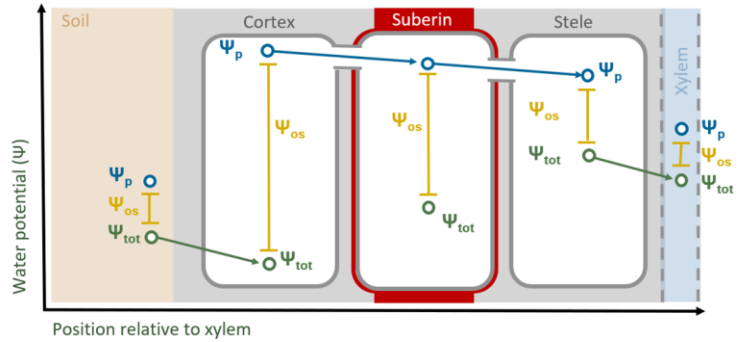
How are driving forces of root water uptake altered in crop plants under water deficit?

Lei Ding

17.06.2025

Rhizosphere 6, 15th-19th June

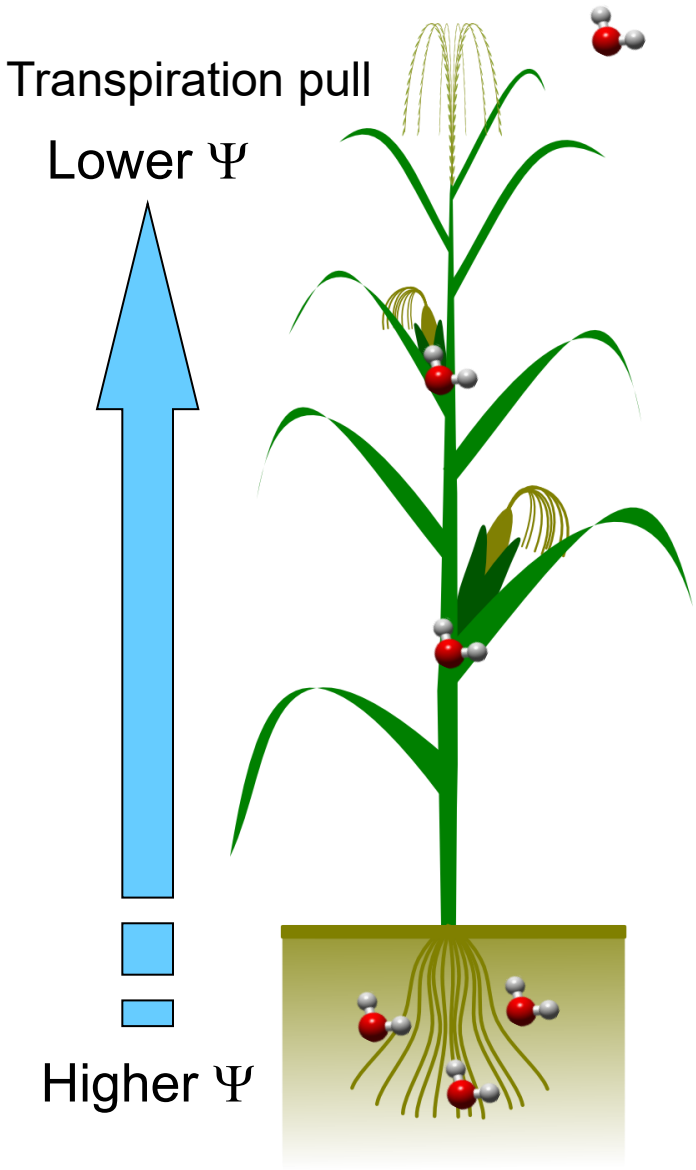
Edinburgh, Scotland

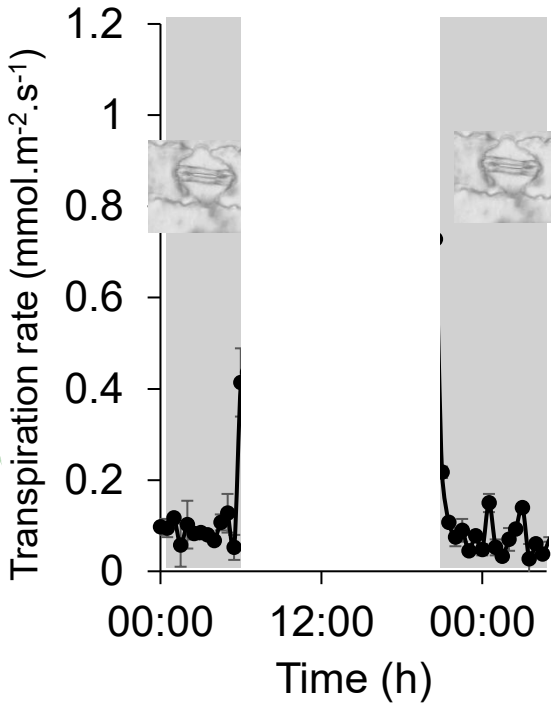


River flow from high to low places;

Uphill movement of water in plants

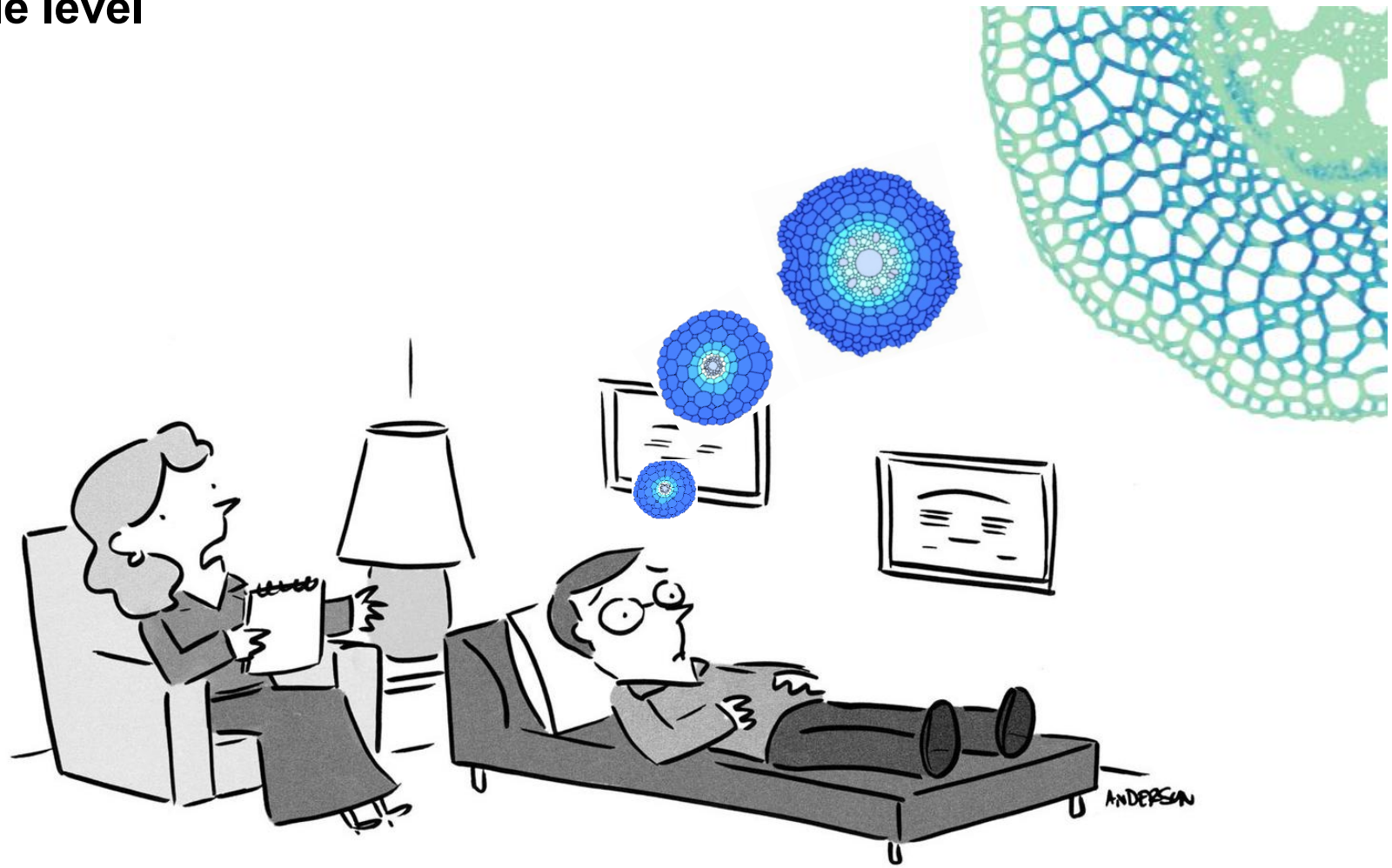
Uphill movement of water in plants



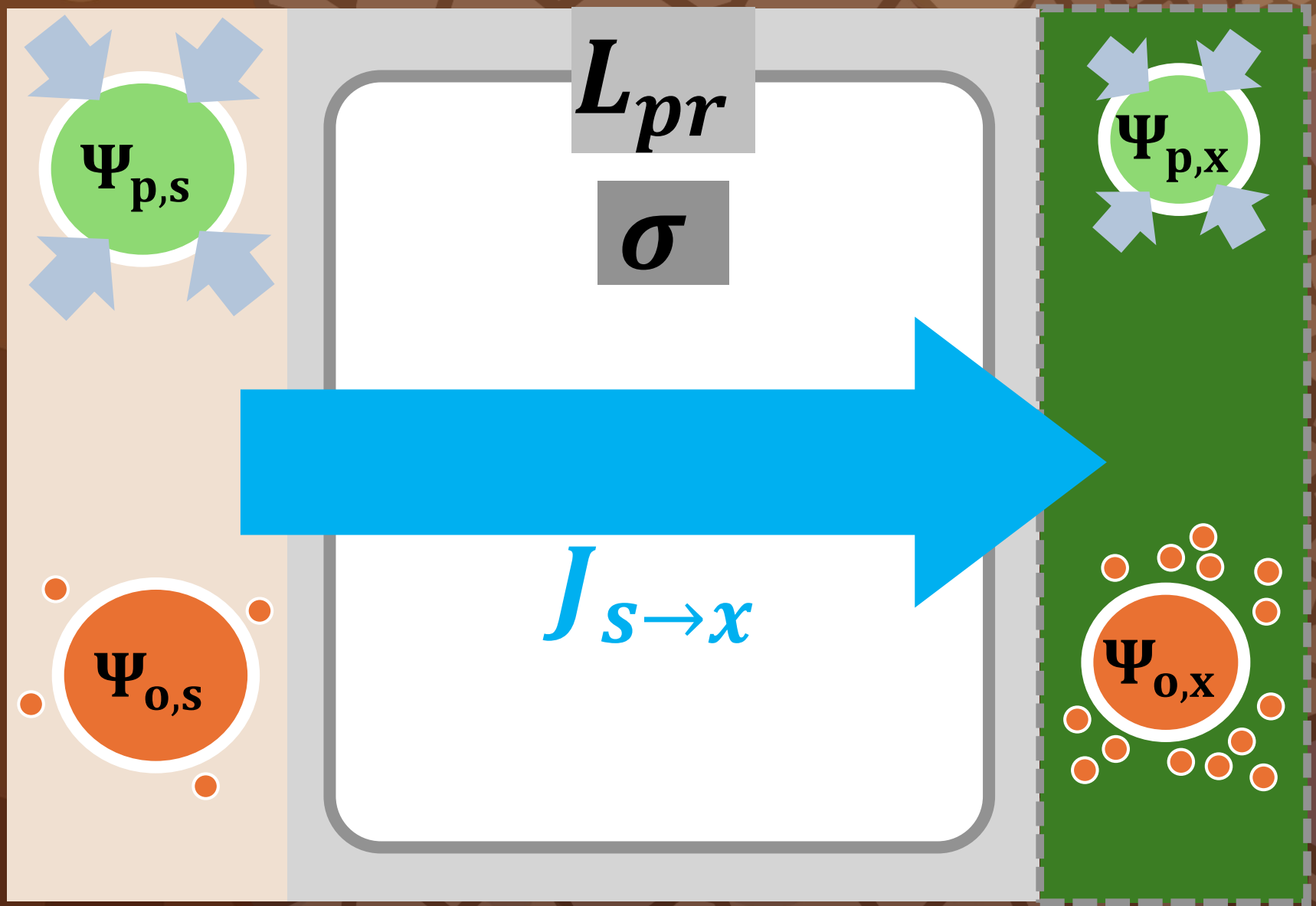


Root pressure

At root micro-scale level

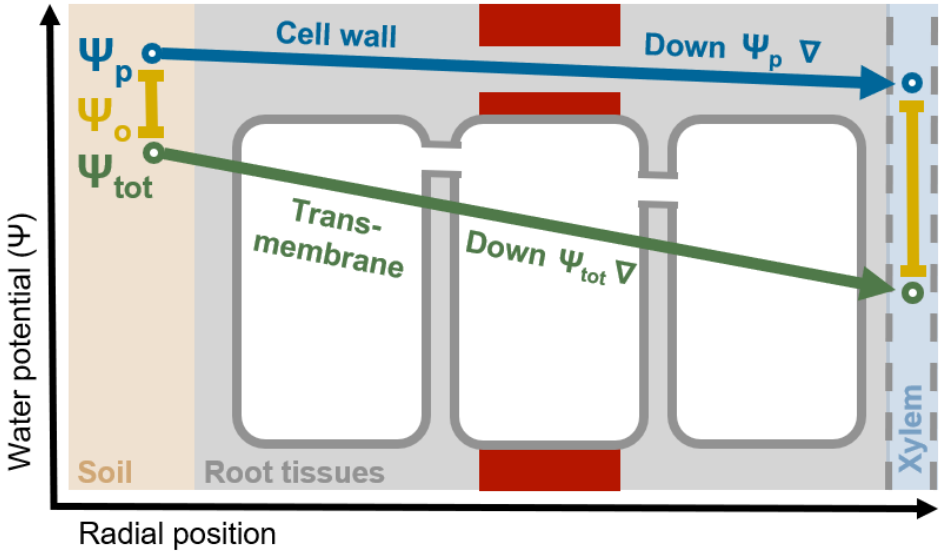


Couvreur et al., 2018, Plant Physiology


L_{pr}
σ
$\Psi_{p,s}$
$\Psi_{o,s}$
$J_{s \rightarrow x}$
$\Psi_{p,x}$
$\Psi_{o,x}$

$$J_{s \to x} = L_{pr} \left[\left(\Psi_{p,s} - \Psi_{p,x} \right) - \sigma \left(\Psi_{o,s} - \Psi_{o,x} \right) \right]$$

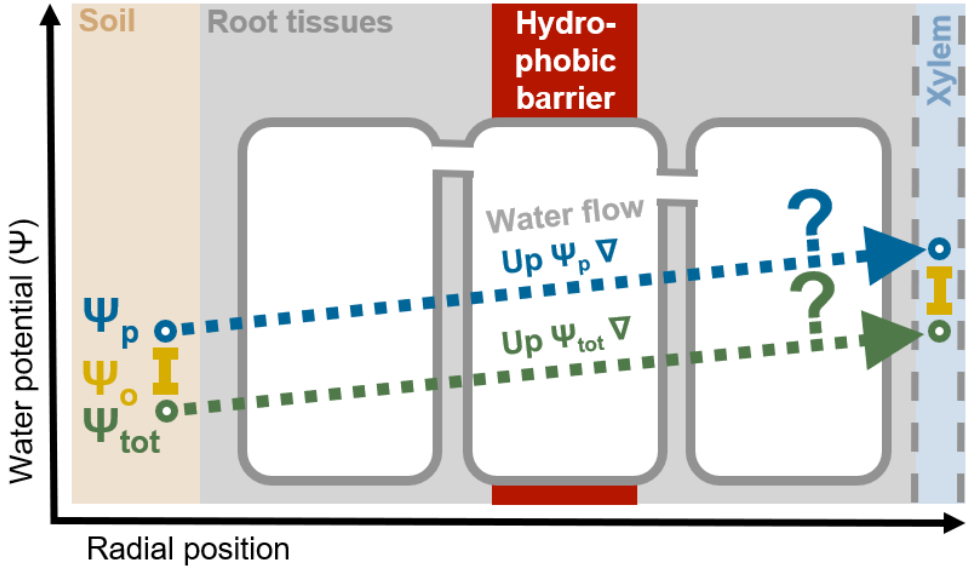
How water flow should be



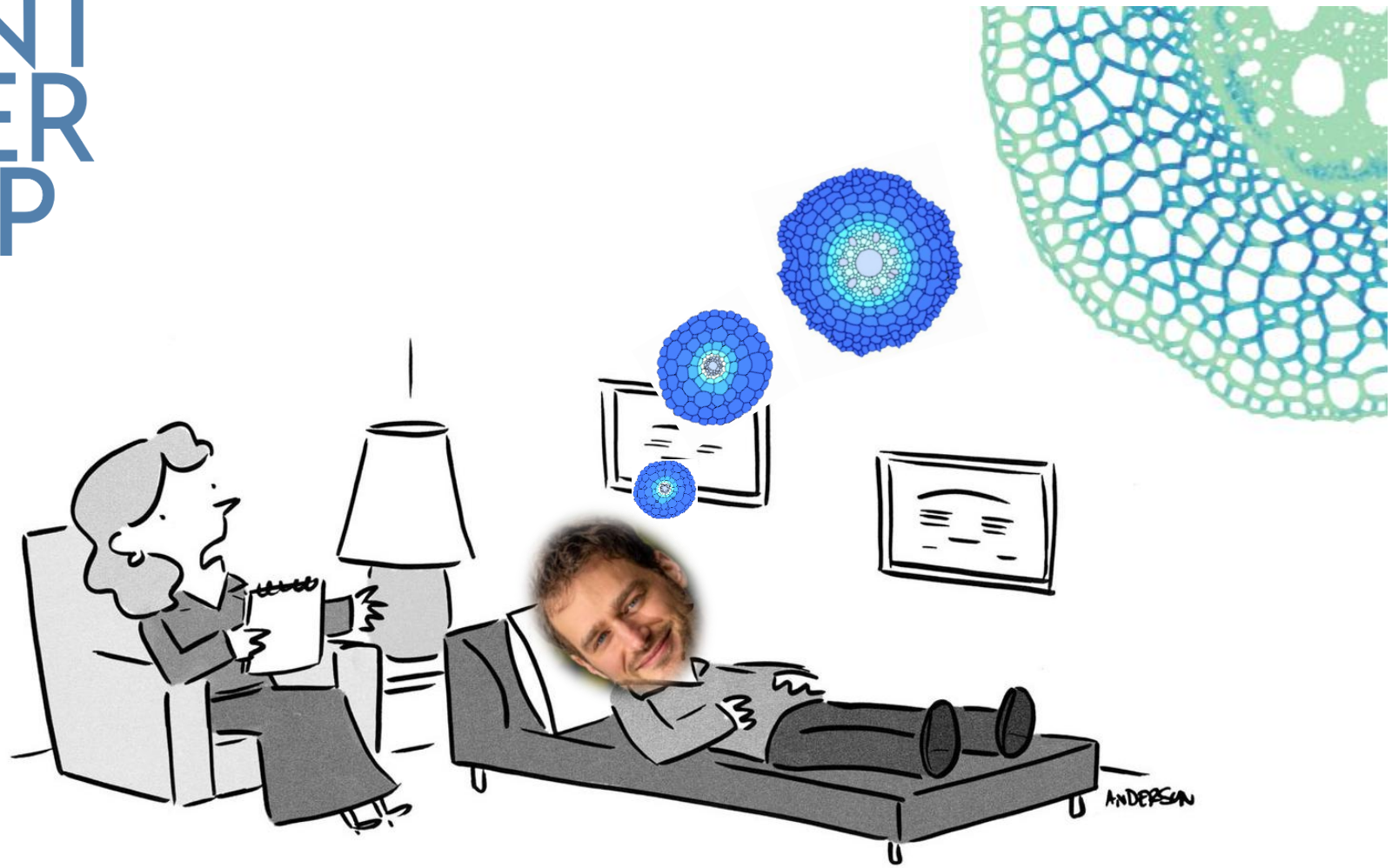
Ψ_o (MPa)	Ψ_x (MPa)[a]
	LMX
−0.09[b]	−0.11 ± 0.06 (25)
−0.15	−0.13 ± 0.07 (25)
−0.225 <	−0.16 ± 0.1[c] (20)
−0.30	−0.17 ± 0.06[c,e] (10)

Enns et al., 2000

What scientists observed



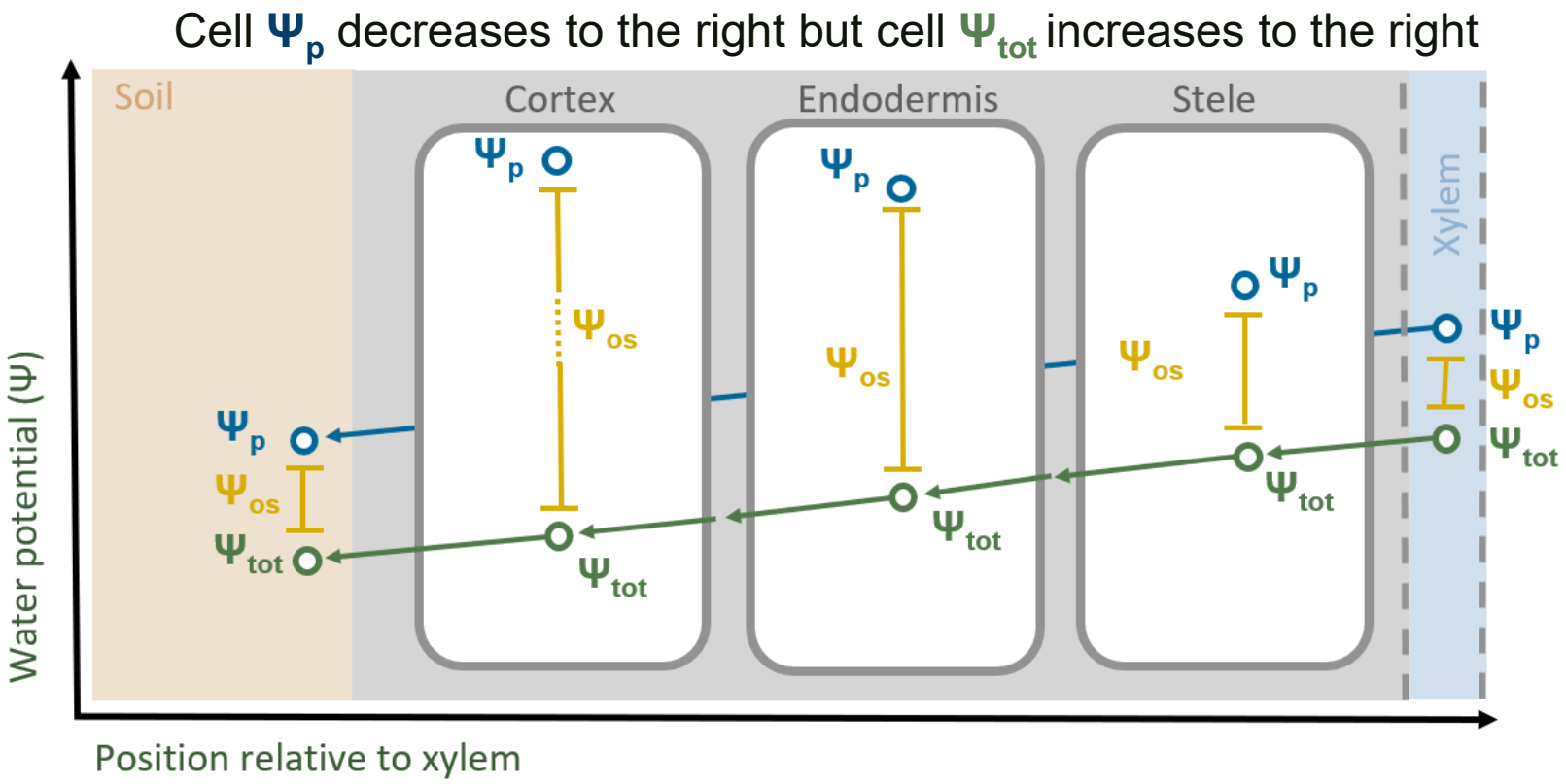
THE PLANT WATER PUMP



Couvreur et al., 2018, Plant Physiology

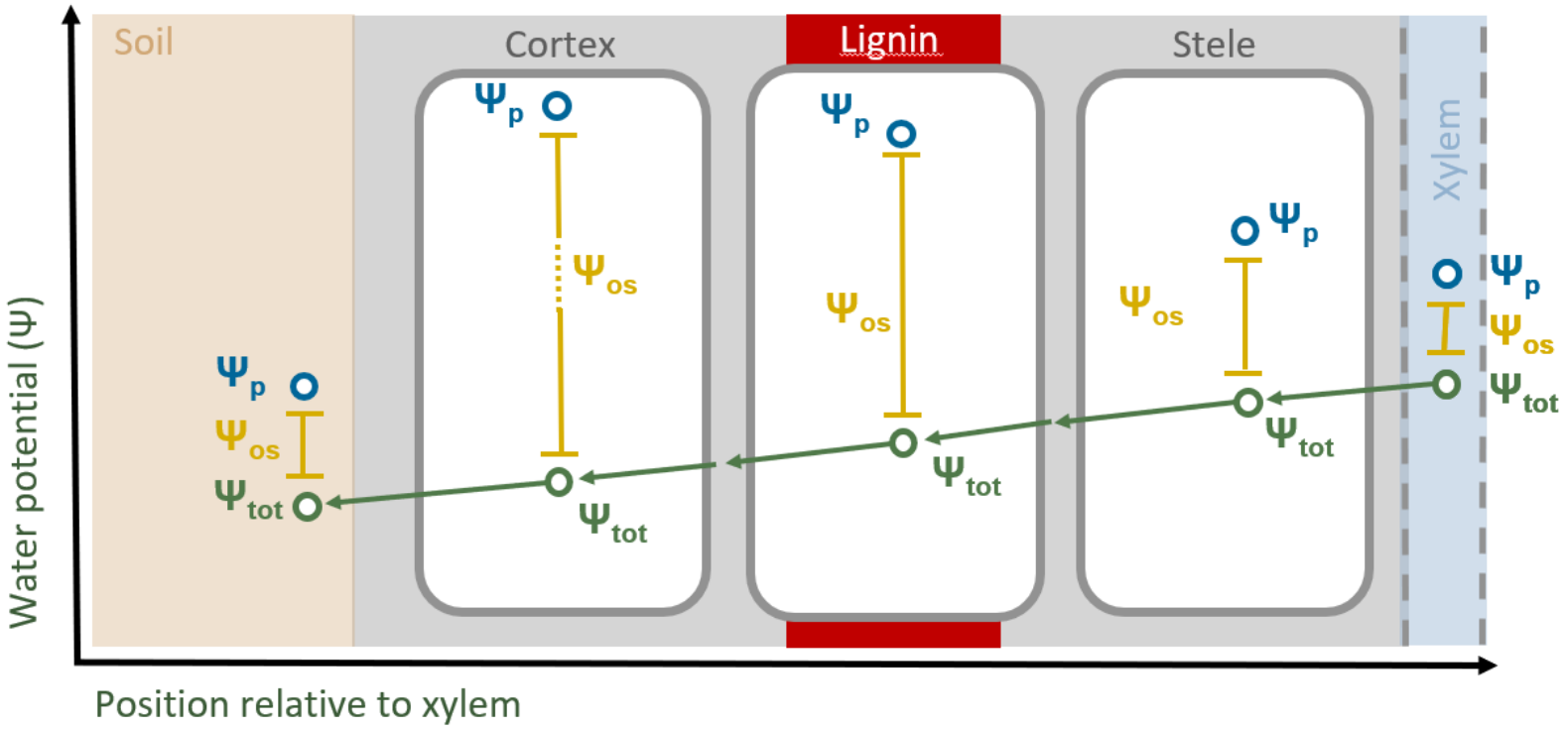
Building a water pump from scratch:

- 3 cells, i.e., cortex, endodermis and stele
- A cellular Ψ_{os} gradient (Enns et al., 2000)



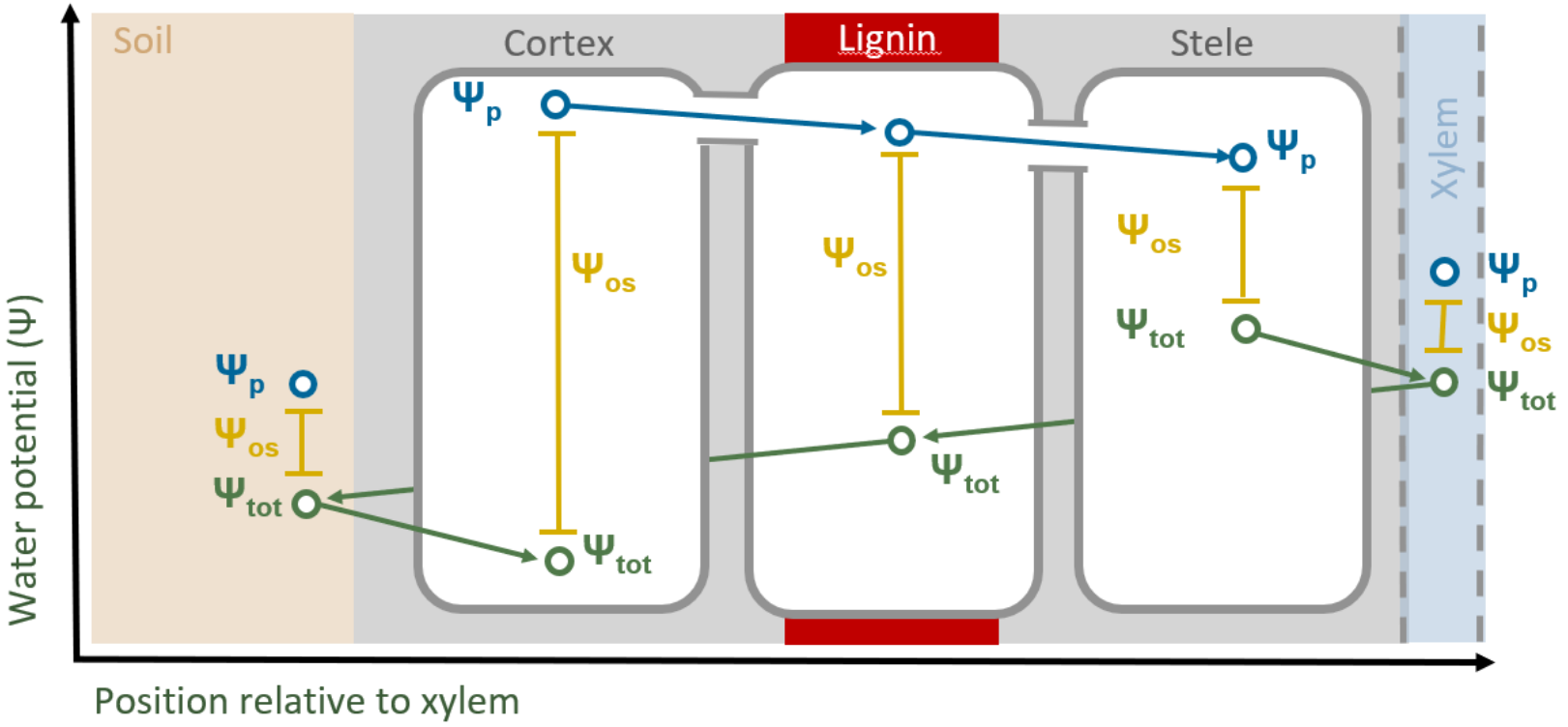
Building a water pump from scratch:

- 3 cells, i.e., cortex, endodermis and stele
- A cellular Ψ_{os} gradient (Enns et al., 2000)
- **An apoplastic barrier**



Building a water pump from scratch:

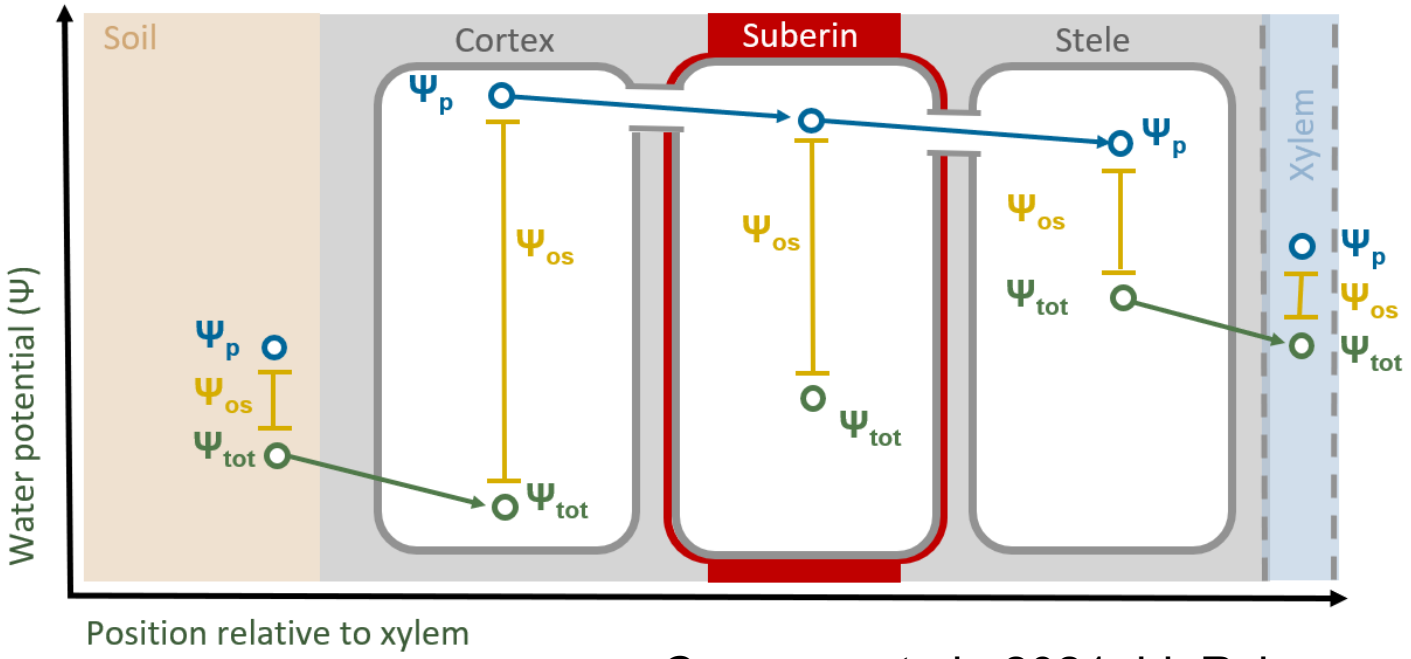
- 3 cells, i.e., cortex, endodermis and stele
- A cellular Ψ_{os} gradient (Enns et al., 2000)
- An apoplastic barrier
- **Plasmodesmatal connections**



Water flow is pressure-driven in plasmodesmata

Building a water pump from scratch:

- 3 cells, i.e., cortex, endodermis and stele
- A cellular Ψ_{os} gradient (Enns et al., 2000)
- An apoplastic barrier
- Plasmodesmatal connections



Pump "upgrade" with suberin lamellae

Couvreur et al., 2021, bioRxiv

Osmotic potential gradient between root cell layers could be the driving force of water flow.

- Does water flow go from low to high Ψ_{tot}?
- Does the osmotic potential gradients exist?
- Is there missing driving force for water flow?

- Does water flow go from low to high Ψ_{tot}?
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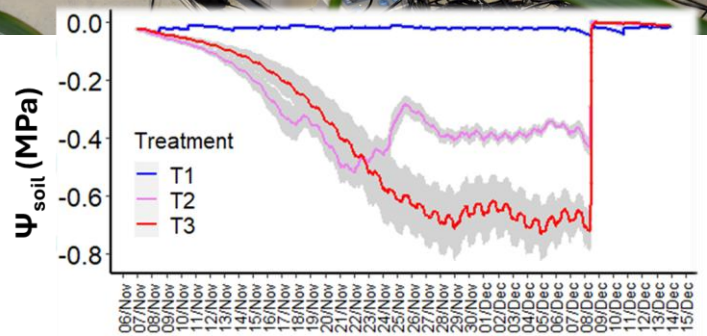
- Does water flow go from low to high Ψ_{tot}?

Maize @ greenhouse

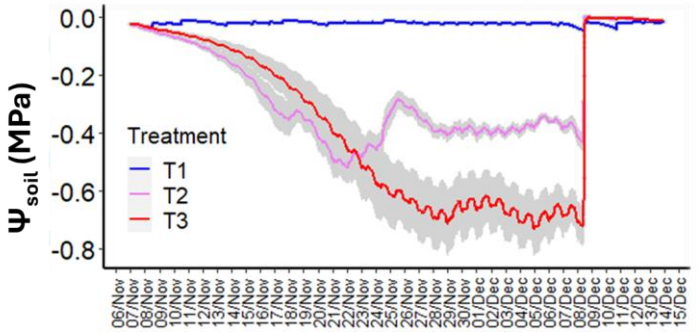


Tomato @ phytotron

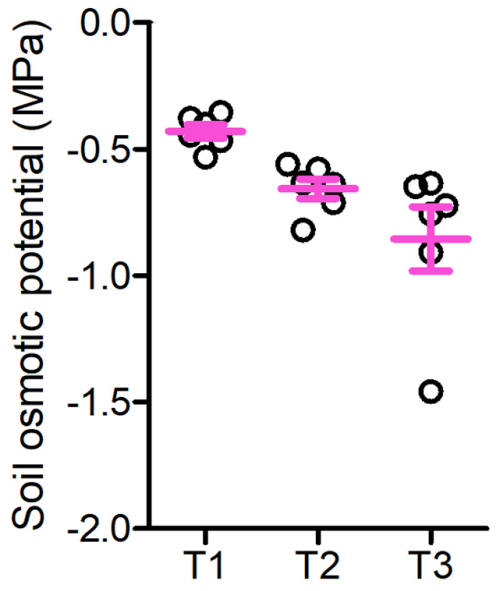
Treatments		Solution osmotic potential (MPa) calculated by EC	Solution osmotic potential (MPa) measured by PSY-1
Control		-0.04	-0.06
NaCl_mild stress	5 g/L	-0.33	-0.56
NaCl_severe stress	10 g/L	-0.66	-0.74
PEG_mild stress	168 g/L	-	-0.27
PEG_severe stress	236 g/L	-	-0.84

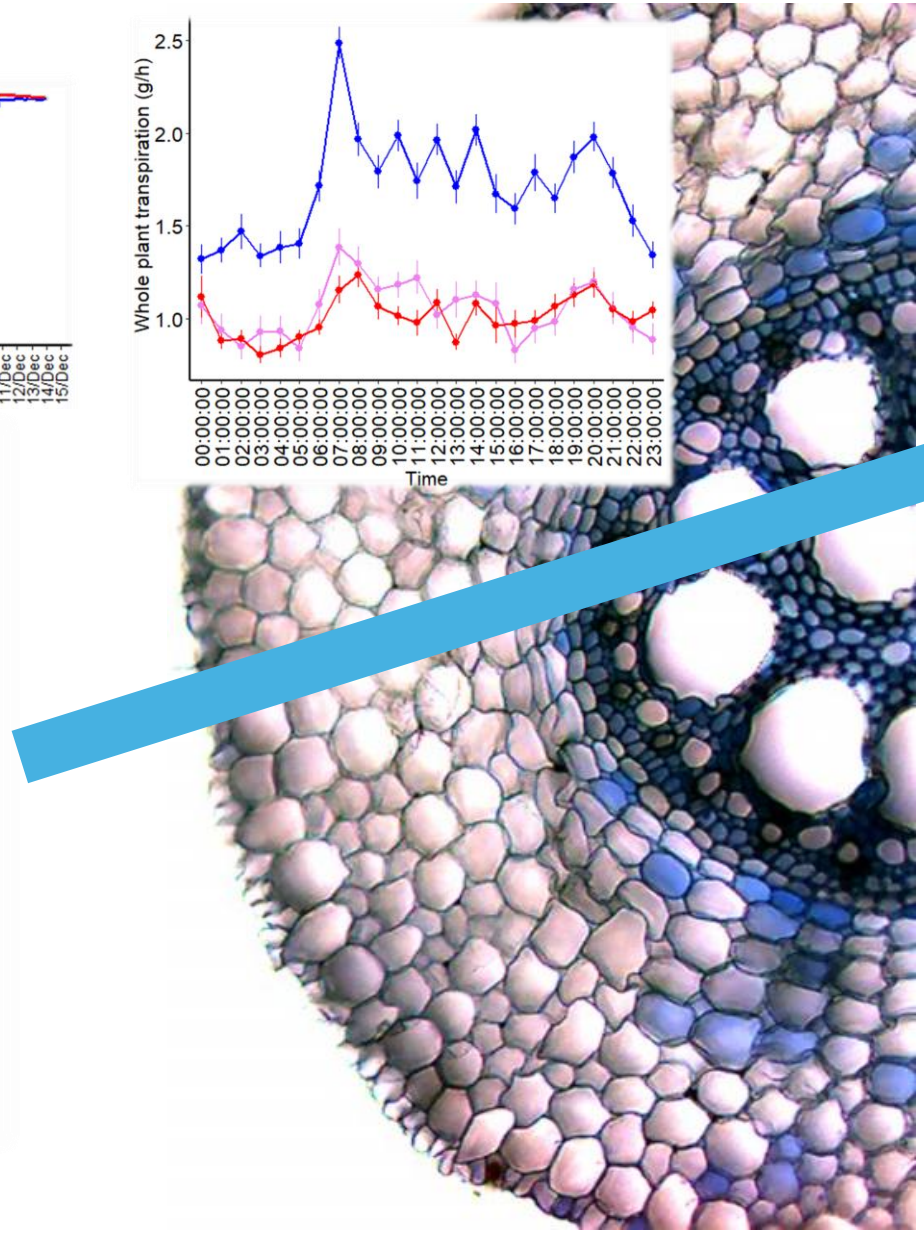
Ψ_{Tot} in soil

-0.7MPa



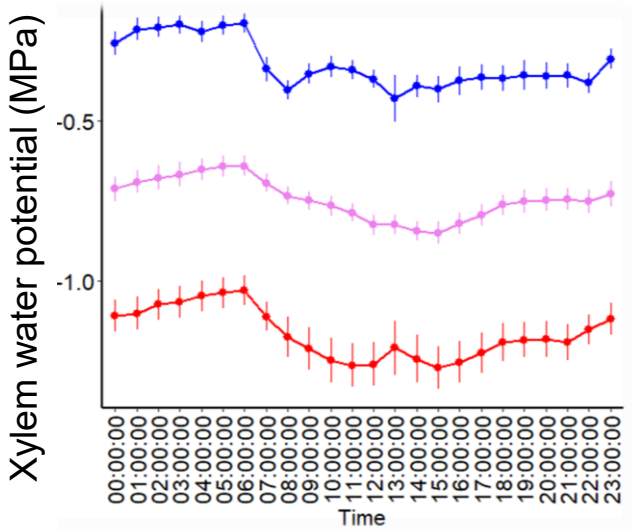
-0.8MPa



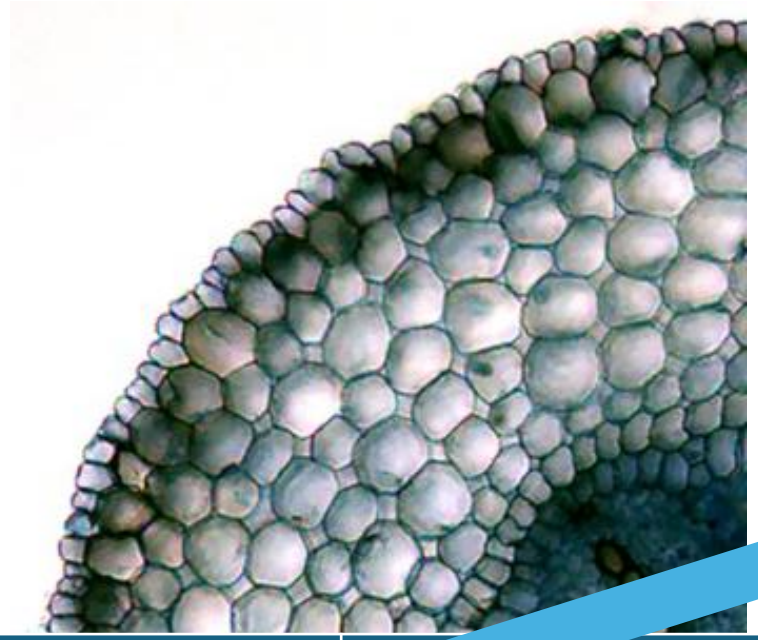


Ψ_{Tot} in xylem

-1.3MPa



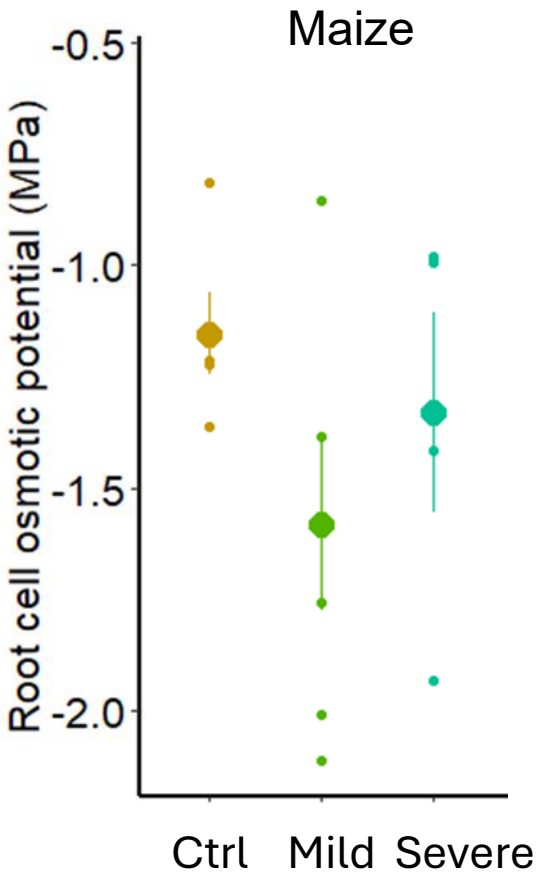
In tomato

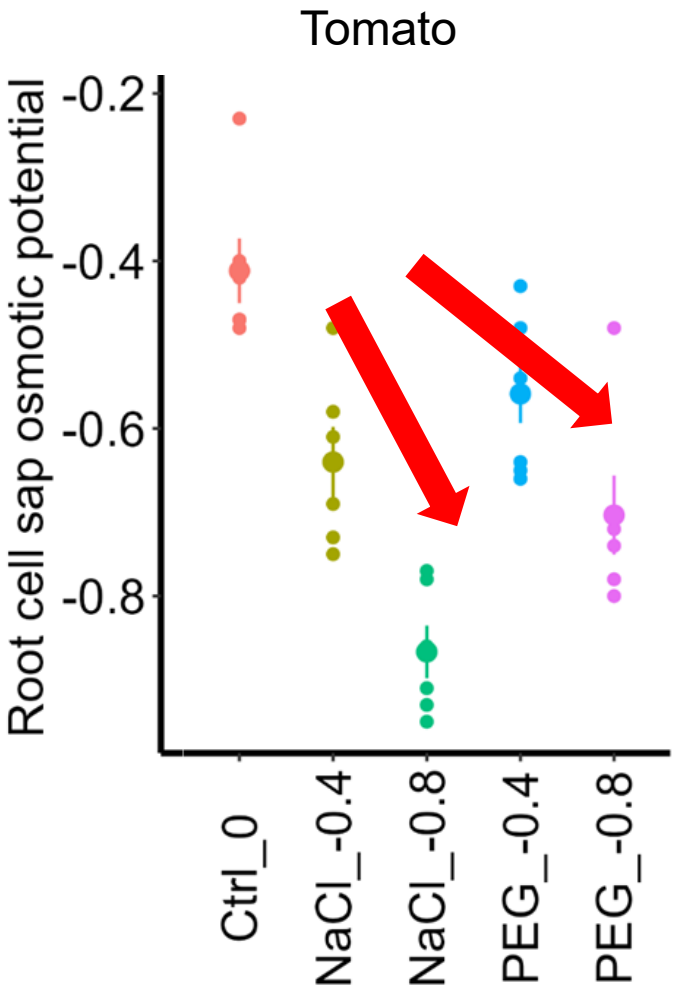


Treatments		$\Psi_{Solution\ osmotic}$	Ψ_{xylem}
Control		**-0.05**	**0~-0.05**
NaCl_mild stress	5 g/L	**-0.45**	**-0.2~-0.5**
NaCl_severe stress	10 g/L	**-0.7**	**-0.75~-1.0**
PEG_mild stress	168 g/L	**-0.27**	**-0.4~-0.5**
PEG_severe stress	236 g/L	**-0.84**	**-0.75~-1.0**

- Does water flow go from low to high Ψ_{tot}?
- Does the osmotic potential gradients exist?
- Is there missing driving force for water flow?

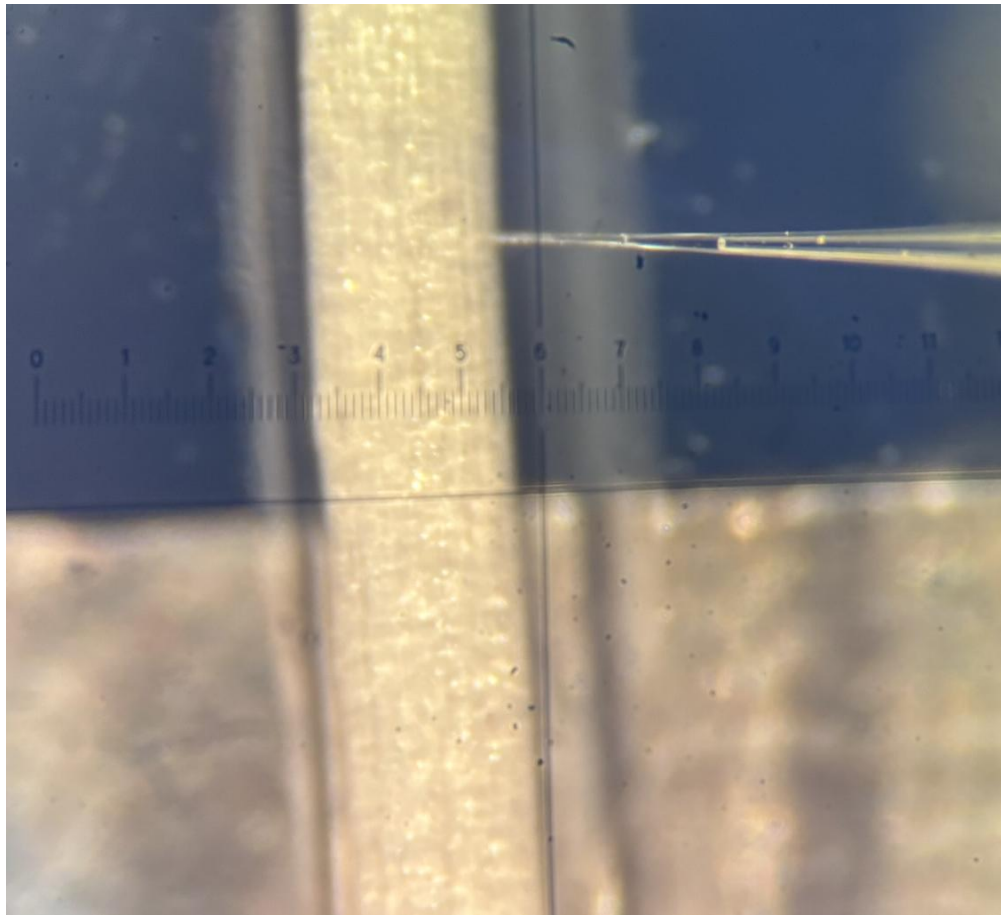
Bulk root cells osmotic potential



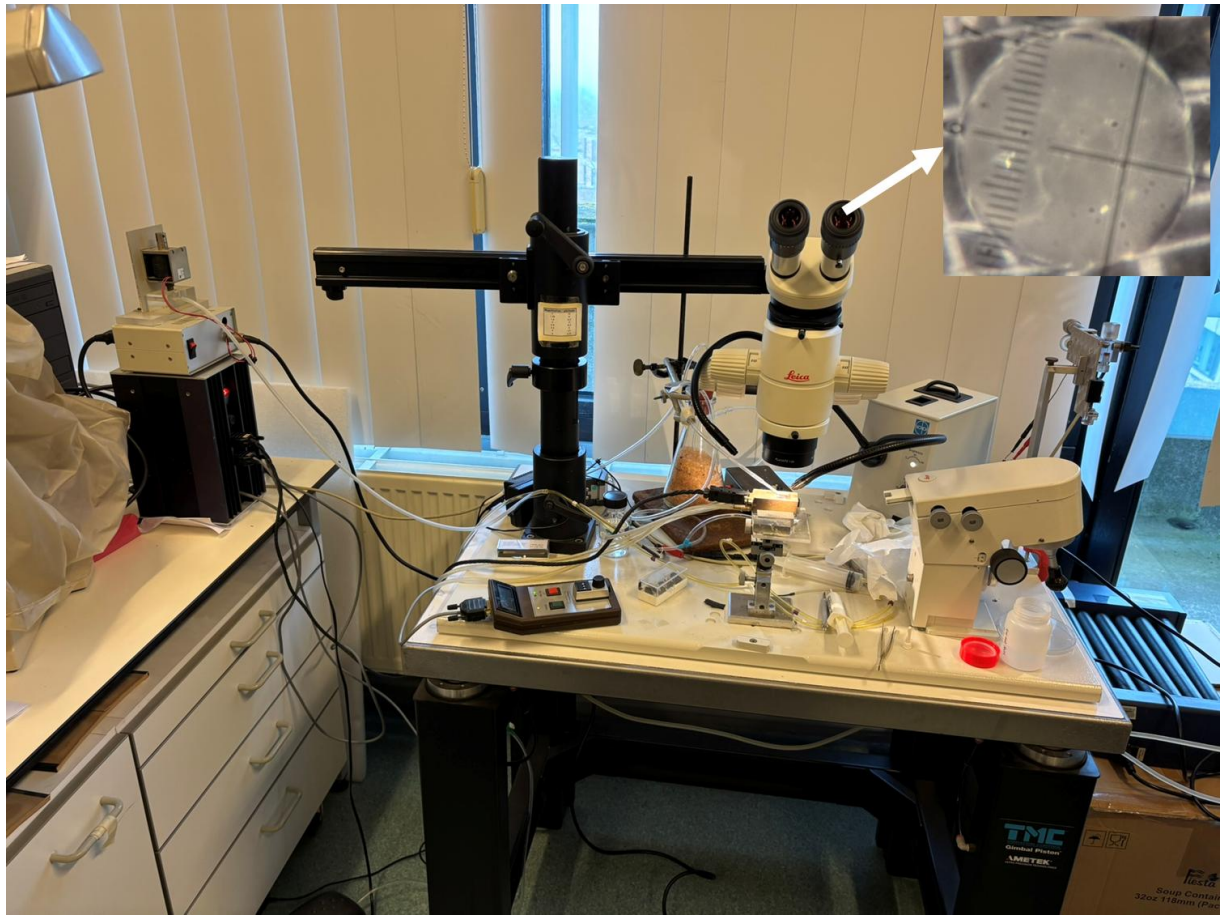


Osmotic potential in different cell layer

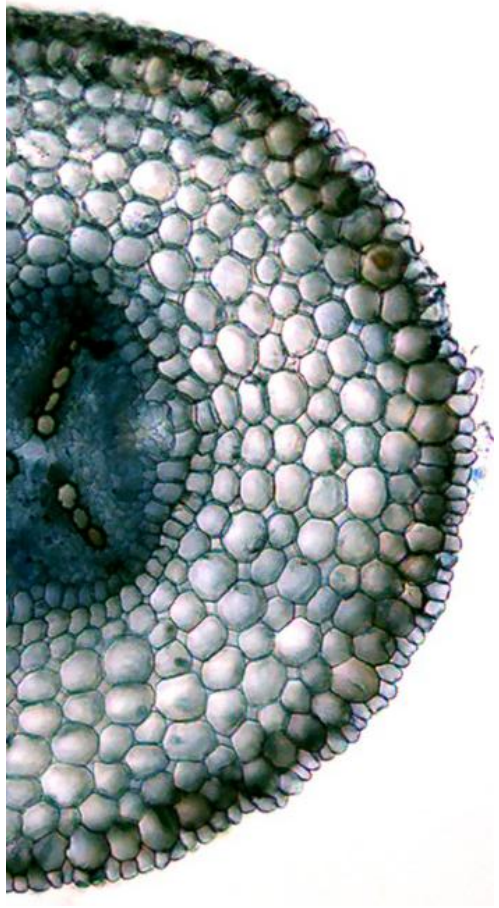
Micro-sampling from each cell layer

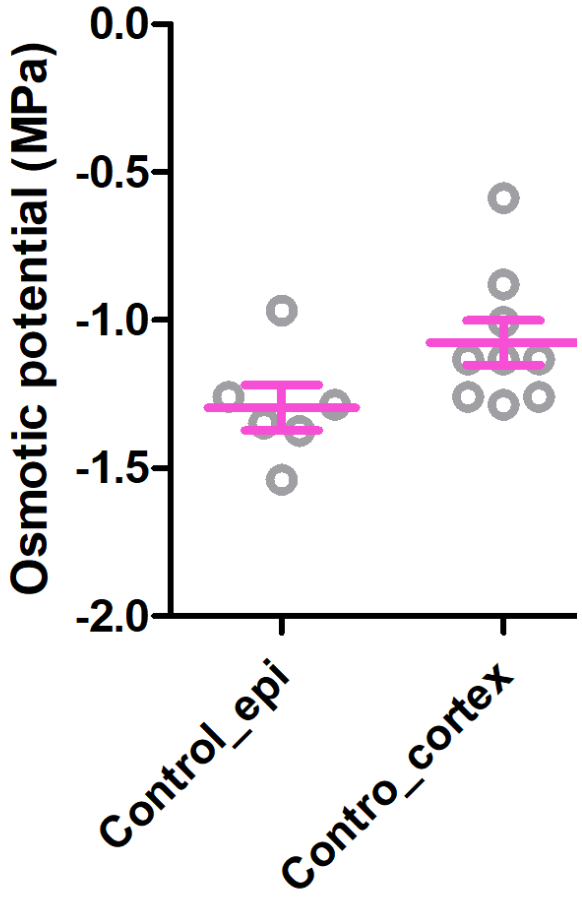


Cell sap osmotic potential is measured by pico-osmometer



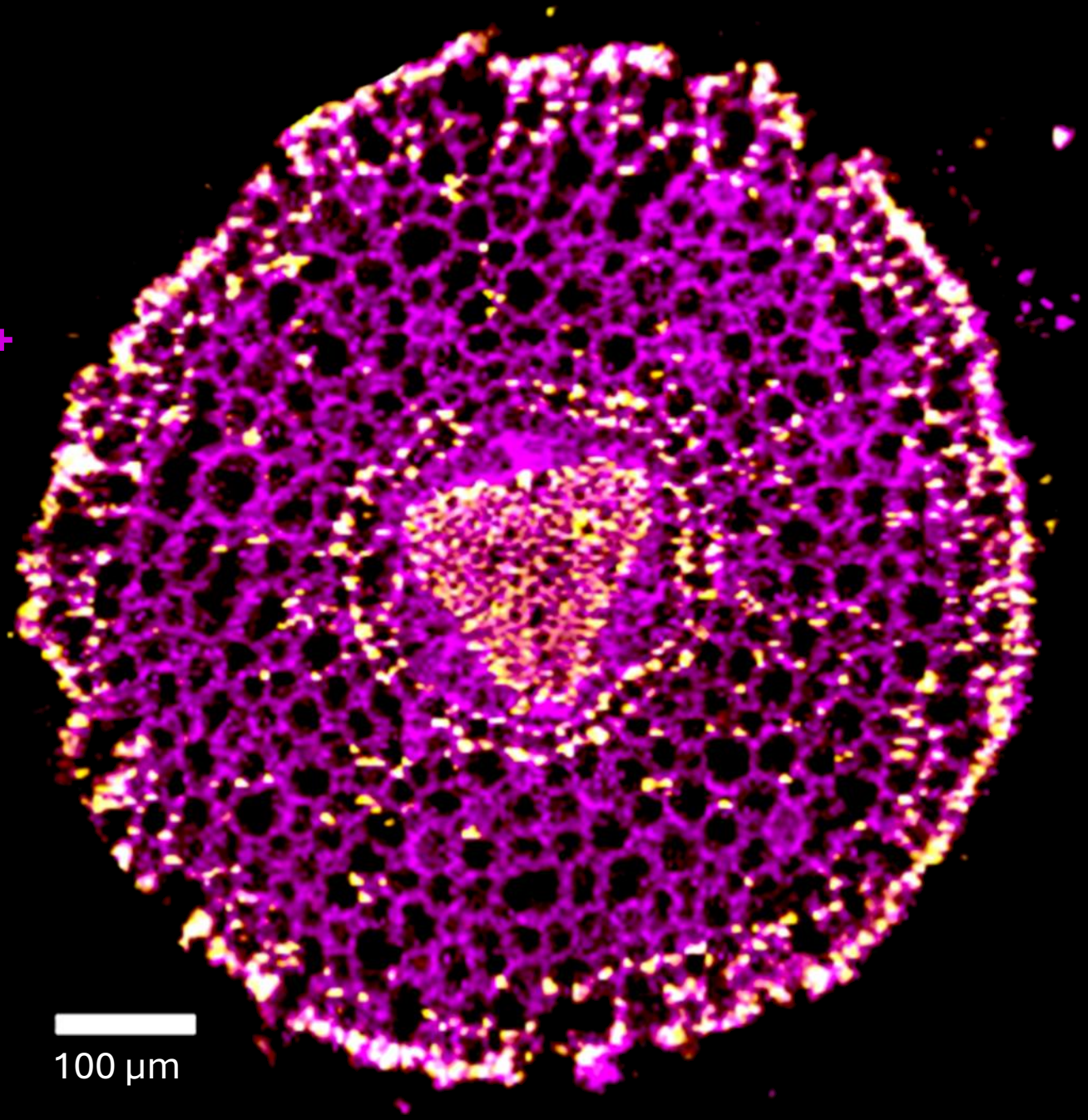
Osmotic potential in epidermis and cortex cells under control and NaCl treatments

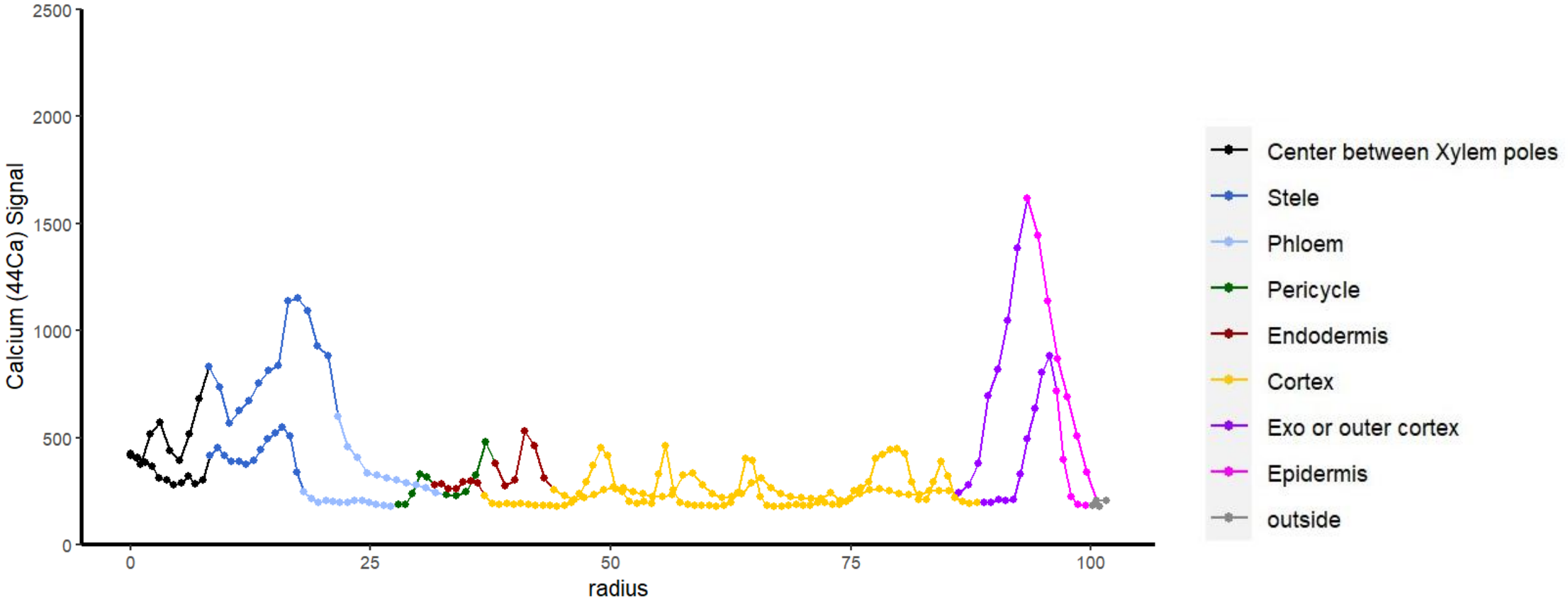


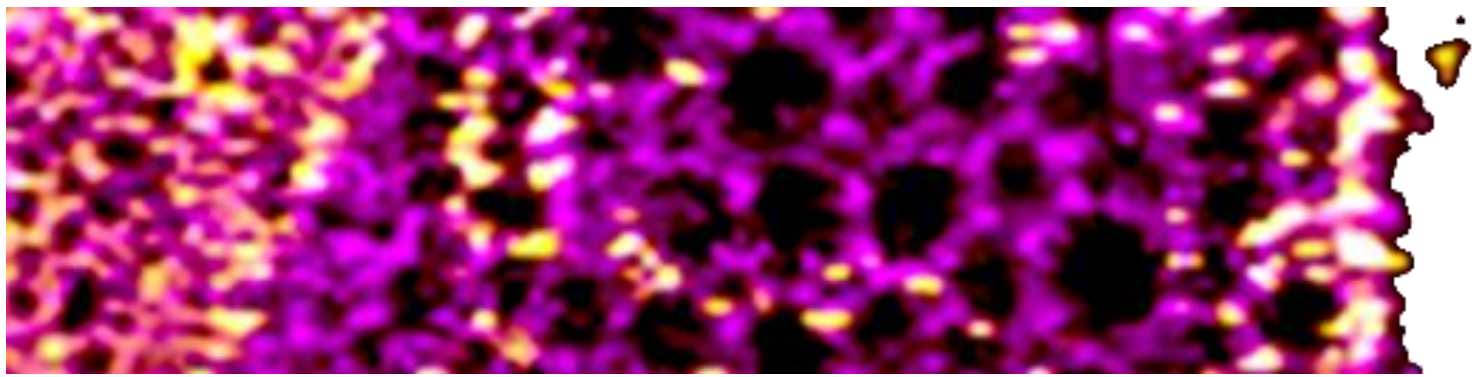


LA-ICP-MS

Ca^{2+} K^{+}




2500
2000
1500
1000
500
0
Calcium (44Ca) Signal
0
25
50
75
100
radius
Center between Xylem poles
Stele
Phloem
Pericycle
Endodermis
Cortex
Exo or outer cortex
Epidermis
outside



Tomorrow @ 3pm @ Lecture Theatre 5 @ Noémie Thiébaut

THE PLANT WATER PUMP

Ion mapping for integration into a micro-hydrological model: Laser Ablation ICP-MS

Naomi Thiébaut, Marco D'Agostino, Théo Degand, Lei Ding, Monica Rothwell, Daniel P. Persson* & Valentin Couvreur*

UCLouvain
EARTH & LIFE INSTITUTE
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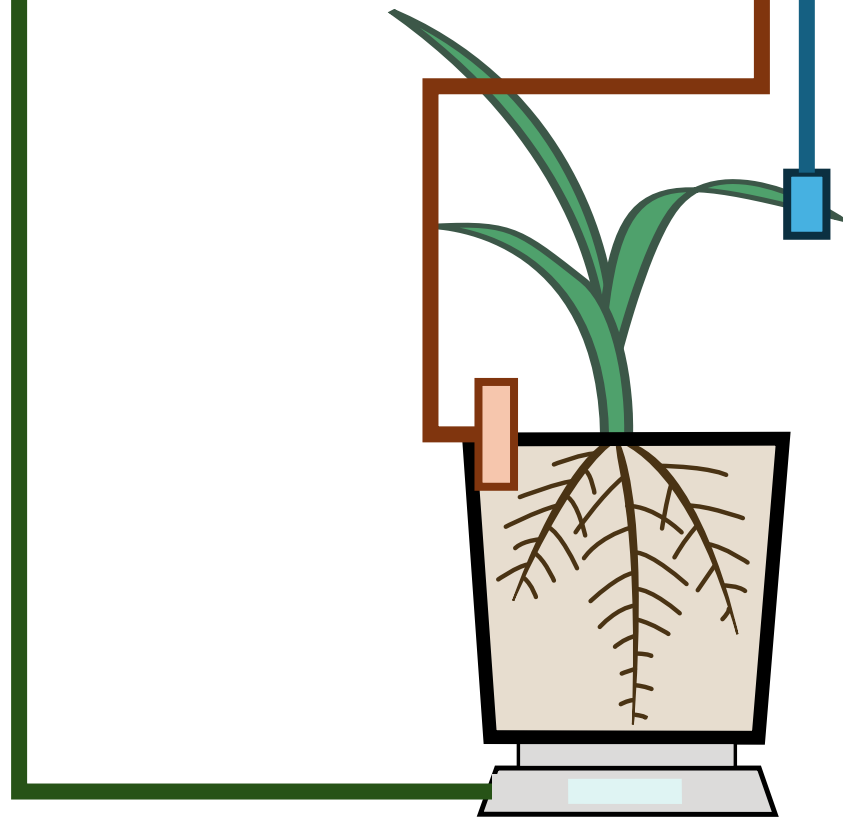
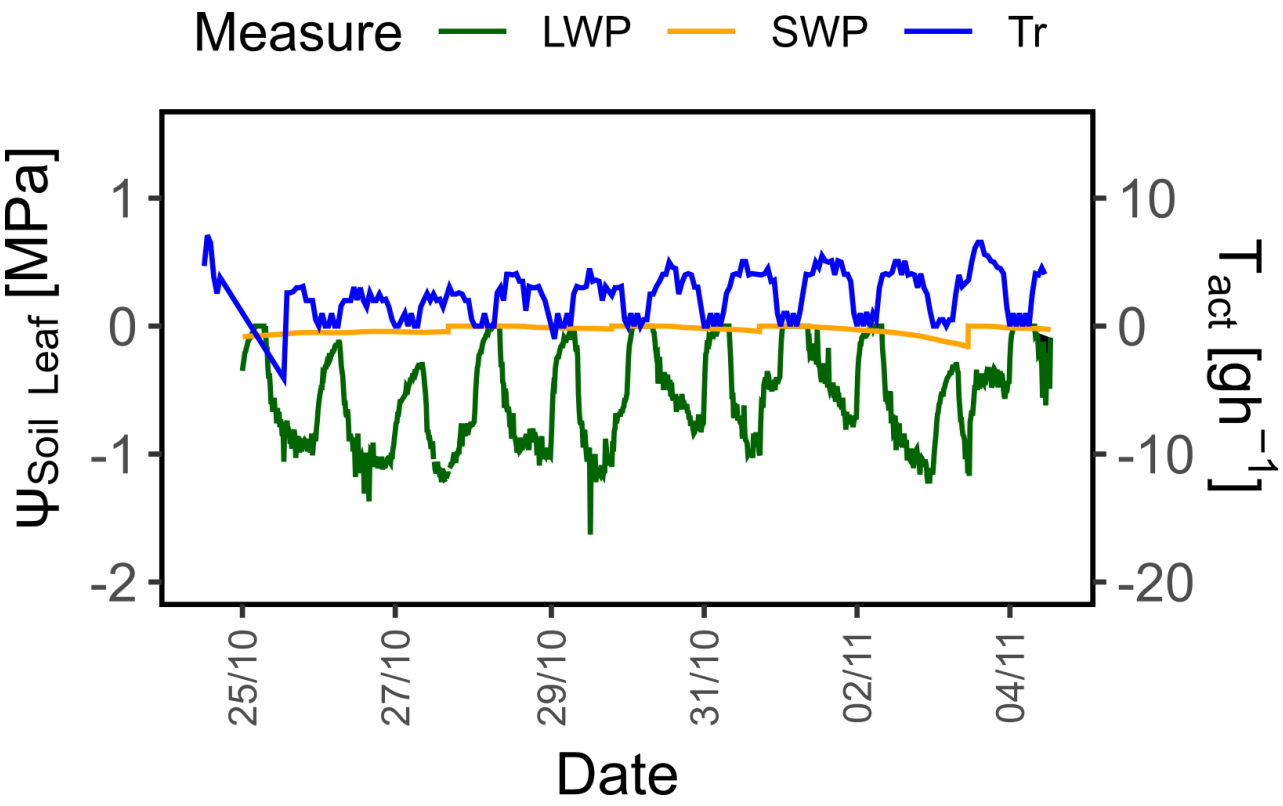
erc European Research Council Established by the European Commission
fnrs LA LIBERTÉ DE CHERCHER

- Does water flow go from low to high Ψ_{tot}?
- Does the osmotic potential gradients exist?
- Is there missing driving force for water flow?

$$T_{act} \overset{???}{=} T_{cal} = L_{pr} \times (\Psi_{soil} - \Psi_{xylem} + \sigma\overline{\Delta\Psi}_{o,apo} - \sigma\overline{\Delta\Psi}_{o,sym})$$





Tomorrow @ 4pm @ Lecture Theatre 5 @ MARCO D'AGOSTINO

MODELING ROOT WATER UPTAKE

INFLUENCE OF SECONDARY GROWTH, HYDROPHOBIC BARRIERS AND DEVELOPMENTAL ANATOMY ON ROOT HYDRAULIC PROPERTIES

MARCO D'AGOSTINO[1], RÉMY SCHOPPACH, ADRIEN HEYMANS[2], VALENTIN COUVREUR[1], GUILLAUME LOBET[1,3]

[1]Earth And Life Institute, UCLouvain, 1348 Louvain-La-Neuve, Belgium

[2]Agrosphere IBG-3, Forschungszentrum Jülich, 52428 Jülich, Germany

[3]Umeå Plant Science Centre, Department Of Forest Genetics And Plant Physiology, Umeå, Sweden

UCLouvain PHENOROB JÜLICH Forschungszentrum erc European Research Council Established by the European Commission

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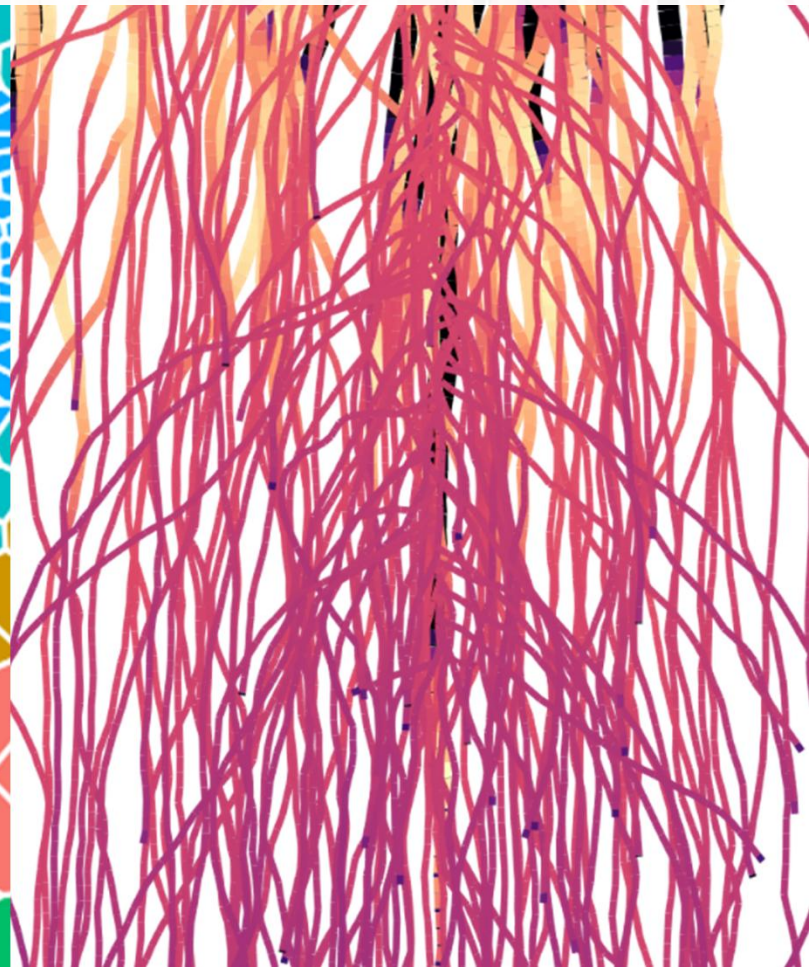

Summary and Perspectives

- We do observe that water may go from low water potential in soil and to high one in xylem vessels;
- Preliminary results indicate that there was osmotic potential gradient in different cell layers (epidermis *vs* cortical);
- Inverse modeling will tell us if there is missing driving force of water flow.

Acknowledgement

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Lei Ding

Marco D'Agostino

Daniel Persson

Marie-Béatrice BOGEAT-TRIBOULOT

Monica Rothwell

Théo Degand

Noémie Thiébaut

Thank you!