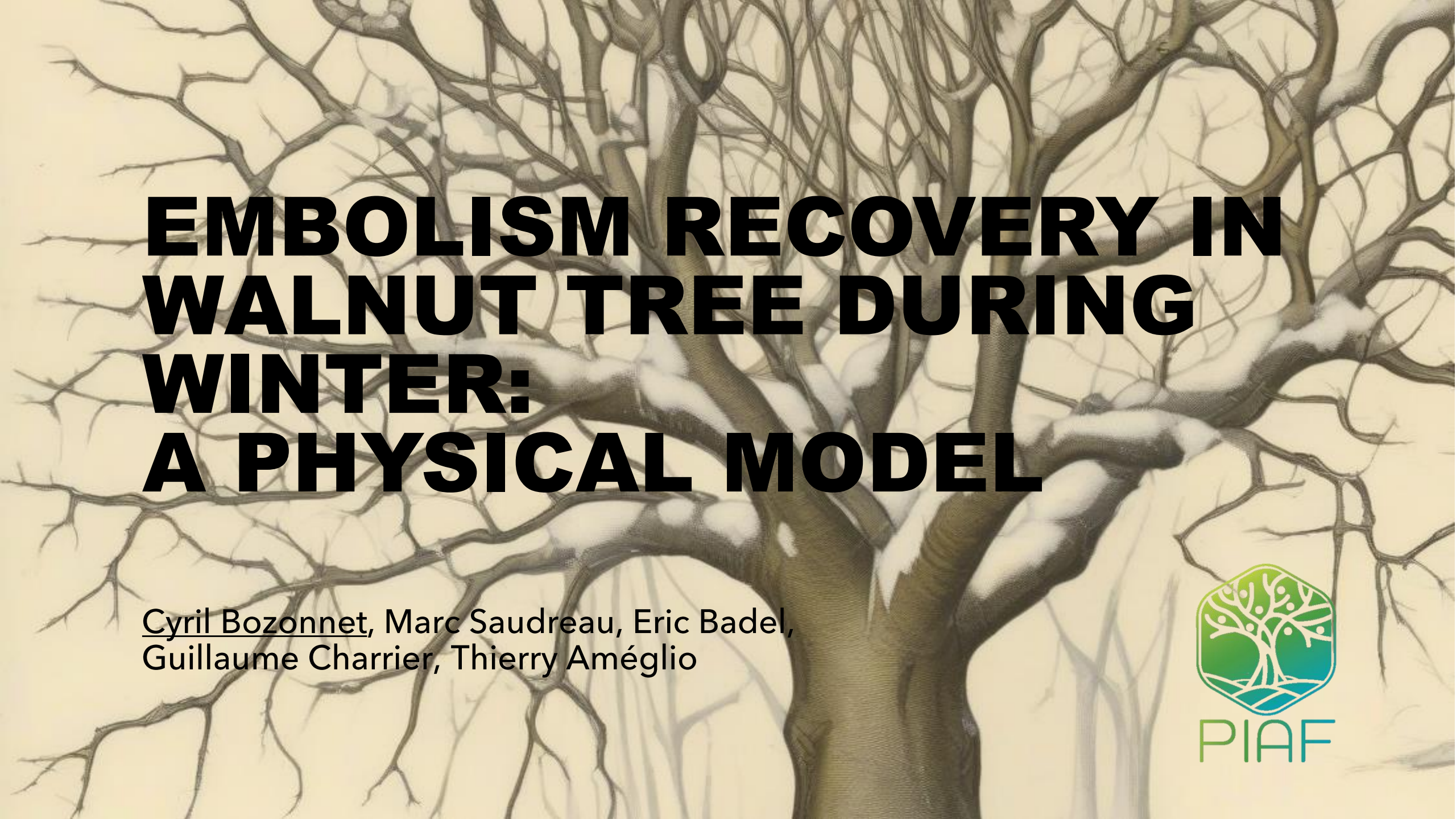
# Walnut winter pressure build-up explained through physical modelling

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



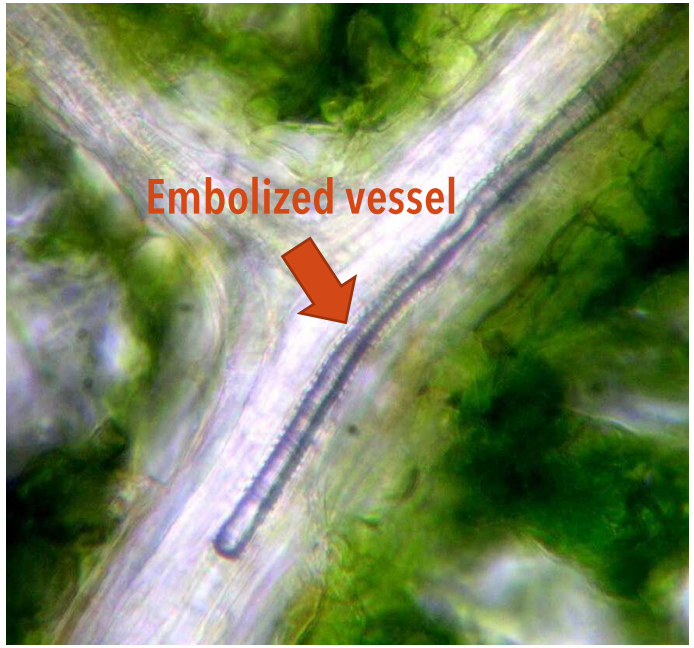
# EMBOLISM RECOVERY IN WALNUT TREE DURING WINTER: A PHYSICAL MODEL

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

PIAF

# EMBOLISM: HOW IT HAPPENS

Summer:
**excessive tension** on the water column

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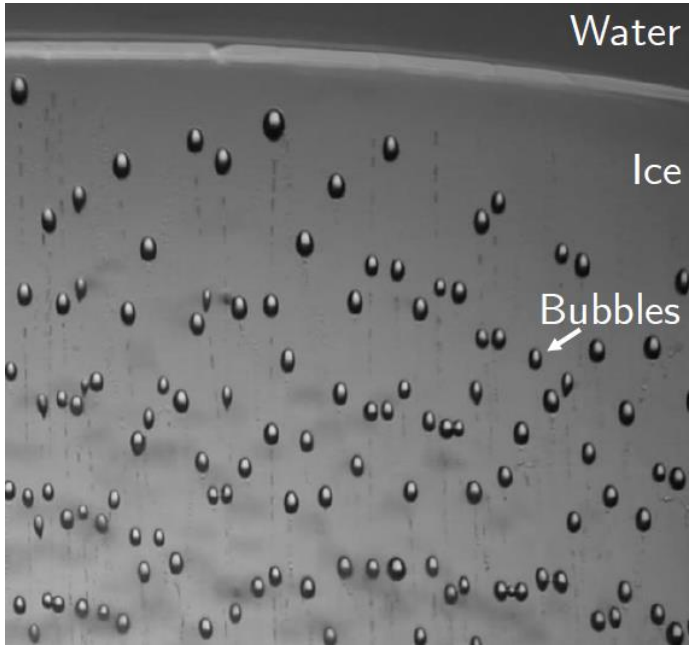
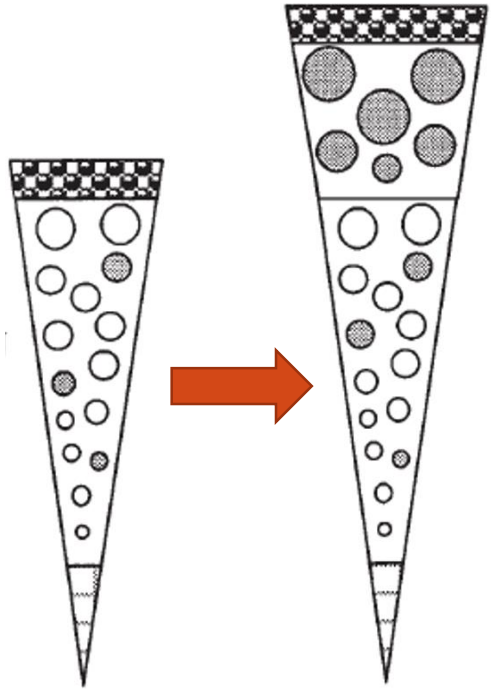
Winter:
**Freeze/thaw cycles**




Thievenaz *et al*, 2024

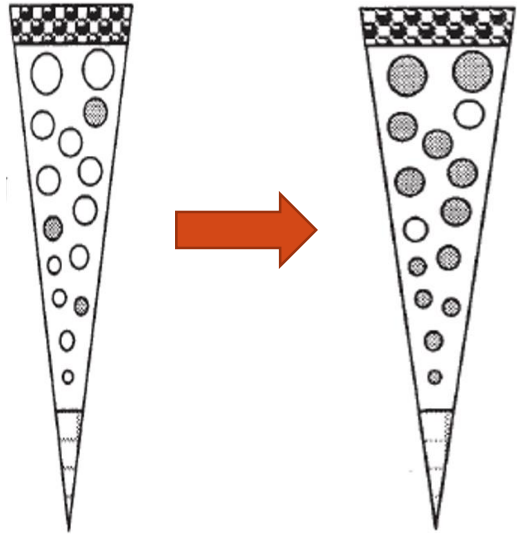
# EMBOLISM RECOVERY: HOW IT HAPPENS

## Creation of new vessels



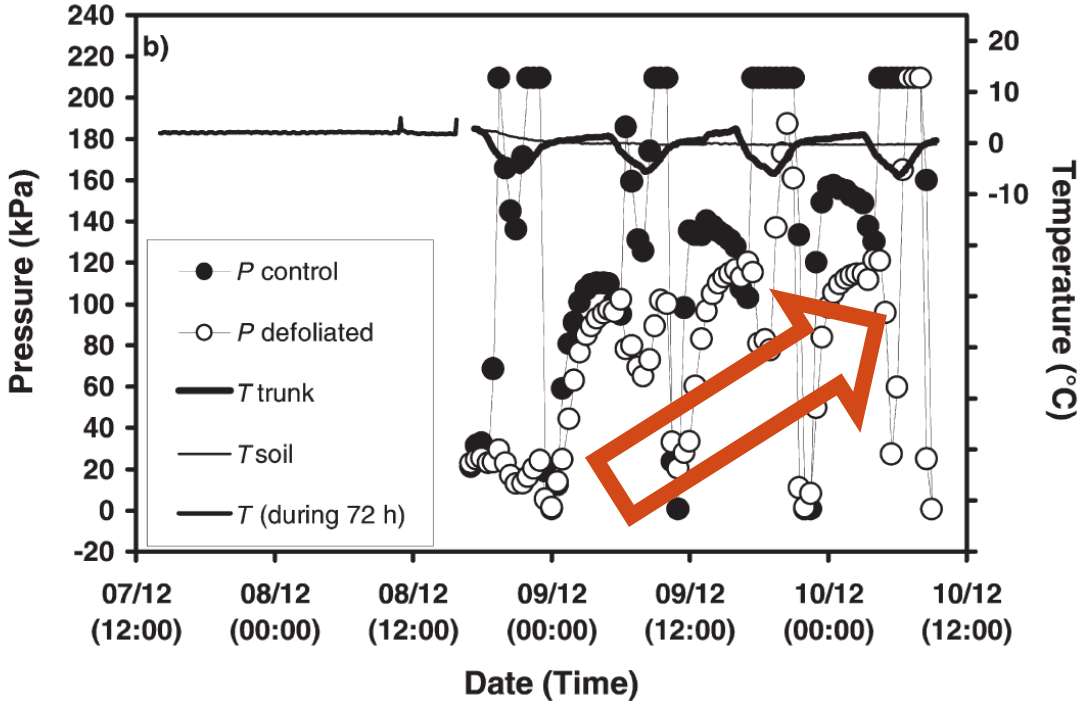
## Refilling by positive pressure

From the roots or from the stems

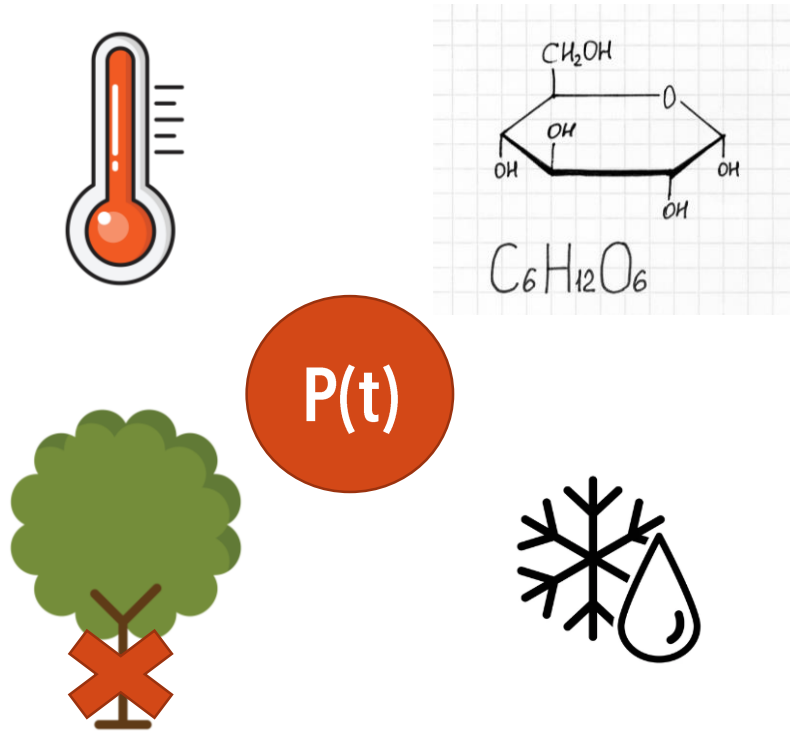


Pictures from Cochard *et al*, Tree Phys., 2001

# STEM PRESSURE IN WALNUT TREE: WHAT DO WE KNOW?



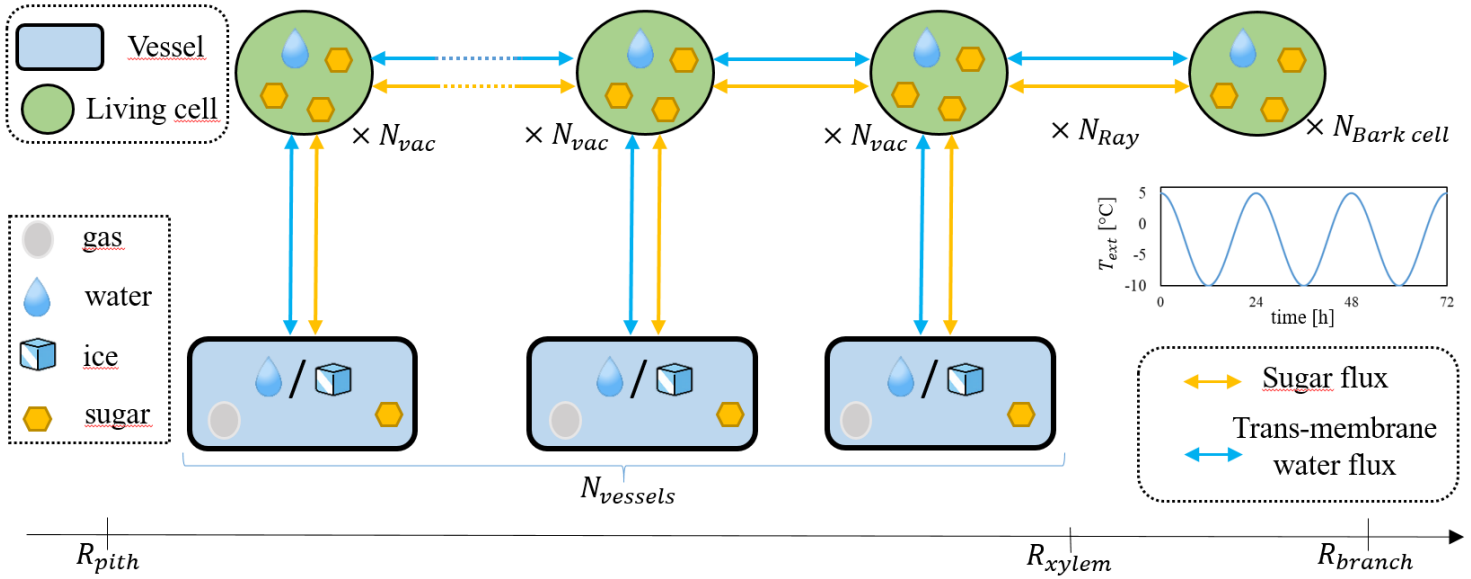

Améglio *et al*, Tree Phys., 2001



# PHYSICAL MODELLING:
# TO REPRODUCE & UNDERSTAND

MATLAB

Walnut branch anatomy




## Heat transfer and phase change

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

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

## Water fluxes and P-V relationships

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

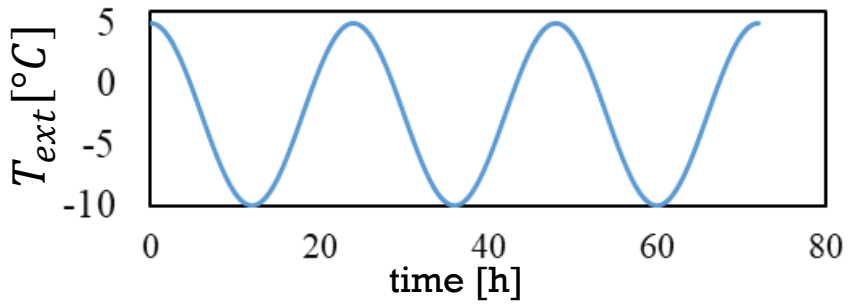
$$\frac{dP^{liv}}{dt} = \frac{E}{V^{liv}}\frac{dV^{liv}}{dt} \qquad P^v \approx \frac{nR_gT}{V_g^v}$$

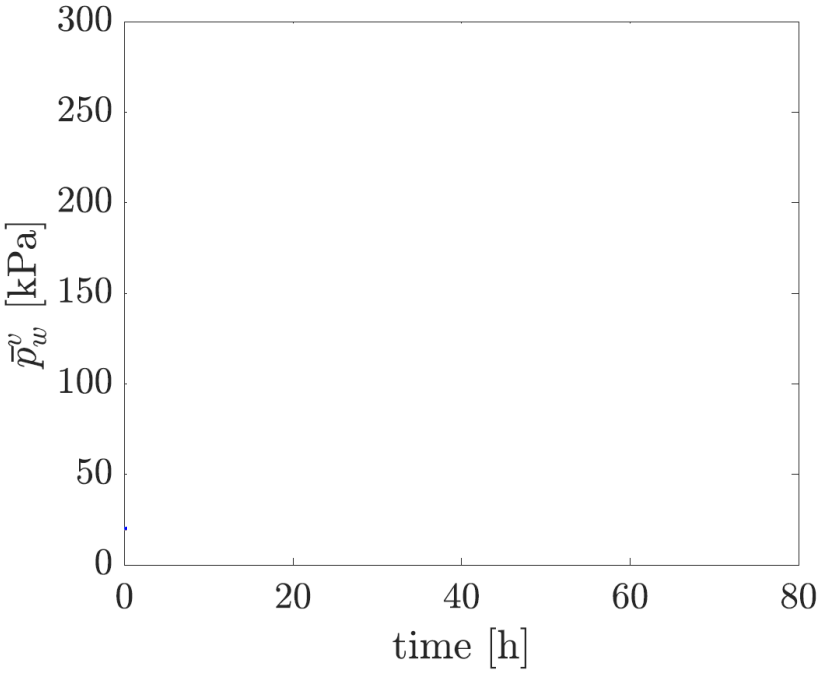
## Diffusive sugar fluxes

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

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

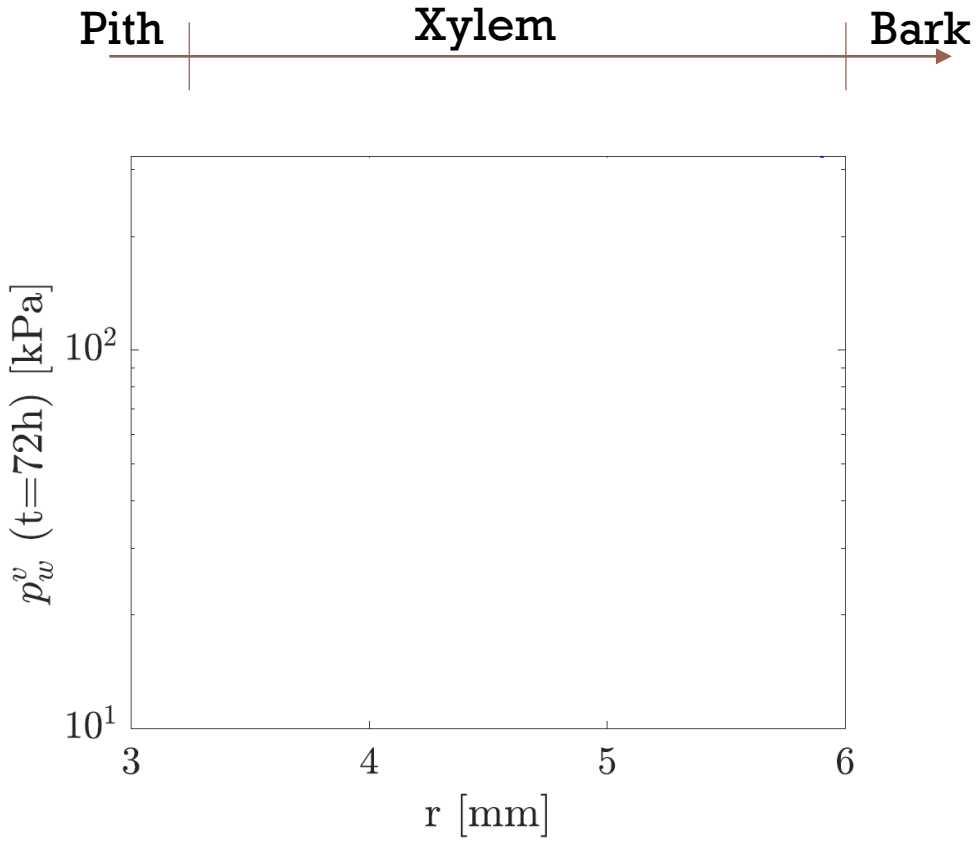
# RESULTS:
# EFFECT OF SUGAR FLUXES



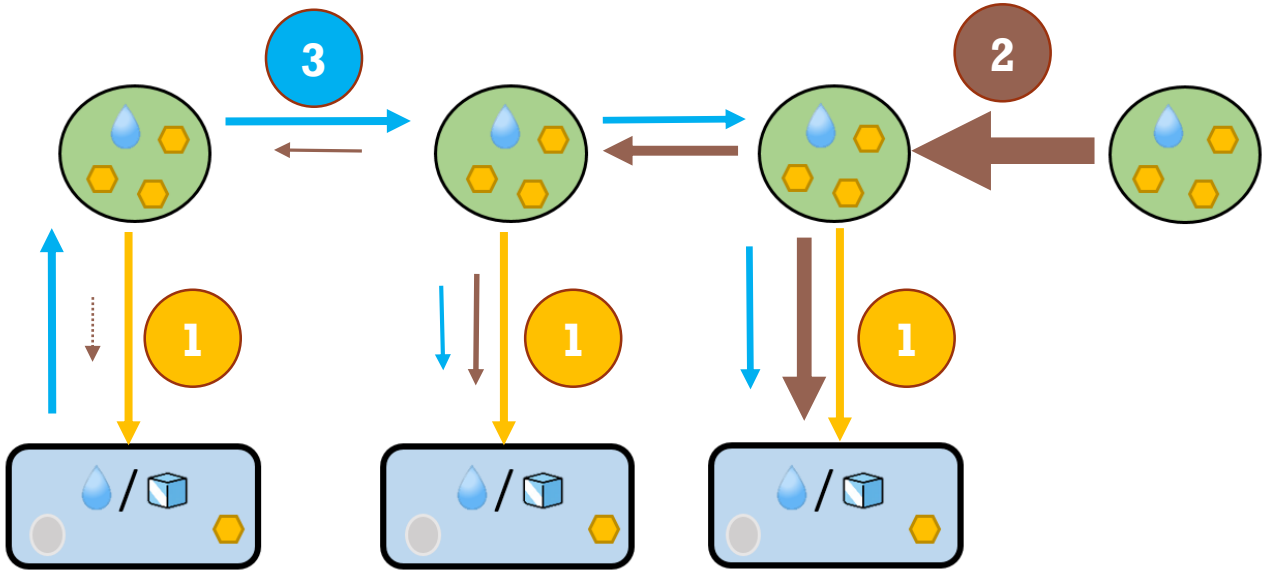

- No sugar fluxes
  - No pressure build-up
- With vessel-VAC fluxes
  - Very little pressure build-up (+0.7kPa)
- With vessel-VAC and ray fluxes
  - Significant pressure build-up (+43kPa)

# 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°C




1 Water and sugar fluxes VAC <-> vessels

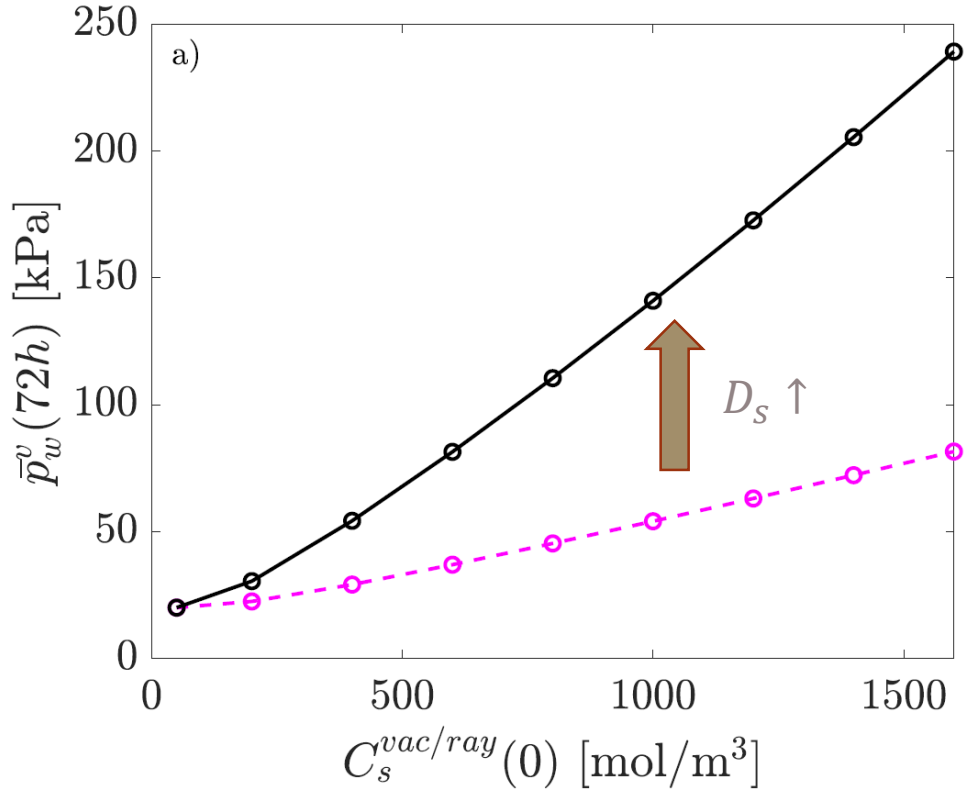
2 Sugar and water transport from the bark

- 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!**

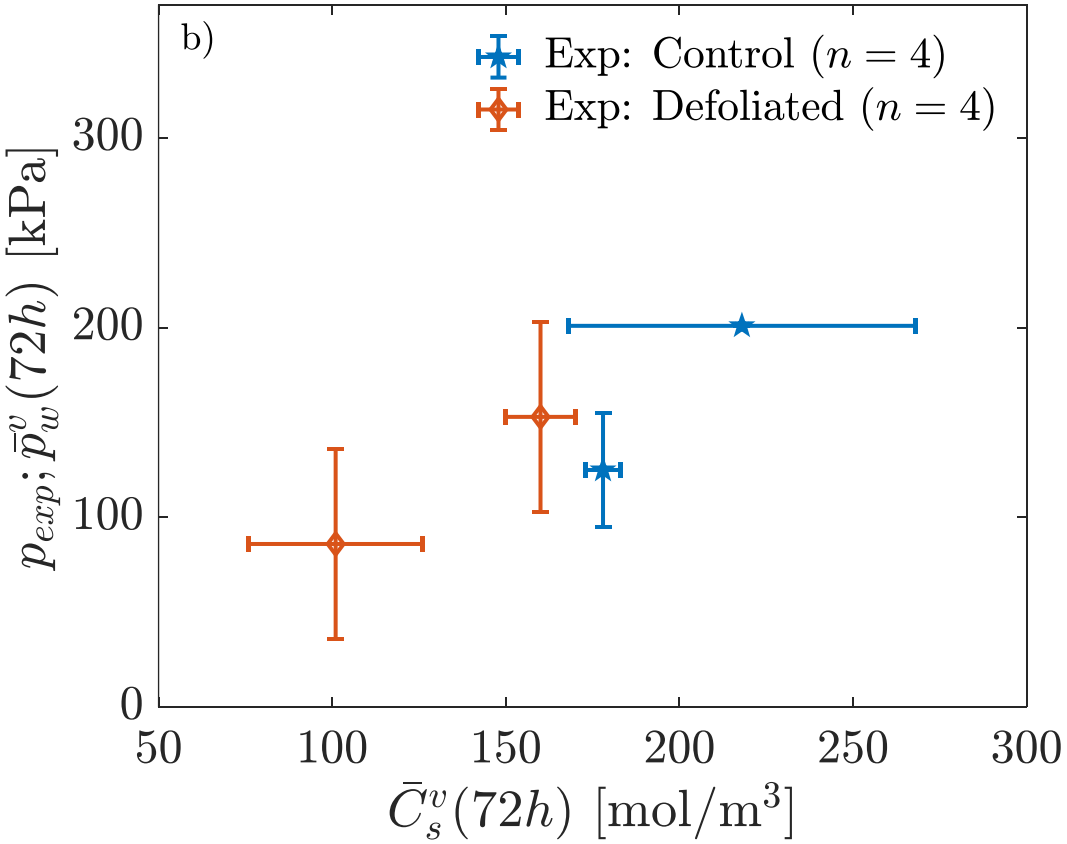
# RESULTS:
# VESSEL PRESSURE *VS* LIVING CELL INITIAL SUGAR CONTENT




Stem pressure build-up occurs if:

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

# VALIDATION:
# VESSEL PRESSURE *VS* VESSEL SUGAR CONTENT



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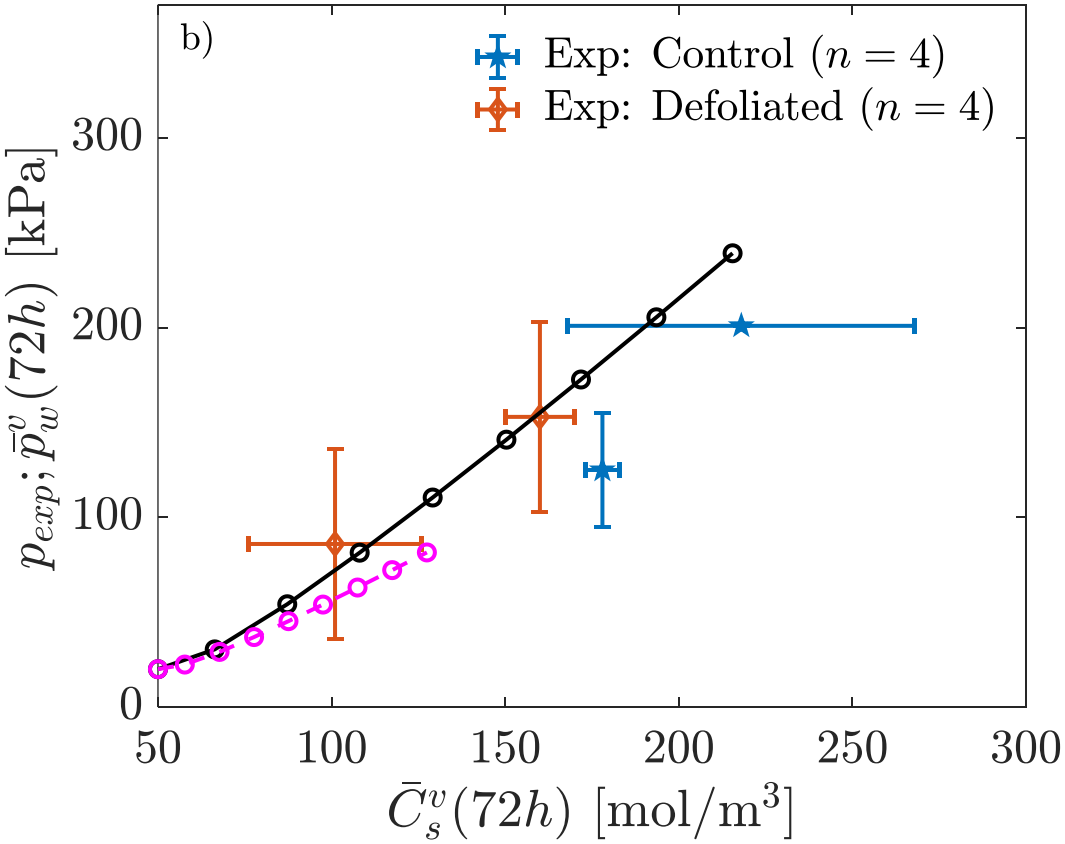
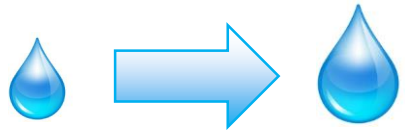
# VESSEL PRESSURE *VS* VESSEL SUGAR CONTENT




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

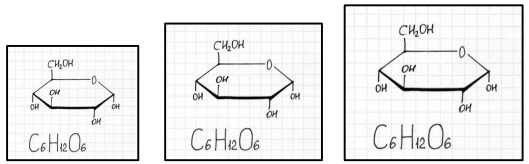
# TO SUM-UP:

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



**…a transfer of water between vessels** across the ray,

triggered by



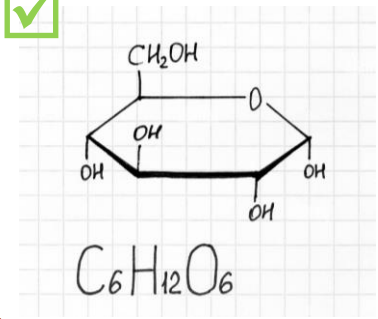

**a radial imbalance in sugar concentration.**

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

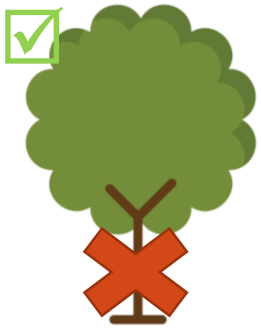
→ Unique abilities in species that develop stem pressure?

# TO SUM-UP:
# & PERSPECTIVES

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

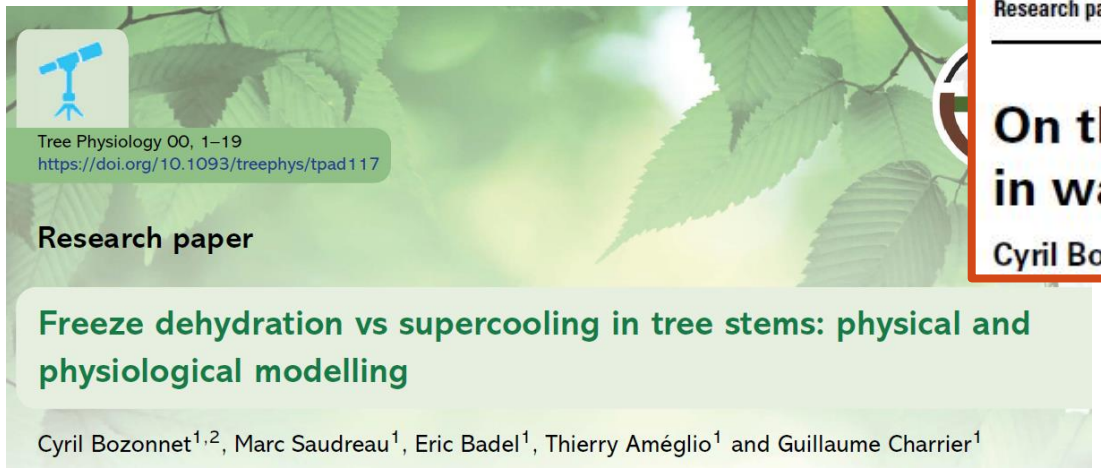



P(t)



Adding dissolved gas expulsion from freezing water?

Heterogeneous pressure build-up → Heterogeneous recovery?





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

# Thank you !

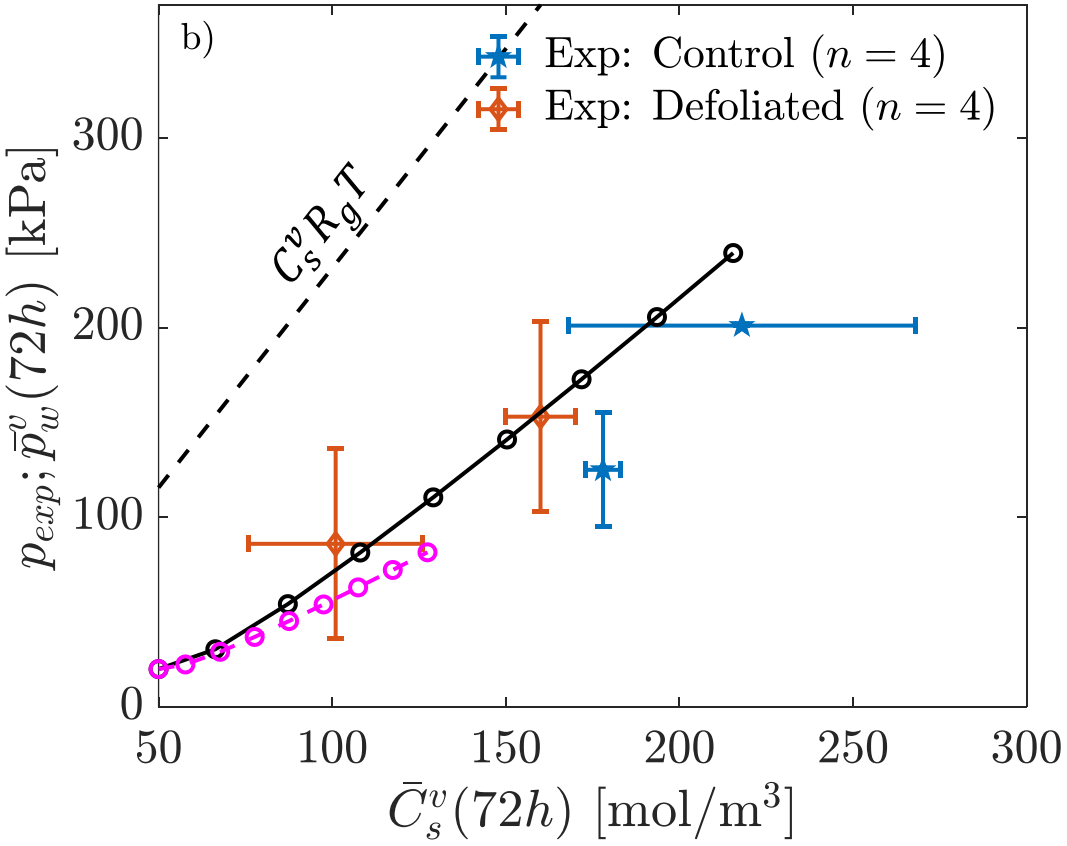
PIAF

anr

FWF

Back-up slides

# VALIDATION:
# VESSEL PRESSURE *VS* VESSEL SUGAR CONTENT

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