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Walnut winter pressure build-up explained through physical modelling

Cyril Bozonnet, M. Saudreau, Eric Badel, Guillaume Charrier, Thierry Ameglio

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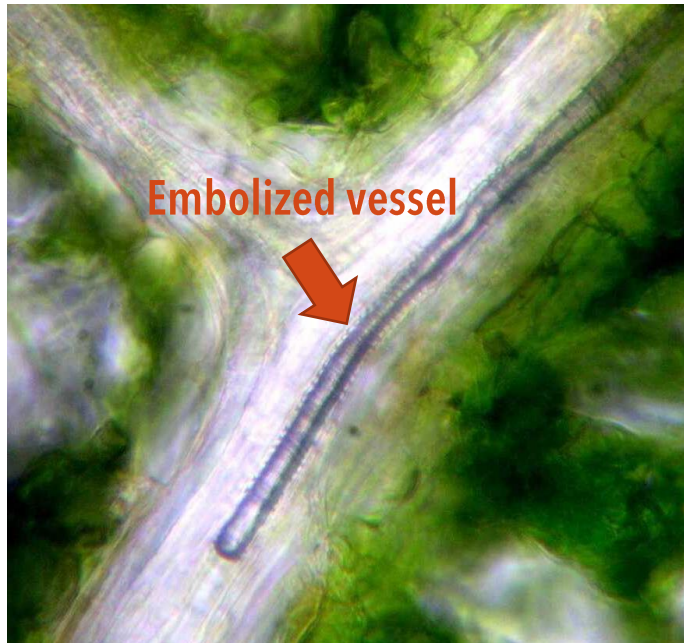
EMBOLISM RECOVERY IN WALNUT TREE DURING WINTER: A PHYSICAL MODEL

Cyril Bozonnet, Marc Saudreau, Eric Badel,
Guillaume Charrier, Thierry Améglio



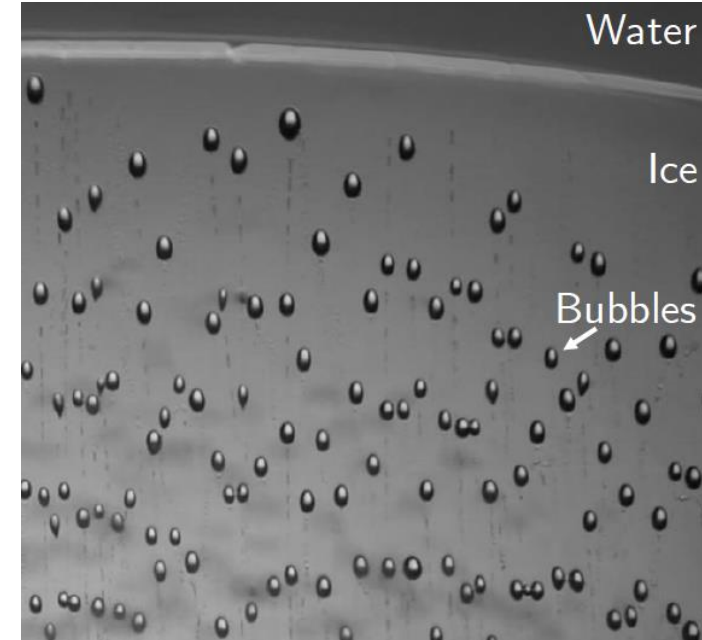
EMBOLISM: HOW IT HAPPENS

Summer:
excessive tension on the water column



© Hervé Cochard

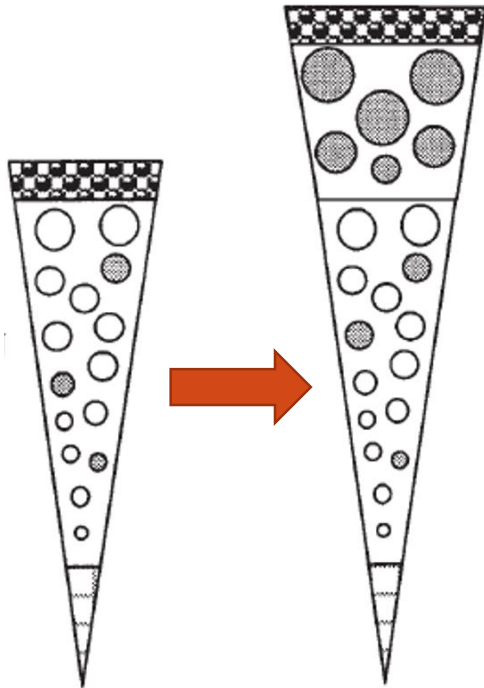
Winter:
Freeze/thaw cycles



Thievenaz *et al*, 2024

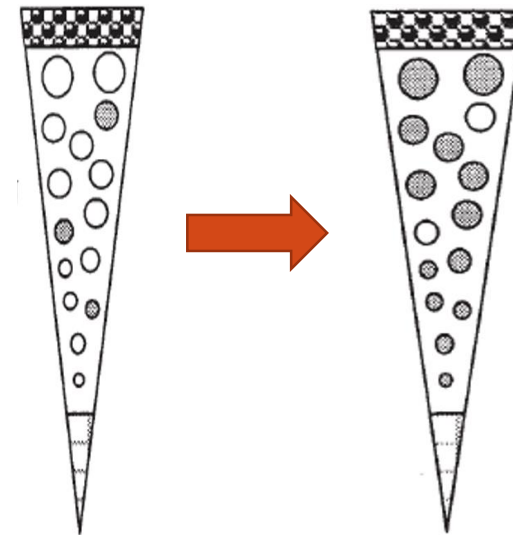
EMBOLISM RECOVERY: HOW IT HAPPENS

Creation of new vessels

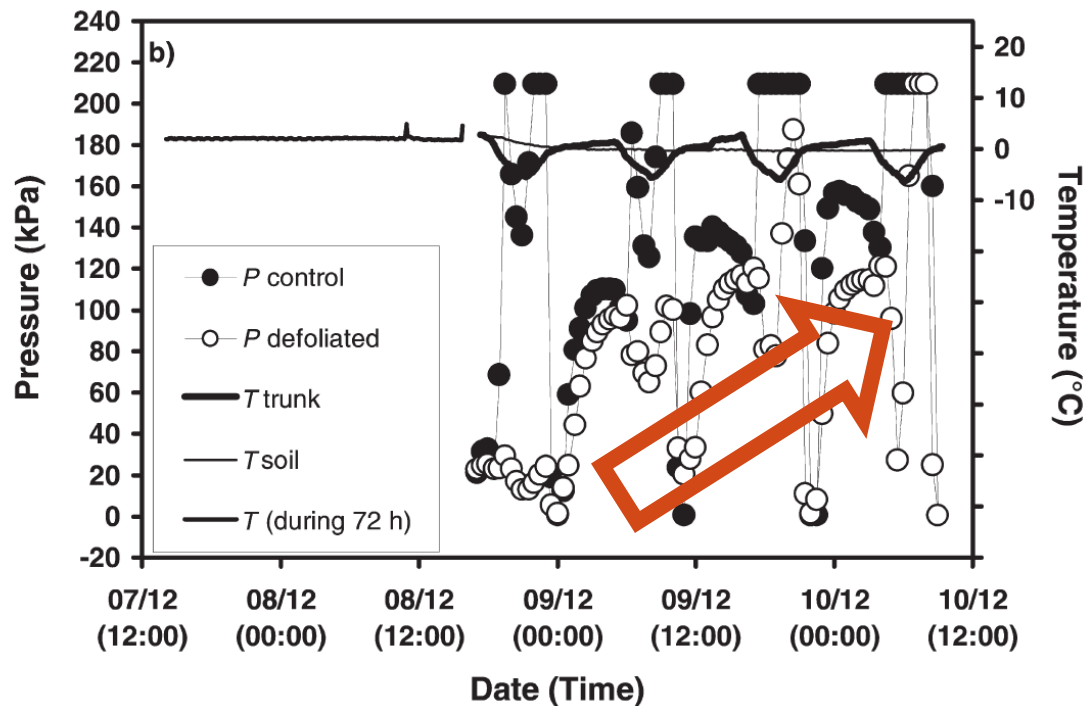


Refilling by positive pressure

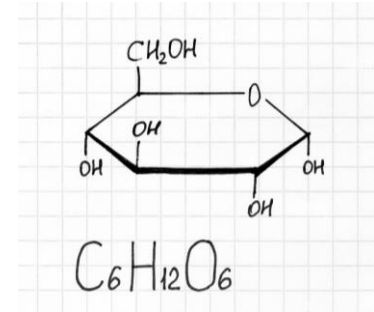
From the roots or **from the stems**



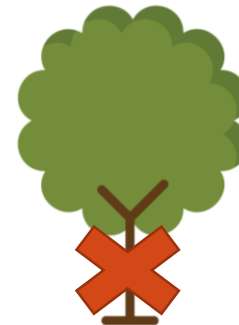
STEM PRESSURE IN WALNUT TREE: WHAT DO WE KNOW?



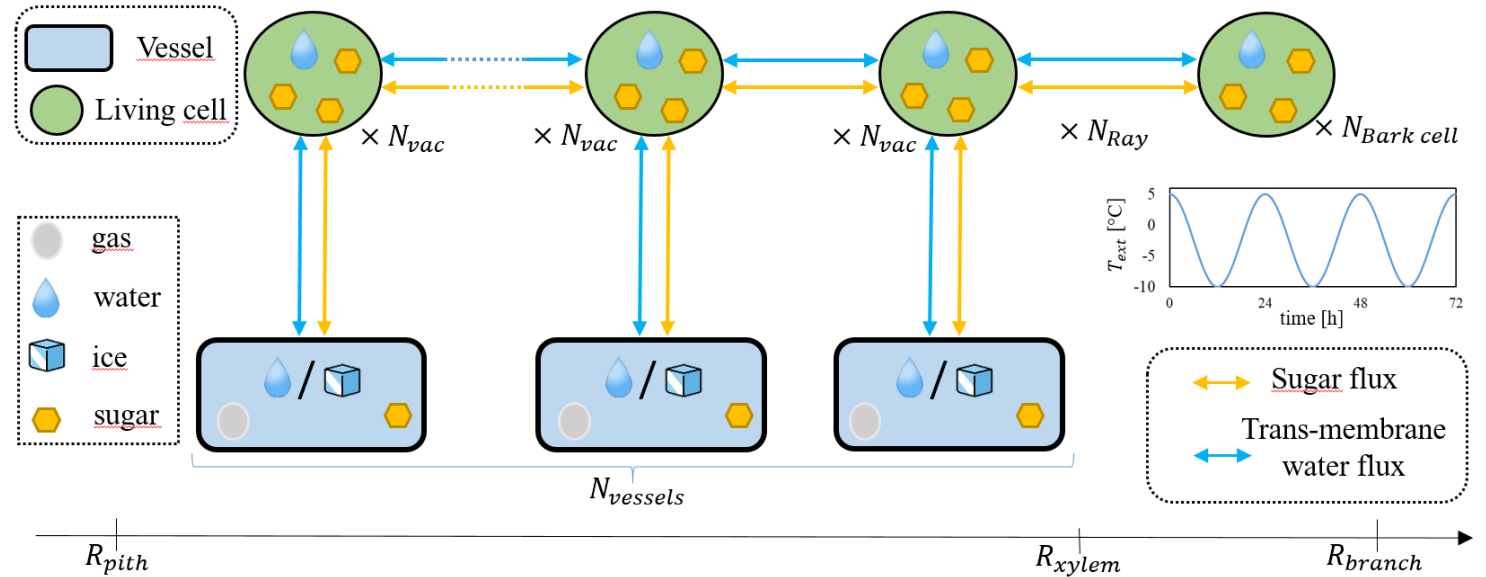
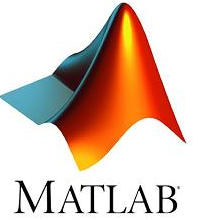
Améglio *et al*, Tree Phys., 2001



$P(t)$



PHYSICAL MODELLING: TO REPRODUCE & UNDERSTAND



Heat transfer and phase change

$$\frac{dH}{dt} = \frac{1}{\rho} \nabla \cdot (k \nabla T)$$

$$p_{ice} = \rho_w L \ln \left(\frac{T}{T_0} \right)$$

Water fluxes and P-V relationships

$$Q = k(\Delta P - \Delta \Pi)$$

$$\frac{dP^{liv}}{dt} = \frac{E}{V^{liv}} \frac{dV^{liv}}{dt} \quad p^v \approx \frac{nR_g T}{V_g^v}$$

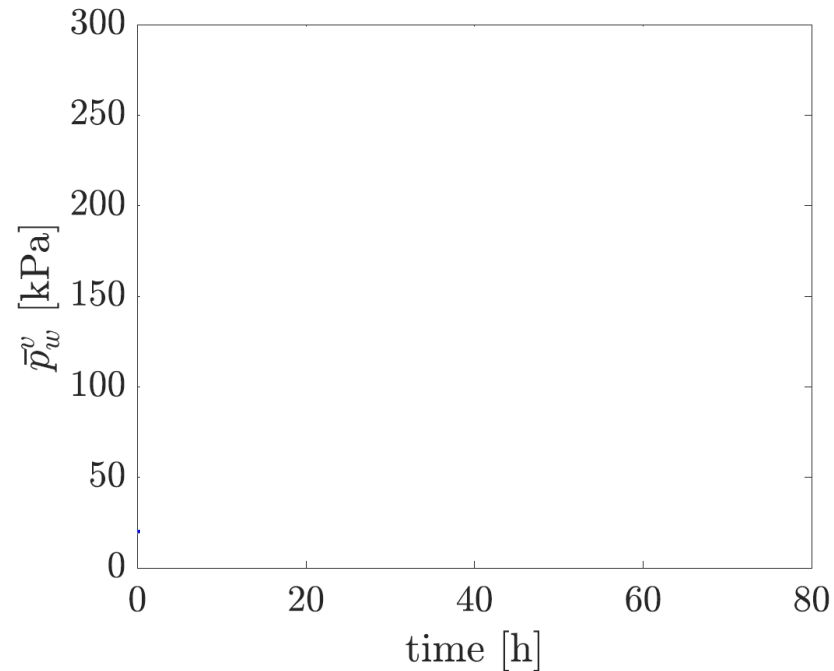
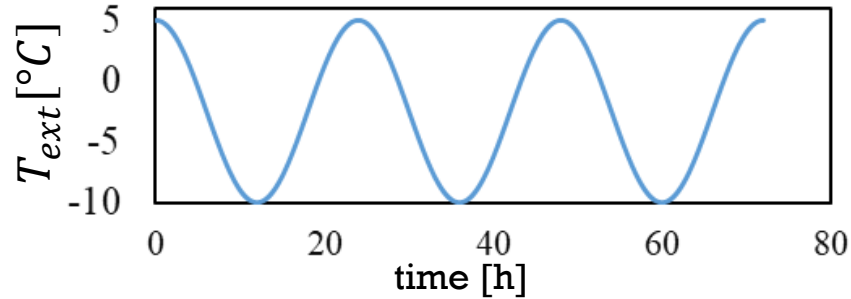
Diffusive sugar fluxes

$$C_s = \frac{n_s}{V}$$

$$\frac{dn_s}{dt} = D_s \Delta C_s$$

RESULTS:

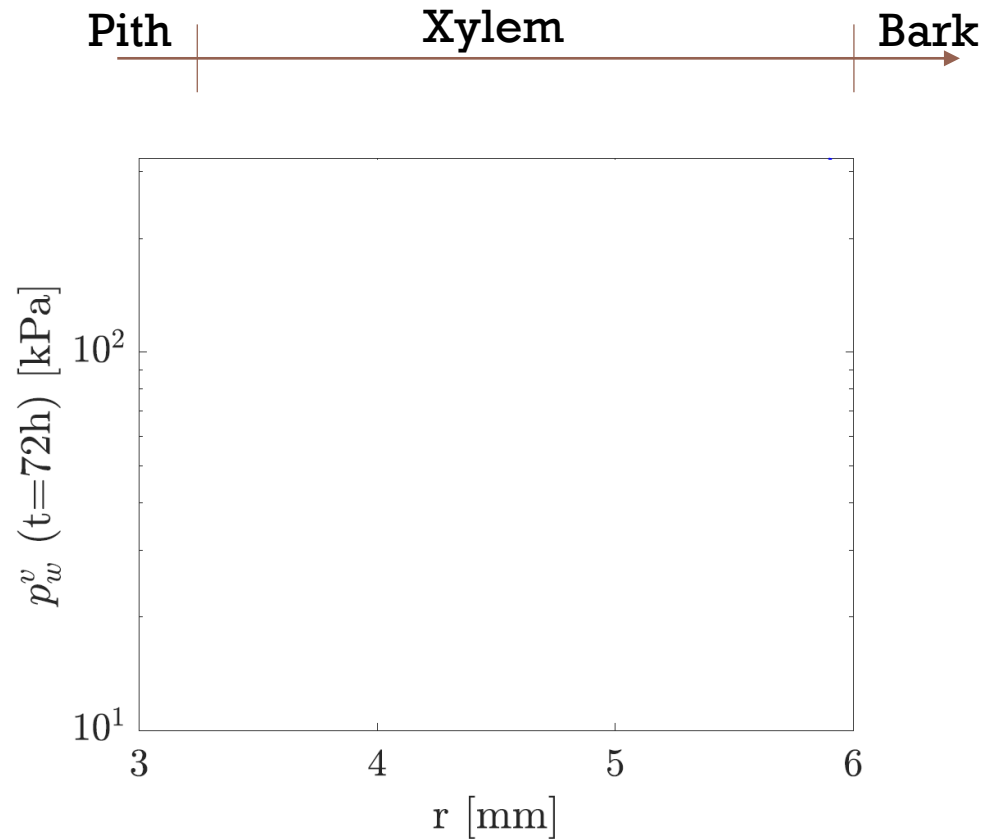
EFFECT OF SUGAR FLUXES



- ❖ No sugar fluxes
 - No pressure build-up
- ❖ With vessel-VAC fluxes
 - Very little pressure build-up (+0.7kPa)
- ❖ With vessel-VAC and ray fluxes
 - Significant pressure build-up (+43kPa)

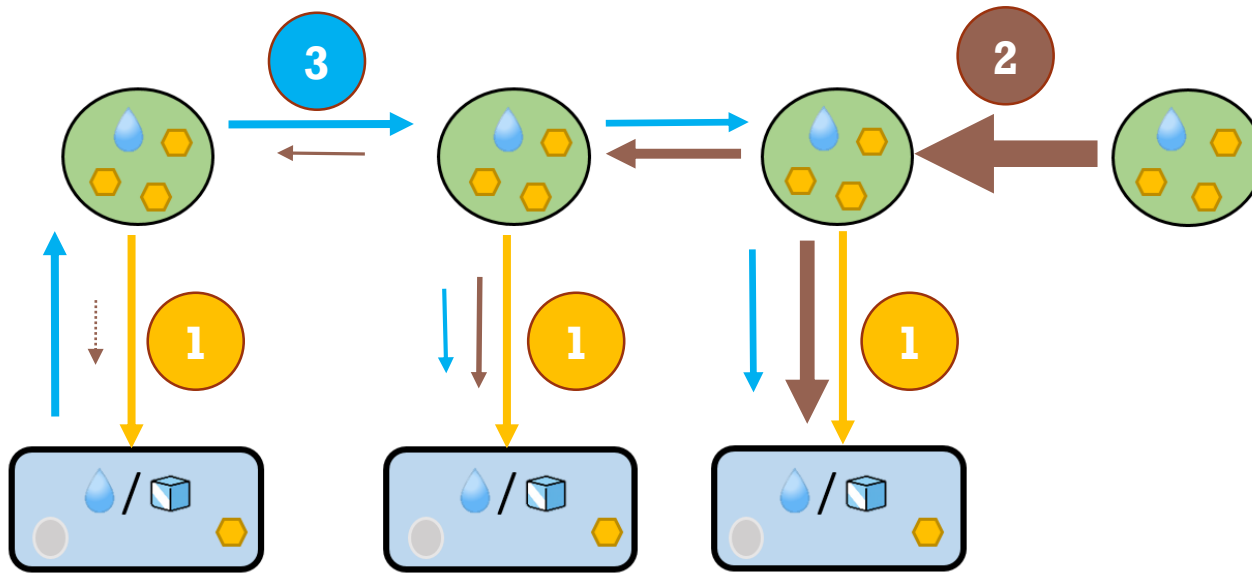
RESULTS:

EFFECT OF SUGAR FLUXES



- ❖ No sugar fluxes
 - Nearly homogeneous pressure profile
- ❖ With vessel-VAC fluxes
 - Homogeneous pressure profile
- ❖ With vessel-VAC and ray fluxes
 - Very high radial gradient

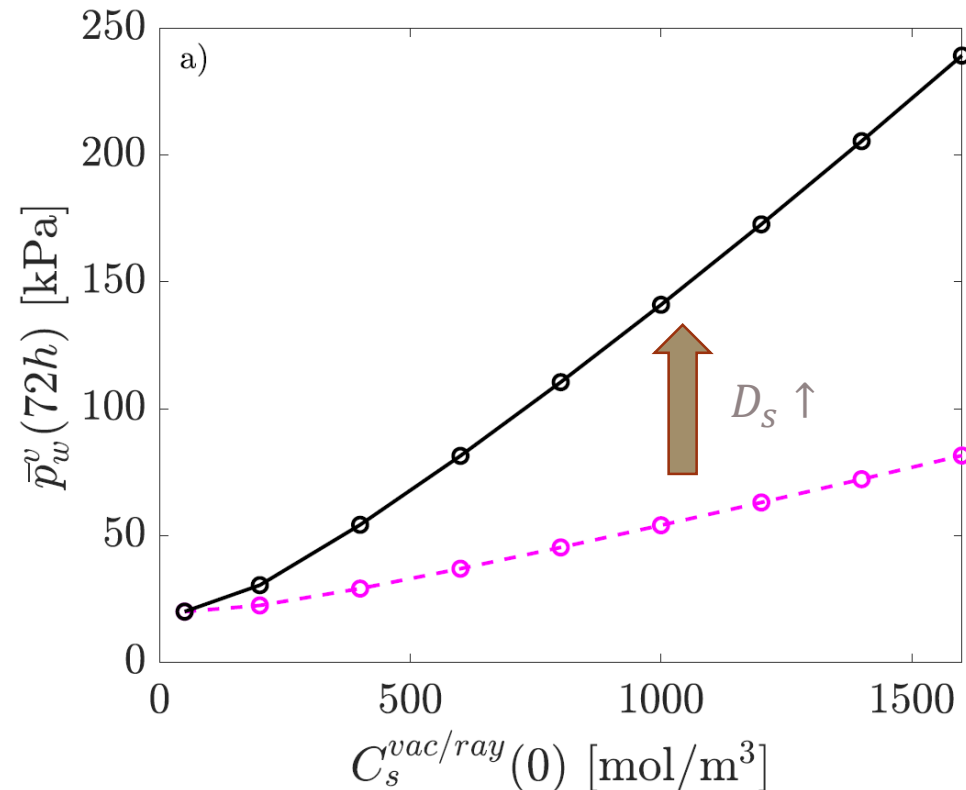
WHAT HAPPENS? FOR $T > 0^\circ\text{C}$



- 1 Water and sugar fluxes VAC \leftrightarrow vessels
- 2 Sugar and water transport from the bark
 - Strong radial osmotic gradient
- 3 Water fluxes between vessels
 - Mean pressure increase ($P \sim \frac{nRT}{V}$)
 - **The pressure build-up is not homogeneous across the stem!**

RESULTS:

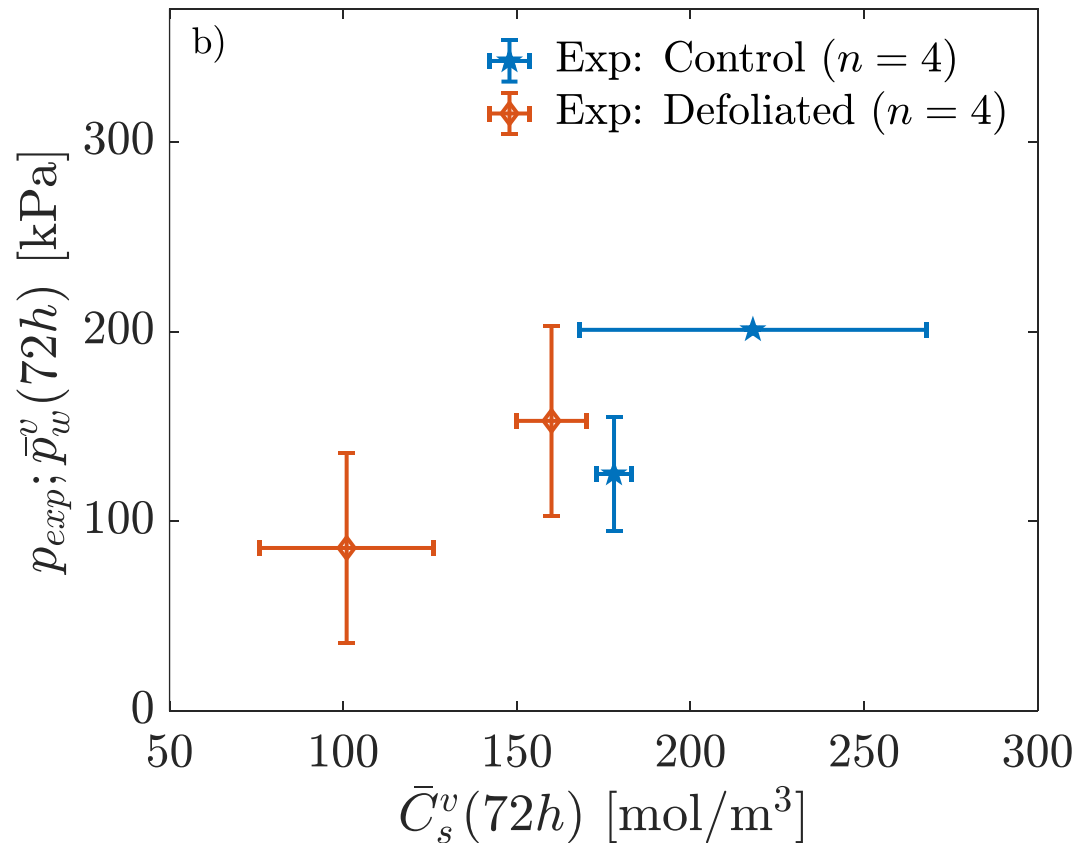
VESSEL PRESSURE VS LIVING CELL INITIAL SUGAR CONTENT



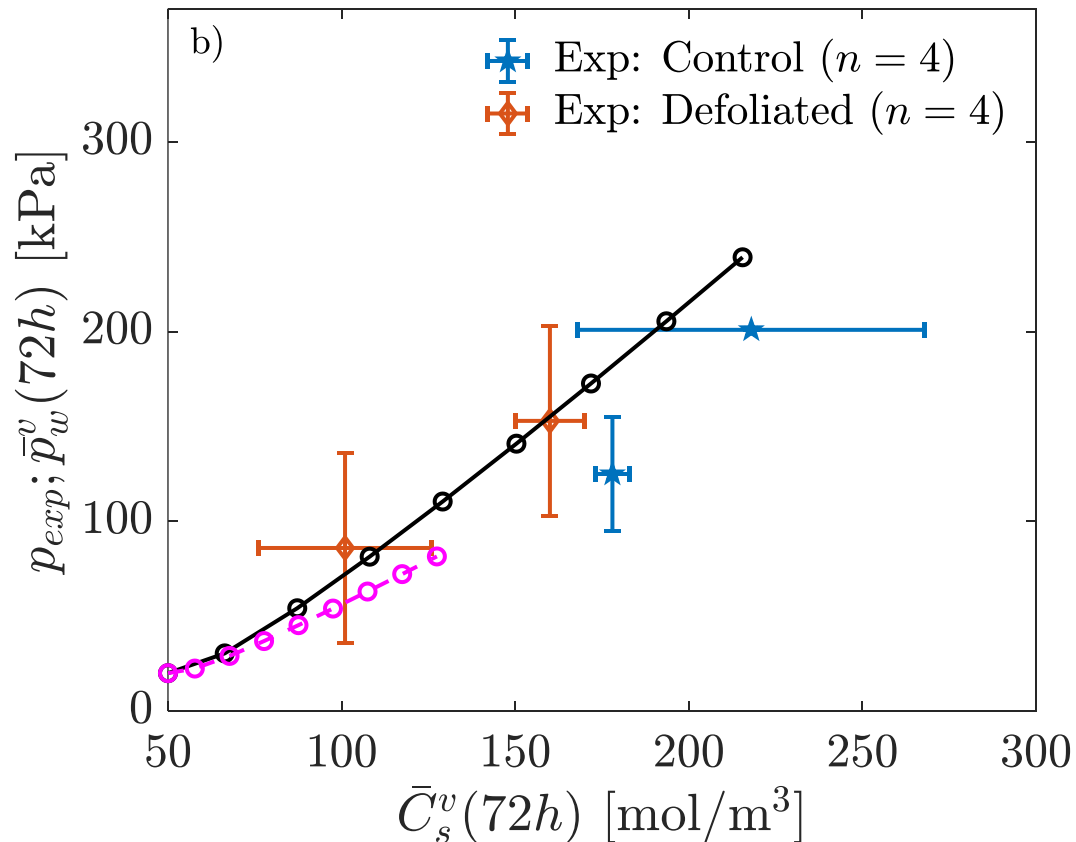
Stem pressure build-up occurs if:

- Living cells contain soluble sugar
- Transport is possible (makes things faster!)

VALIDATION: VESSEL PRESSURE VS VESSEL SUGAR CONTENT



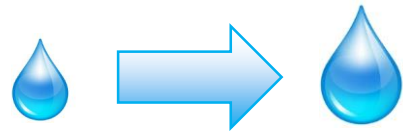
VALIDATION: VESSEL PRESSURE VS VESSEL SUGAR CONTENT



- ✓ Strong correlation between vessel pressure and vessel sugar content (both are measurements/results !)
- ✓ Similar magnitudes.

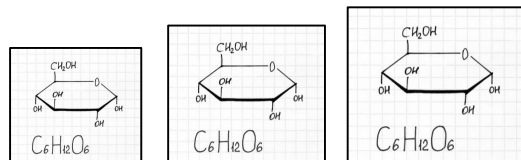
TO SUM-UP:

Stem pressure build-up in walnut tree seems to be due to...



...a transfer of water between vessels across the ray,

triggered by



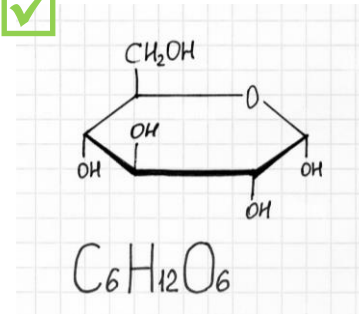
a radial imbalance in sugar concentration.

The ability to dispose of soluble sugar and transport them radially are keys to pressure build-up.

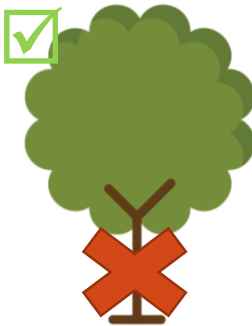
Unique abilities in species that develop stem pressure?

TO SUM-UP: & PERSPECTIVES

Addition of temperature dependant H⁺/sugar co-transport?



P(t)



Adding dissolved gas expulsion from freezing water?

Heterogeneous pressure build-up → Heterogeneous recovery?



Tree Physiology 00, 1–19
<https://doi.org/10.1093/treephys/tpad117>

Research paper

Freeze dehydration vs supercooling in tree stems: physical and physiological modelling

Cyril Bozonnet^{1,2}, Marc Saudreau¹, Eric Badel¹, Thierry Améglio¹ and Guillaume Charrier¹

Tree Physiology, 2024, **44**, tpae037
<https://doi.org/10.1093/treephys/tpae037>
Advance access publication date 26 March 2024
Research paper



On the mechanism for winter stem pressure build-up in walnut trees

Cyril Bozonnet^{*}, Marc Saudreau, Eric Badel, Guillaume Charrier[†], Thierry Améglio[†]

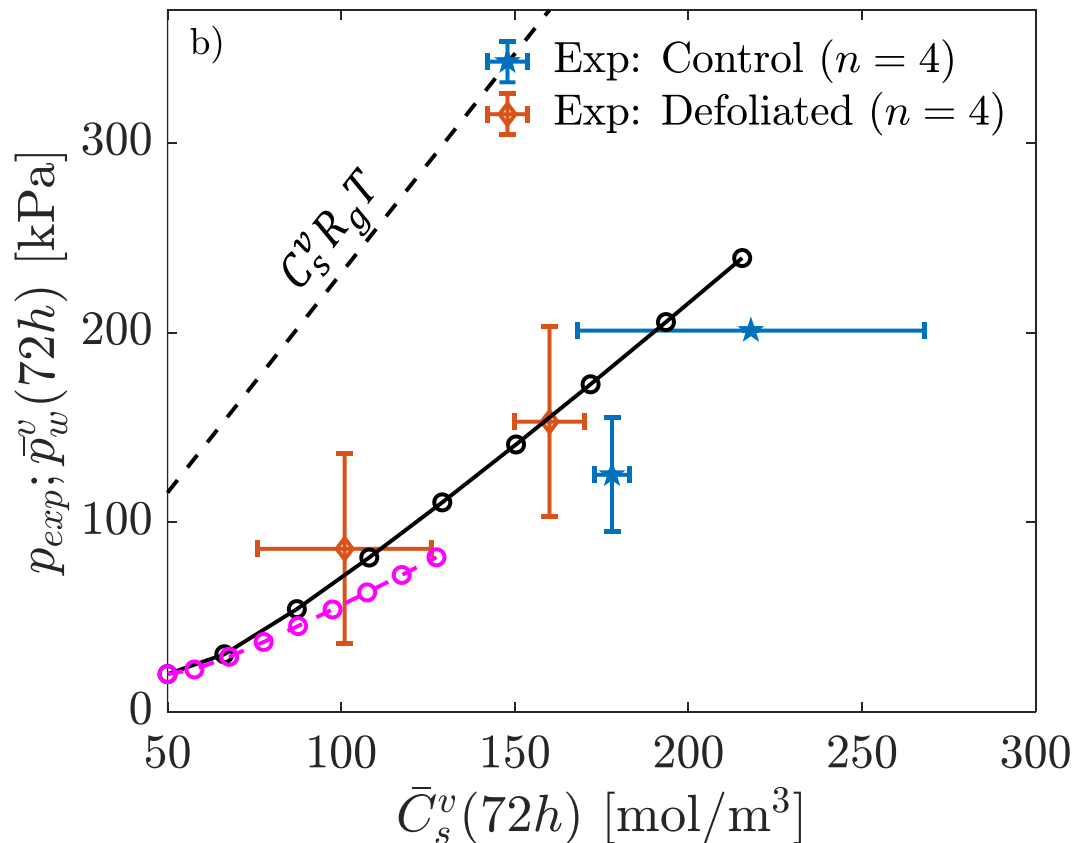
Code available at: <https://github.com/cyrilbz>

Thank you !



Back-up slides

VALIDATION: VESSEL PRESSURE VS VESSEL SUGAR CONTENT



- ✓ Strong correlation between vessel pressure and vessel sugar content (both are measurements/results !)
- ✓ Similar magnitudes.