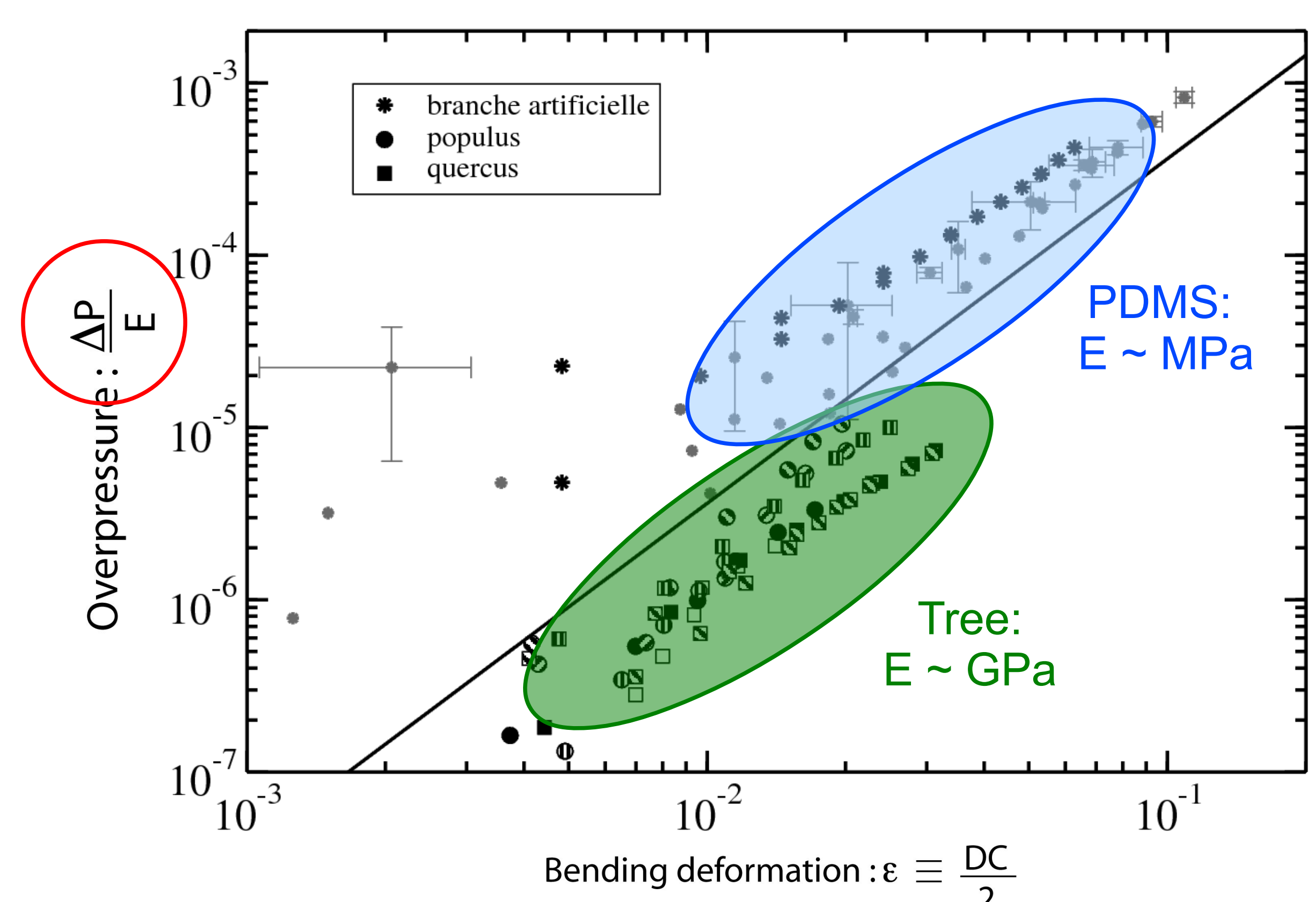


Hybrid Poplar	Green Oak
Young modulus E	
2.2 ± 1.0 GPa	3.7 ± 0.6 GPa
Mean diameter of the channels	
31 ± 14 μ m	51 ± 17 μ m
Permeability	
1.2 ± 0.4 μ m ²	1.3 ± 0.5 μ m ²



→ Same non-linear pressure response !

Comparison between artificial and natural branches



Perspectives:

Generalisation to other species
Role of these hydromechanical coupling in plants mechanoperception