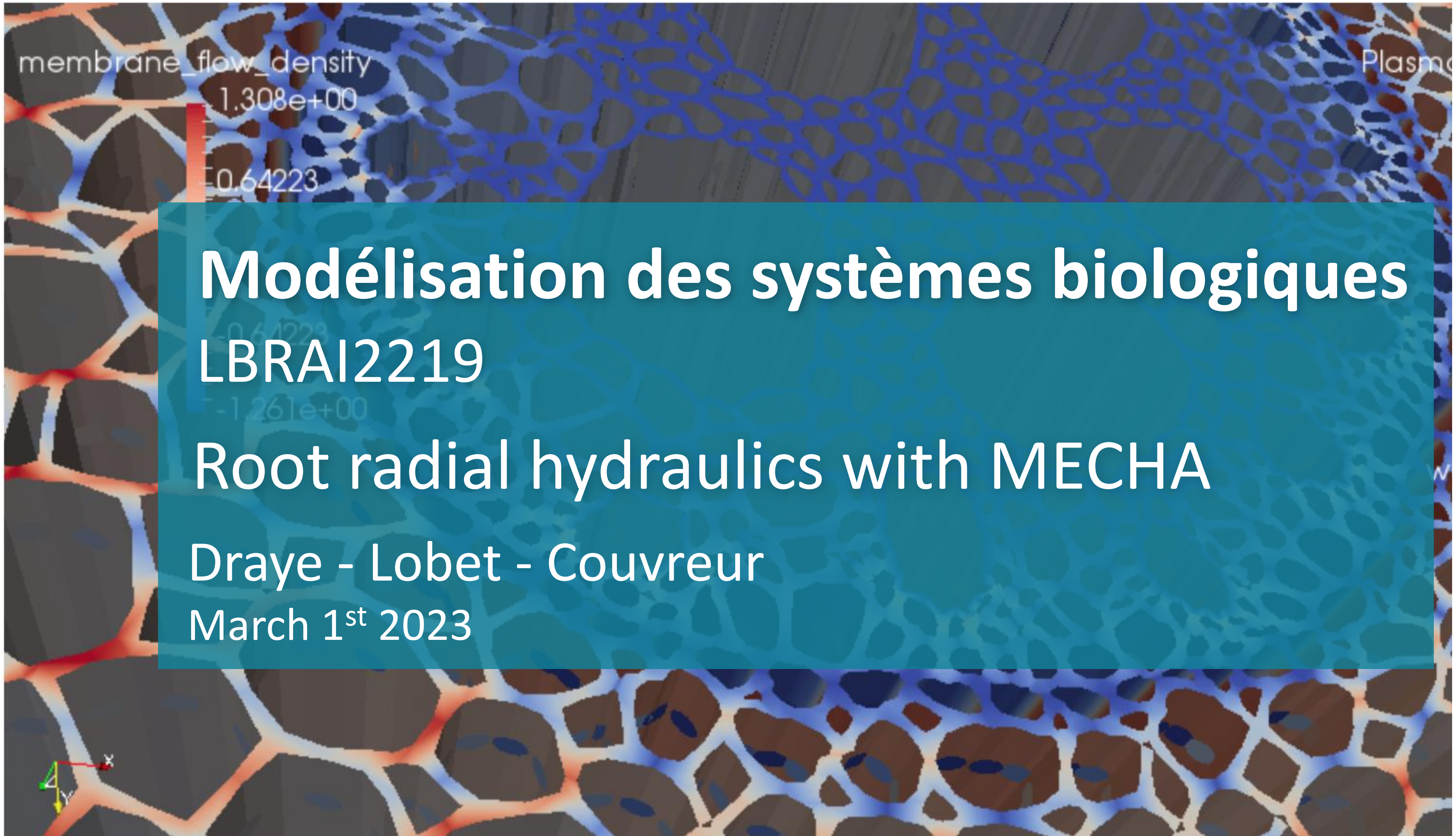
UCLouvain
Faculté des bioingénieurs

AGRO LOUVAIN



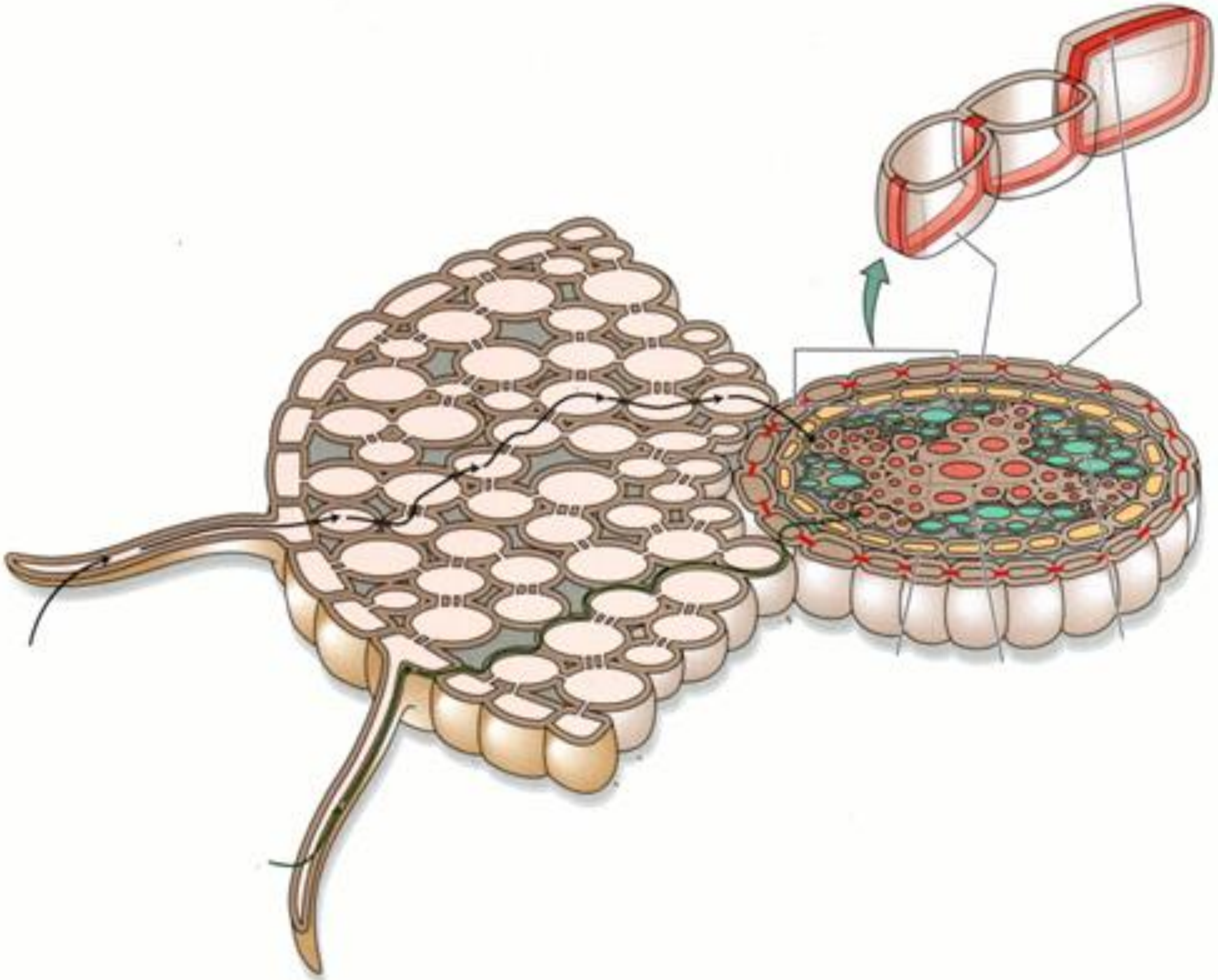
Modélisation des systèmes biologiques

LBRAI2219

Root radial hydraulics with MECHA

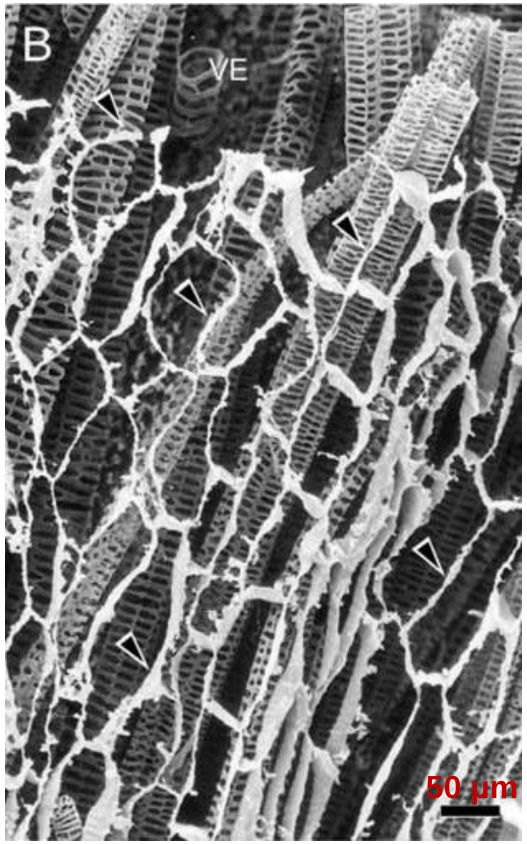
Draye - Lobet - Couvreur

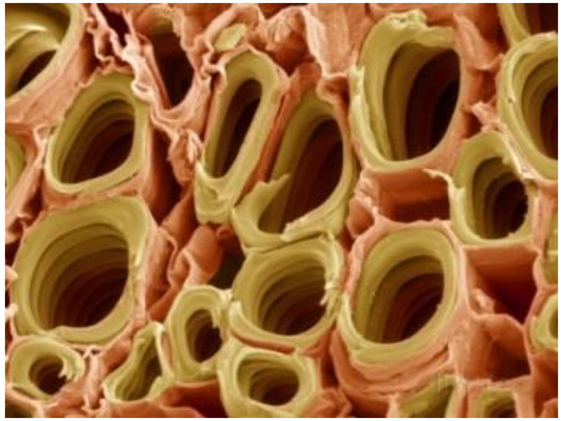
March 1st 2023

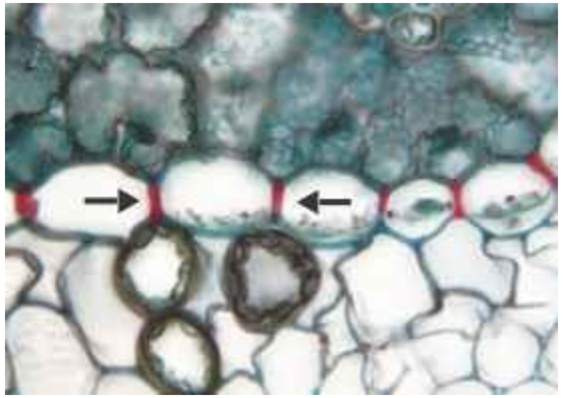


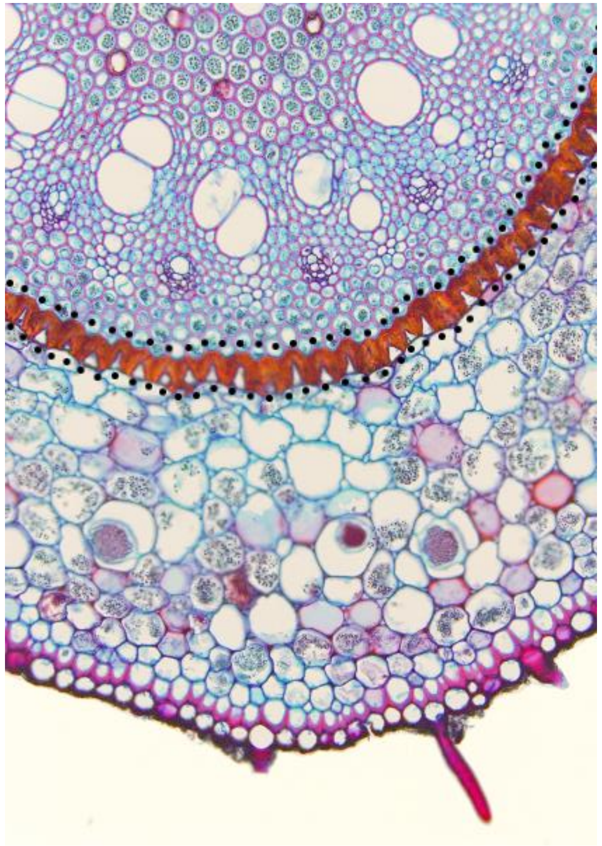
Apoplastic structures

- Scaffolds: Physical **separation** of compartments
- Thickening: Physical **support** against implosion / explosion
- Pipes: Long distance water **transport**



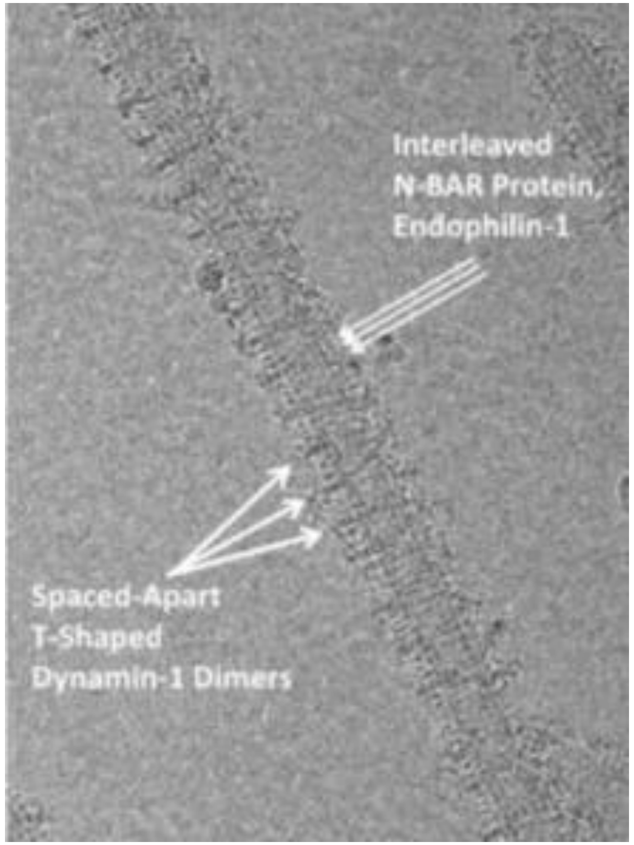


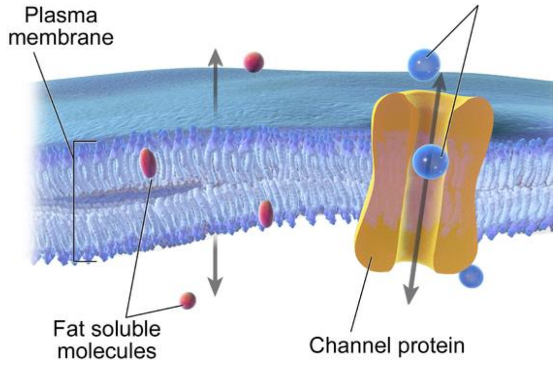


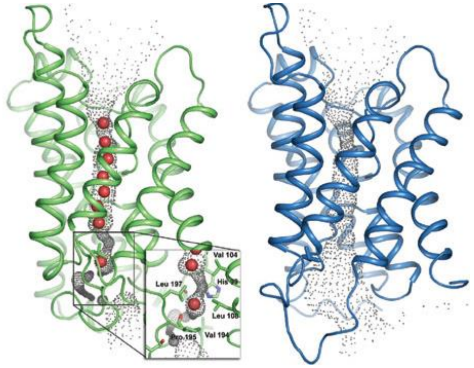


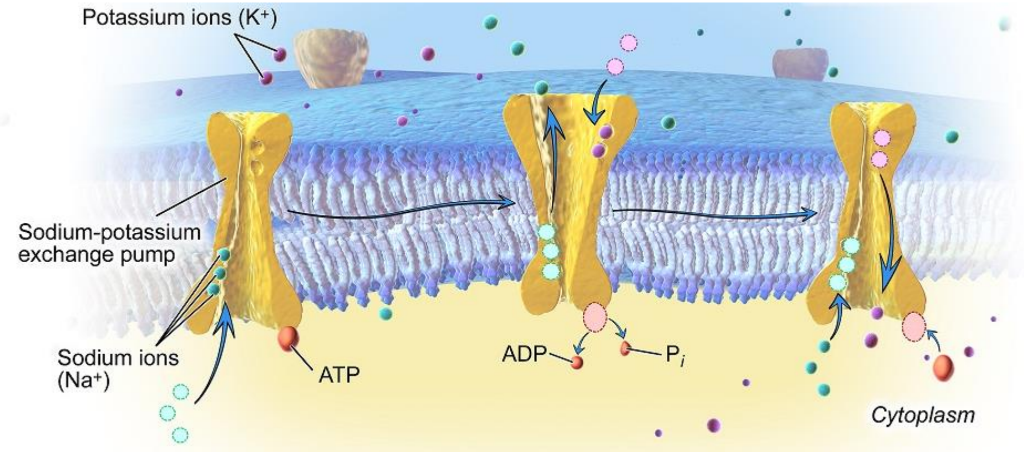
Transmembrane structures

- Pumps: Active **accumulation** of ions / molecules
- Channels: Passive **diffusion** of ions / molecules



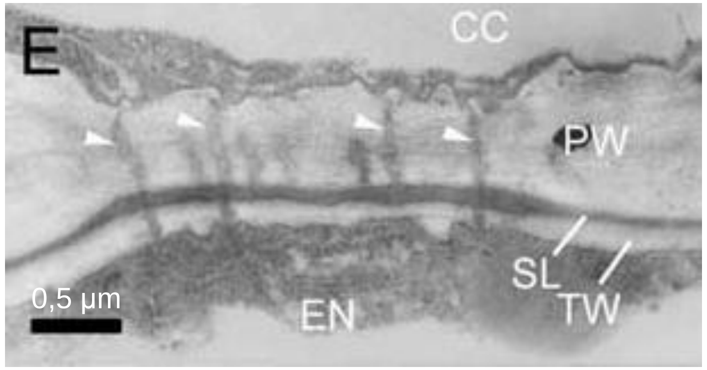


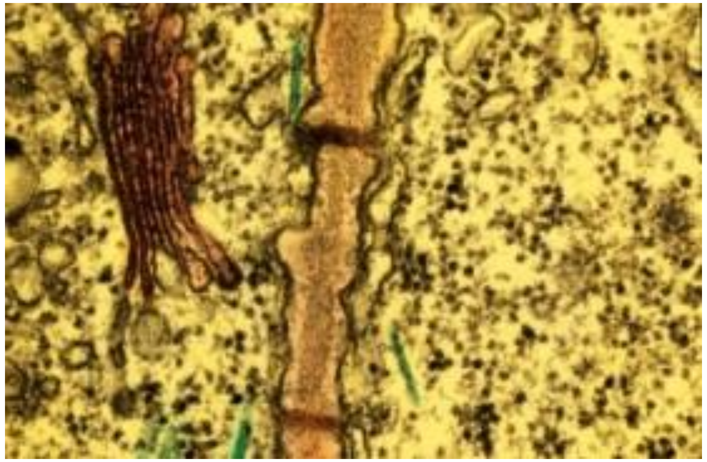


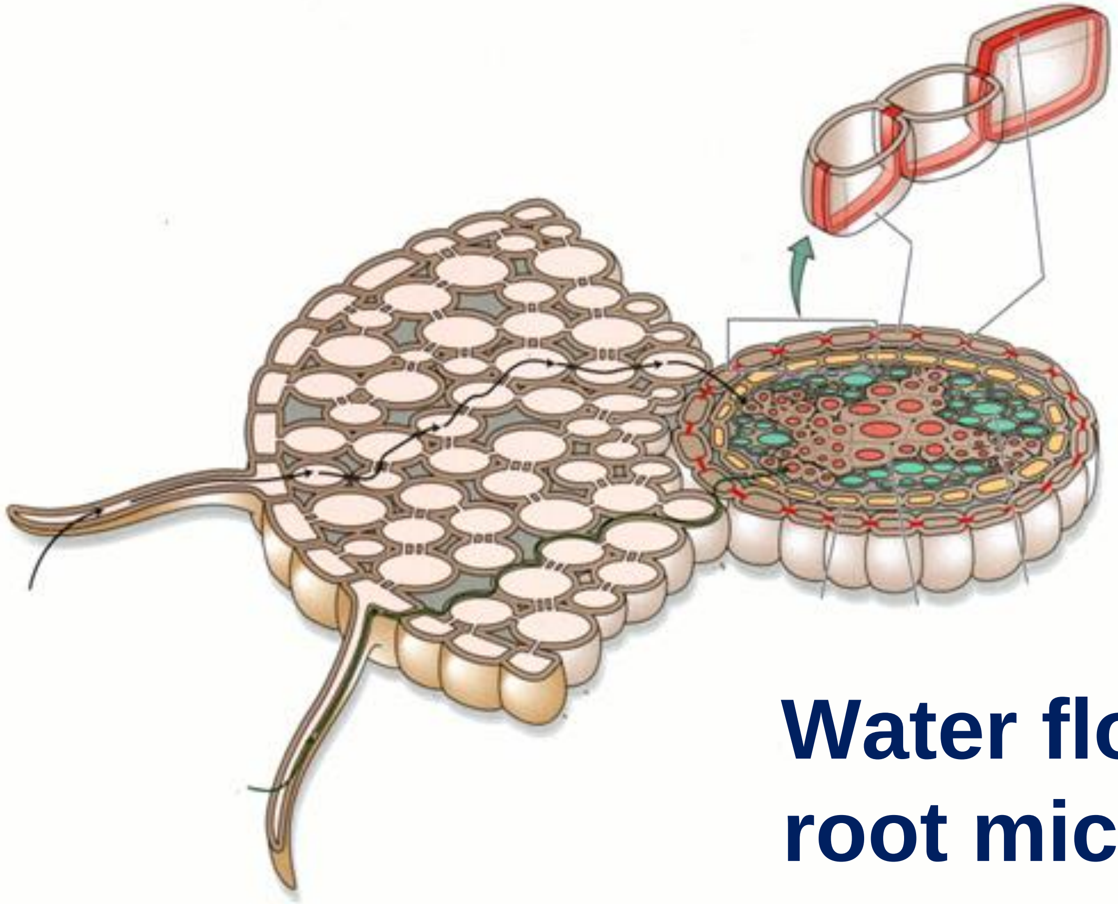


Symplastic structures

- Plasmodesmata: Passive **diffusion** of ions / molecules



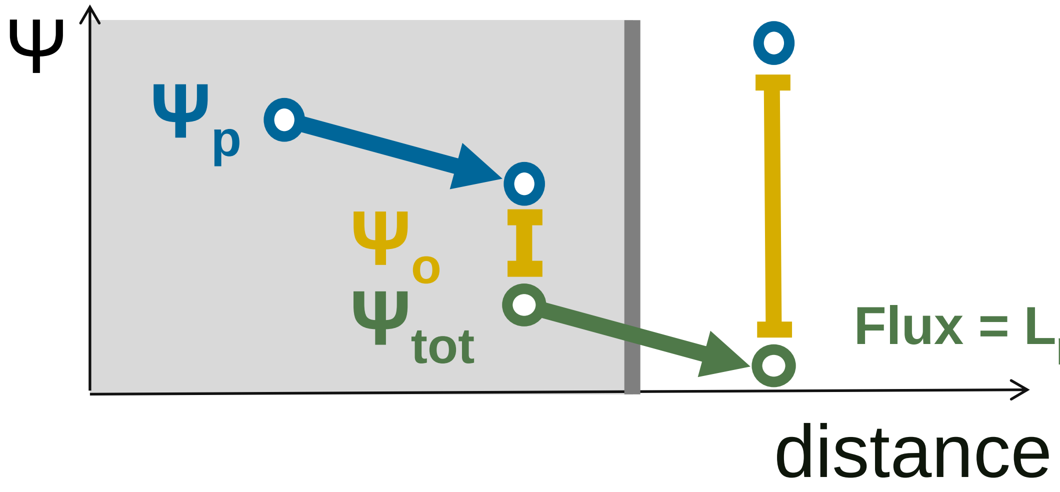




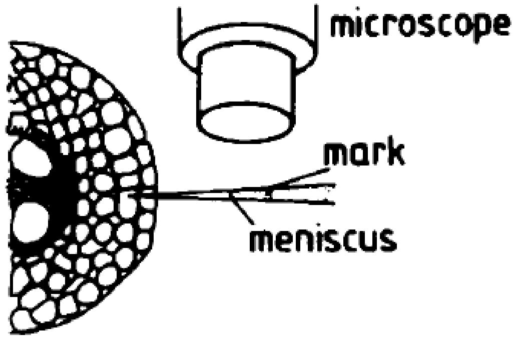
Water flow across root micro-structures

Cell level hydrological principles

Water flow across
cell walls & membranes



$$\text{Flux} = L_p\,(\Delta\Psi_p + \Delta\sigma\Psi_{os})$$



Zhu and Steudle (1991)
Plant Physiol., 95, 305-15

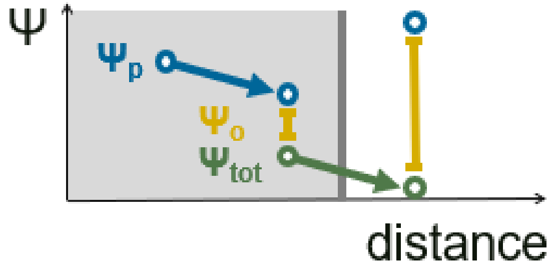
$$\Psi_{tot} = \Psi_p + \Psi_o$$

where

$$\Psi_o = -\,RT\,C_{os}$$

Current paradigm of water flow across root tissues

Water flow across cell walls & membranes

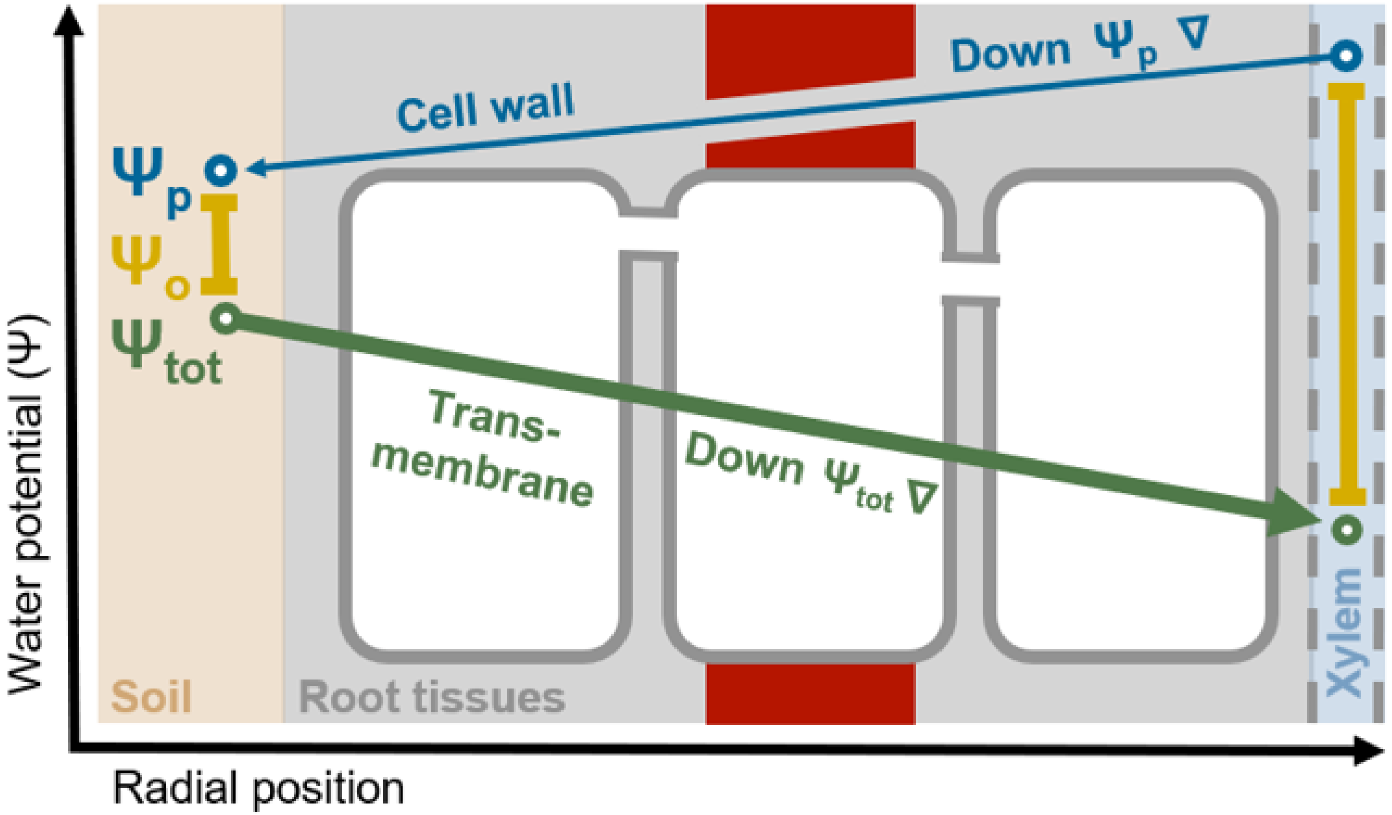


$$\Psi_{tot} = \Psi_p + \Psi_o$$

where

$$\Psi_o = -RT\,C_{os}$$

Root radial flow is analog to flow across a "big membrane"

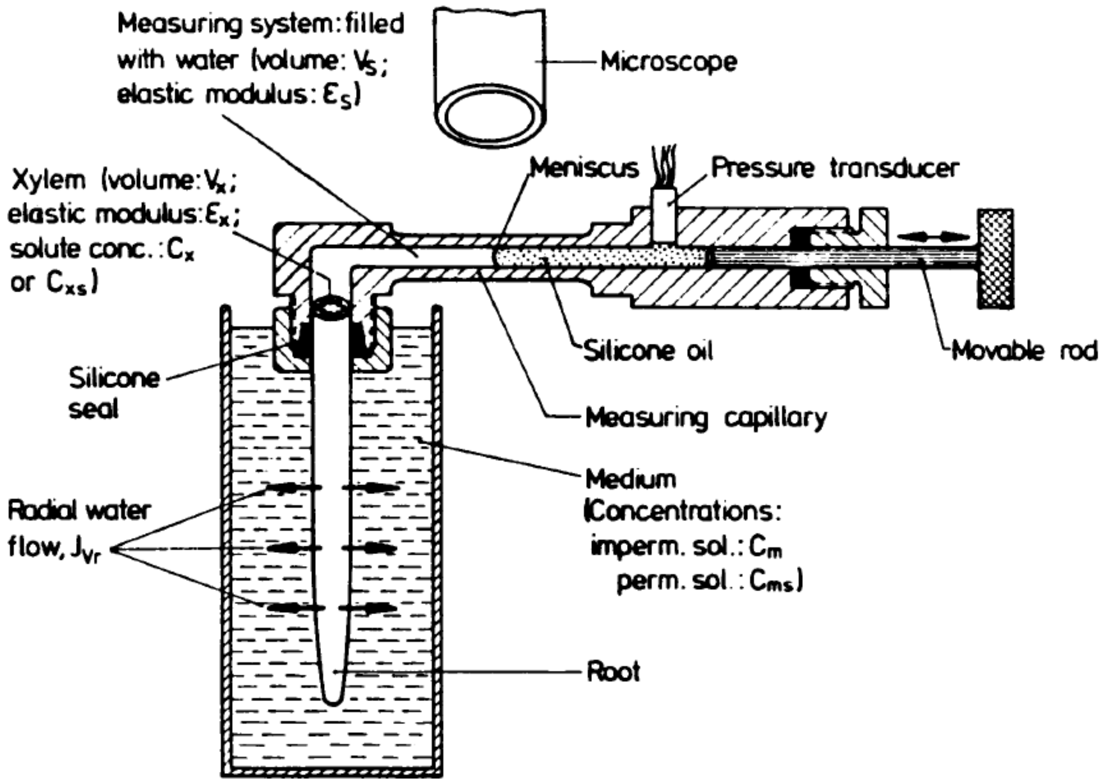


Root level hydrological principles

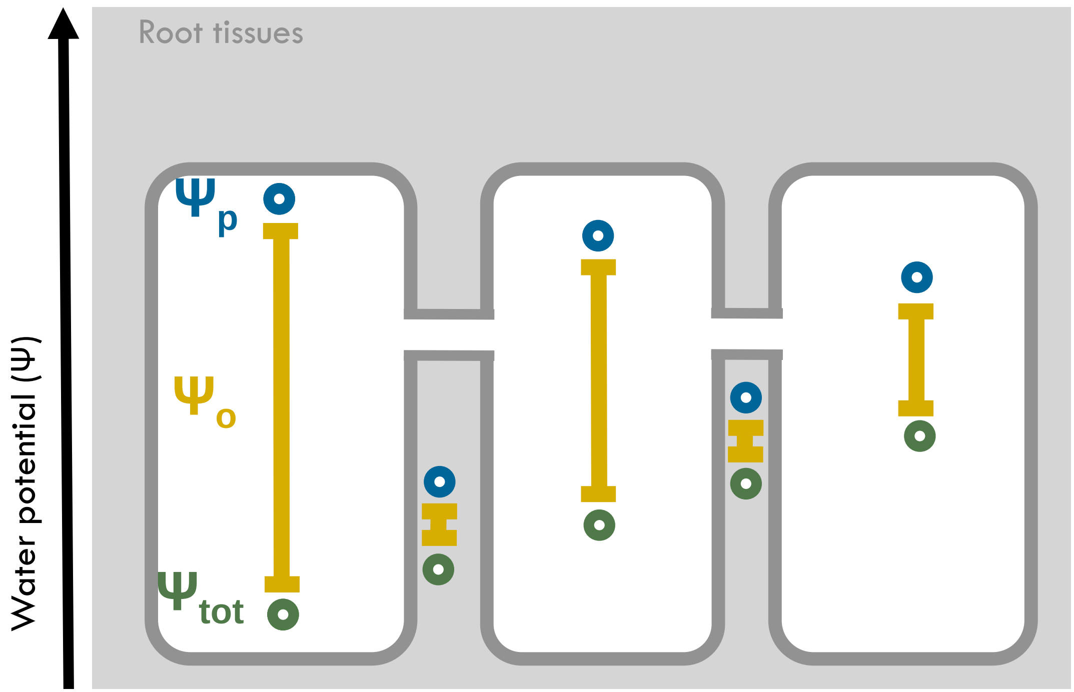
$$\text{Flux} = L_{pr}\,(\Delta\Psi_p + \Delta\sigma\Psi_{o,\,apo})$$

Fiscus and Kramer (1975) PNAS, 72, 3114-8

where $\Psi_o = -RT\,\Sigma C_o$



Does water flow to the right or to the left ?

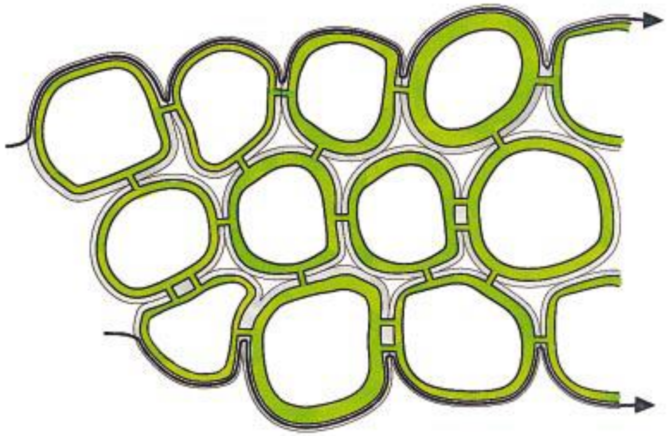


1 Allez sur wooclap.com

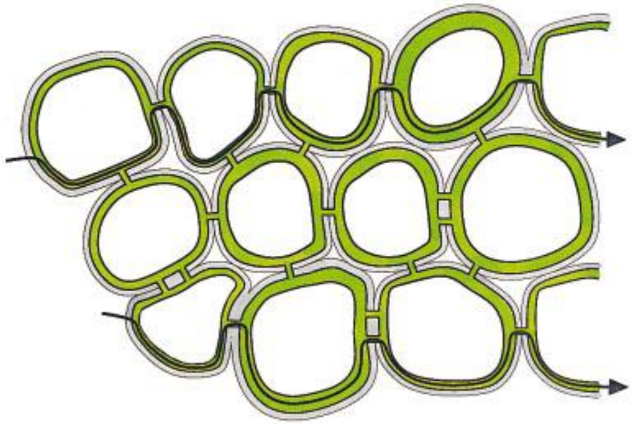
2 Entrez le code d'événement dans le bandeau supérieur

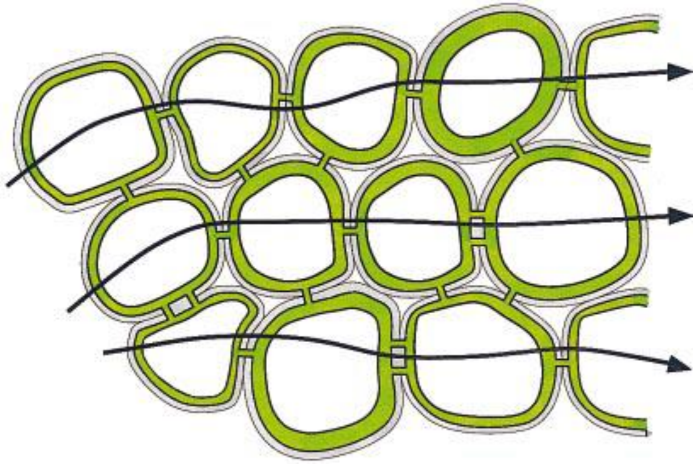
Code d'événement
MECHA2219

Does water flow to the right or to the left ?



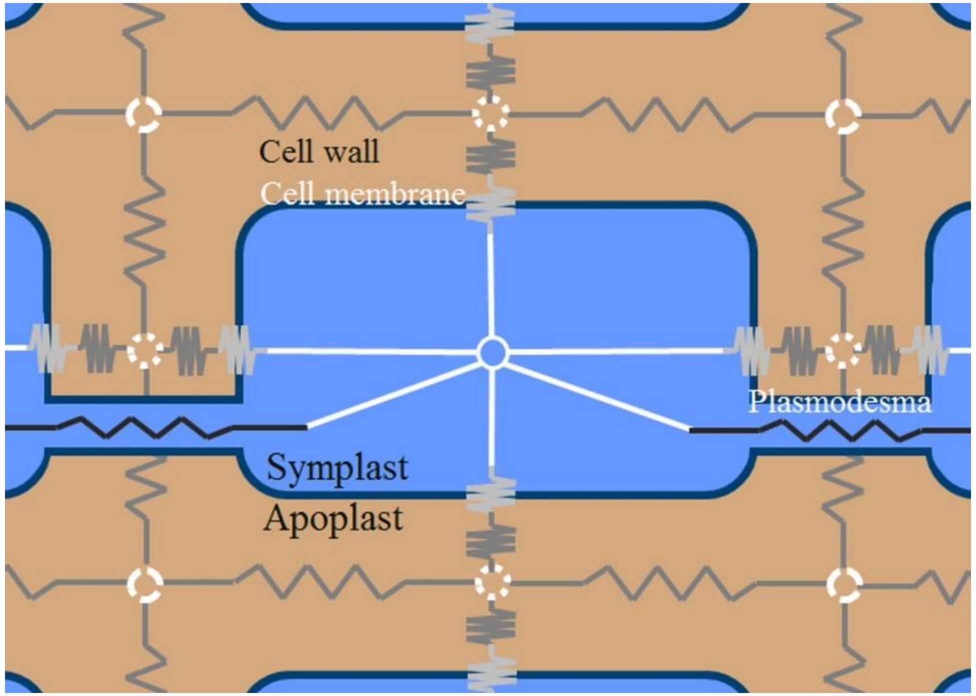
Setting hydraulic principles on a biological layout





Cell level hydraulic model

Permeability of cell walls (Steudle and Boyer, 1985), membranes (Elhert et al., 2009), and plasmodesmata (Bret-Hart and Silk, 1994; Warmbrodt, 1985; Clarkson et al., 1987)



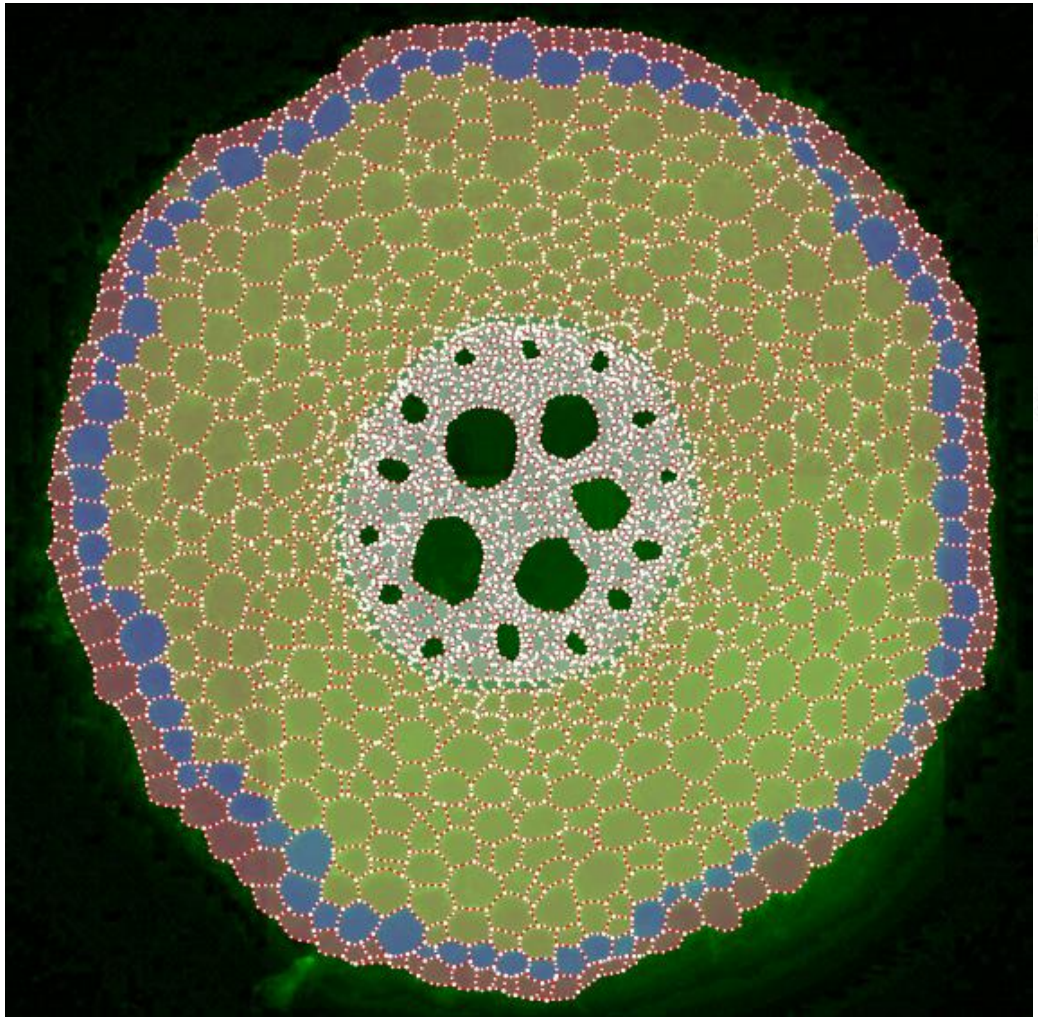
Flow principles:

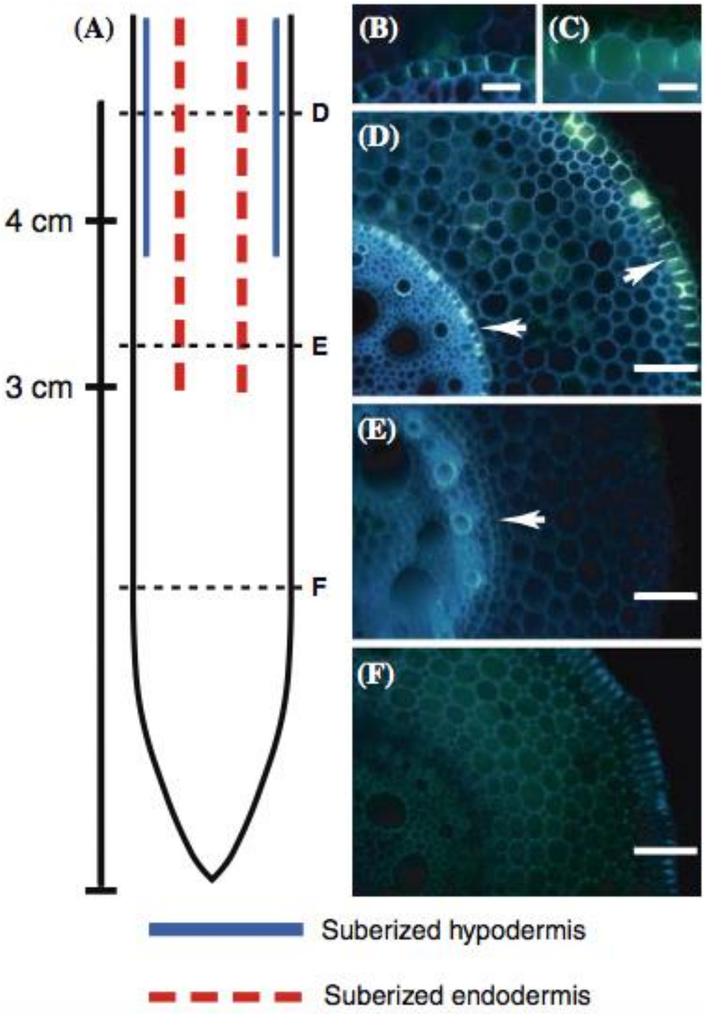
- Ψ_p driven in walls and plasmodesmata
- Ψ_{tot} driven flow across membranes

Plasmod.: 2.0 10^{-4} cm hPa^{-1} d^{-1}
Membrane: 5.0 10^{-4} cm hPa^{-1} d^{-1}
Young root: 1.0 10^{-4} cm hPa^{-1} d^{-1}

Cell wall: 0.005 cm^2 hPa^{-1} d^{-1}
Silty clay: 0.5 cm^2 hPa^{-1} d^{-1}

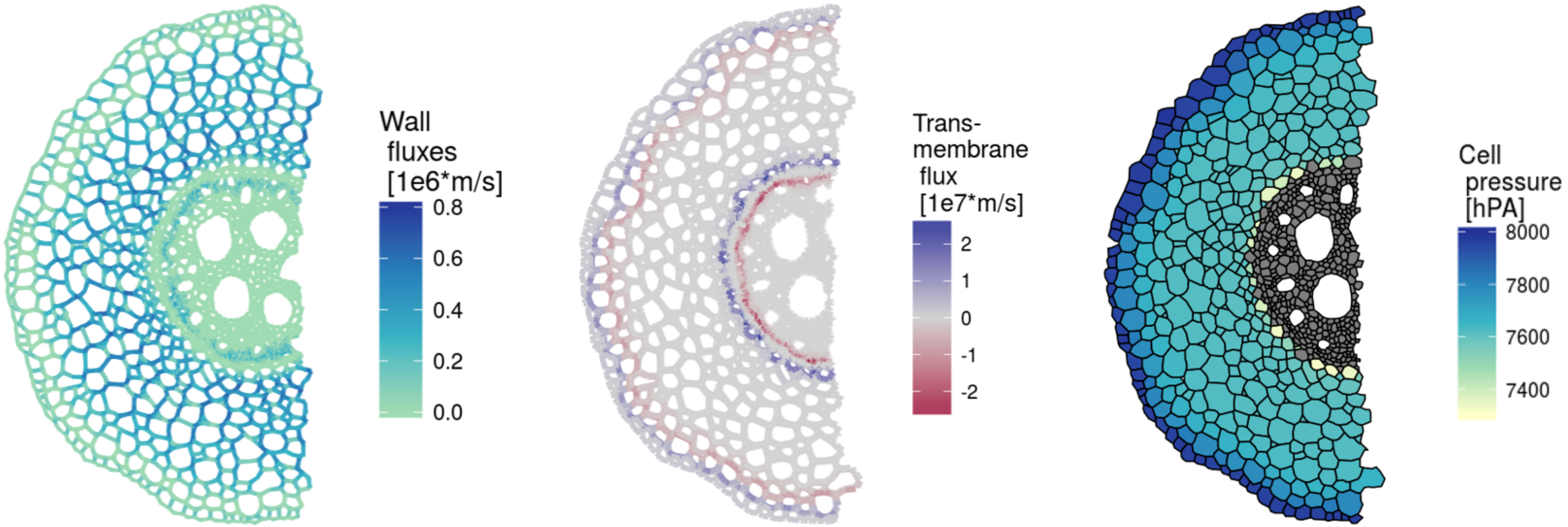
Root anatomy and location of apoplastic barriers





MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -



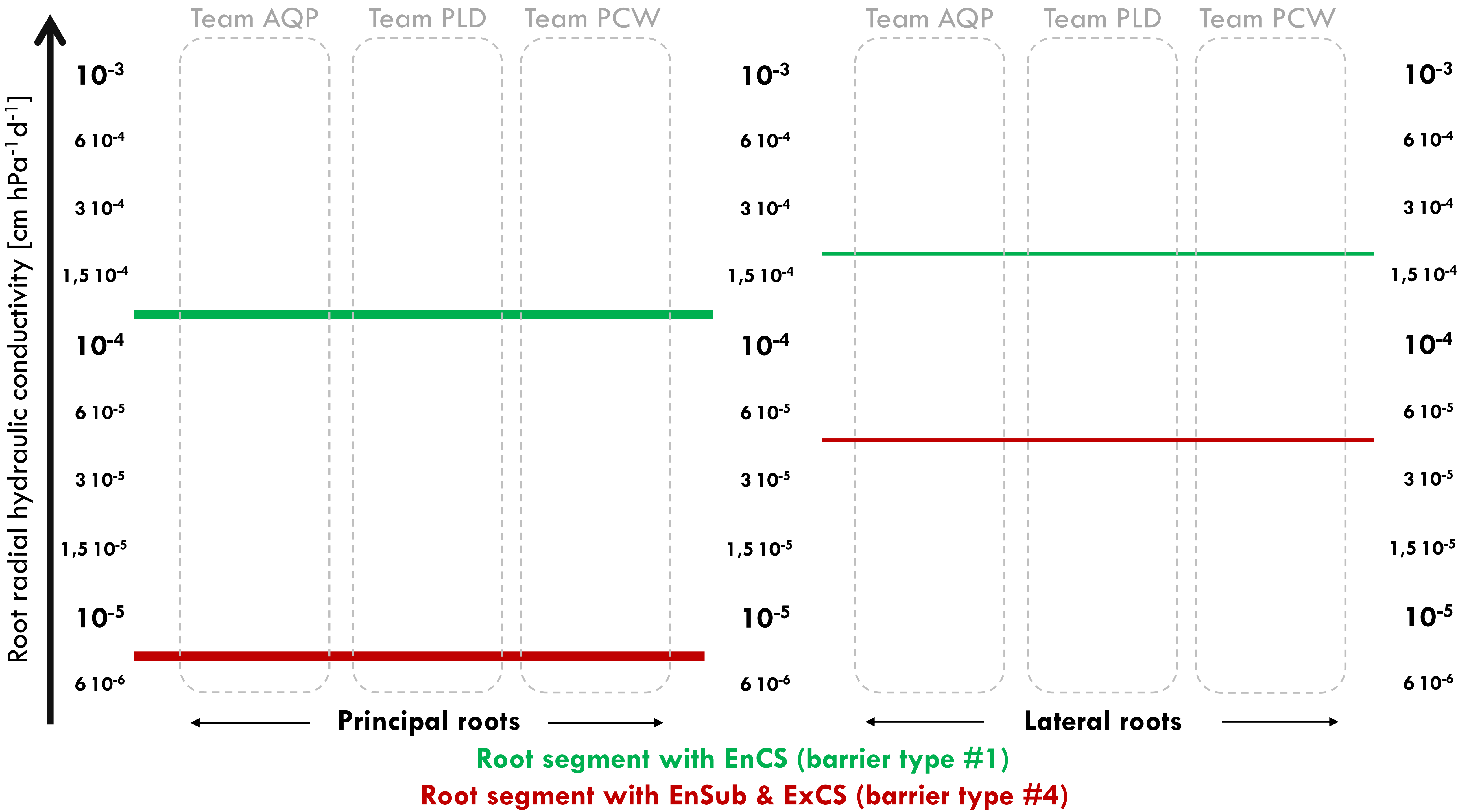
Open Source

mecharoot.github.io

Couvreur et al, 2018
Going with the Flow: Multiscale Insights into the Composite Nature of Water Transport in Roots[1[OPEN]]

RADIAL CONDUCTIVITY

AXIAL CONDUCTIVITY

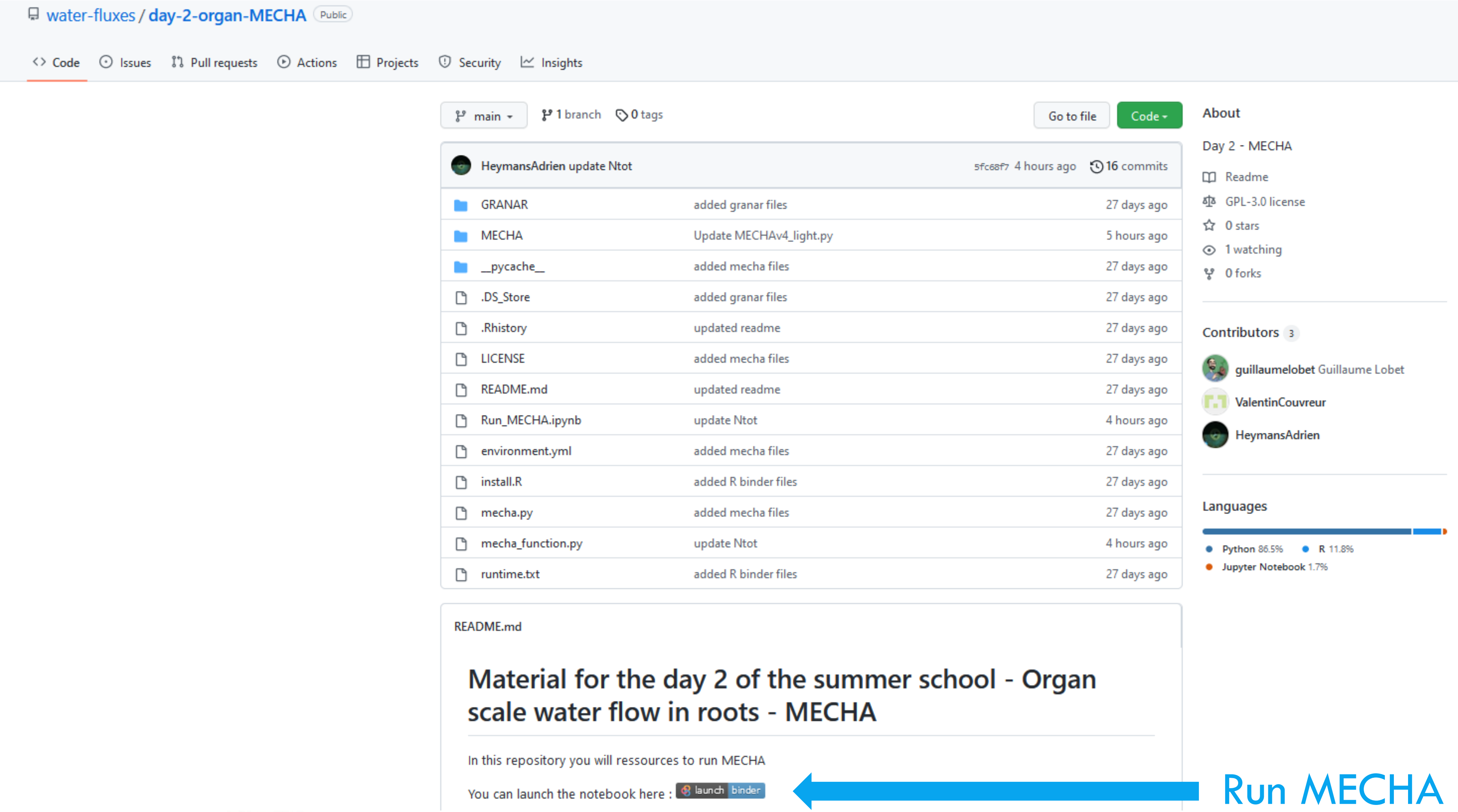


Root radial hydraulic conductivity [cm hPa-1 d-1]
Team AQP
Team PLD
Team PCW
Team AQP
Team PLD
Team PCW
10-3
6 10-4
3 10-4
1,5 10-4
10-4
6 10-5
3 10-5
1,5 10-5
10-5
6 10-6
Principal roots
Lateral roots
Root segment with EnCS (barrier type #1)
Root segment with EnSub & ExCS (barrier type #4)

MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

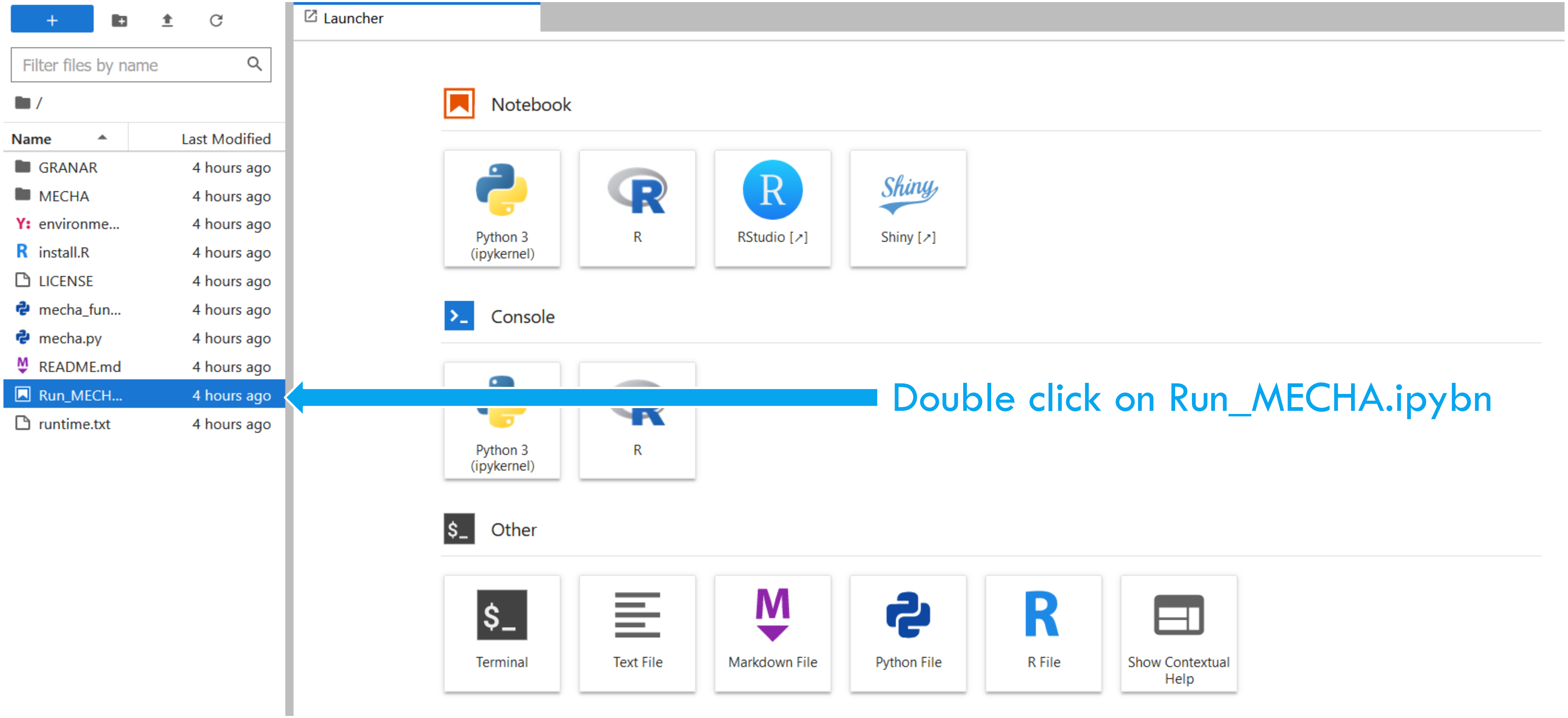
https://github.com/water-fluxes/day-2-organ-MECHA



Run MECHA via Binder

MODELLING WATER FLOW AT THE ORGAN SCALE
- MECHA -

Once on Binder… let's open the Jupyter Notebook!

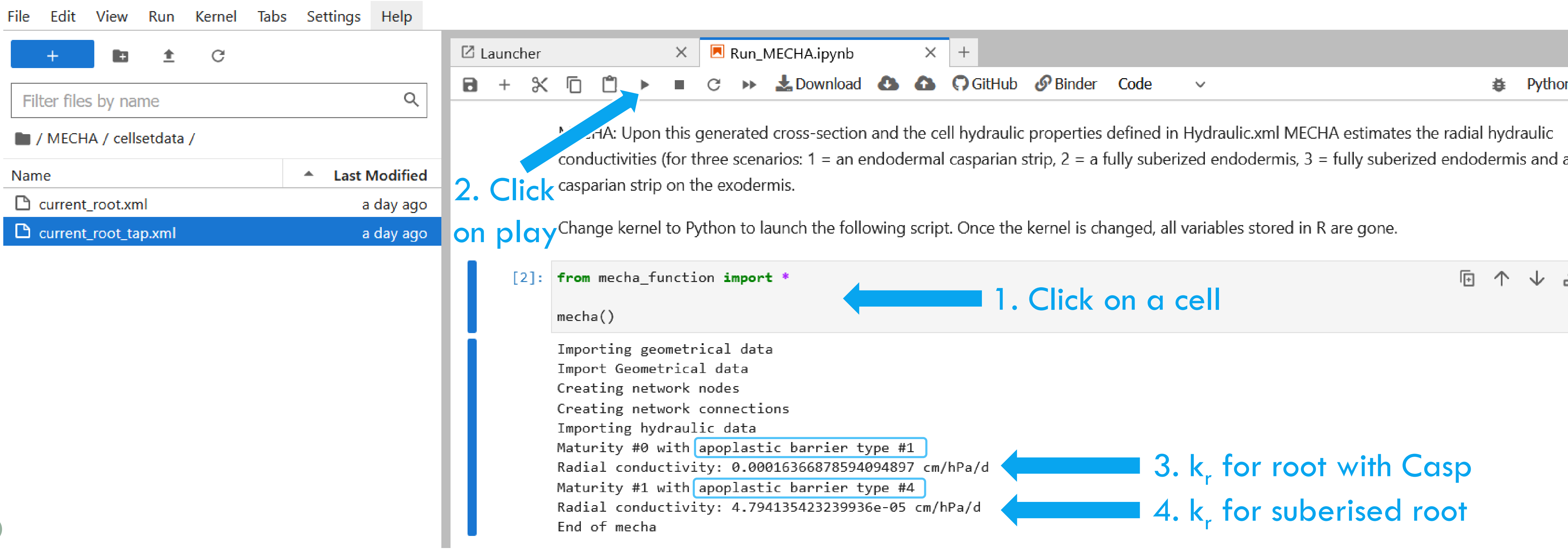


Double click on Run_MECHA.ipybn

MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

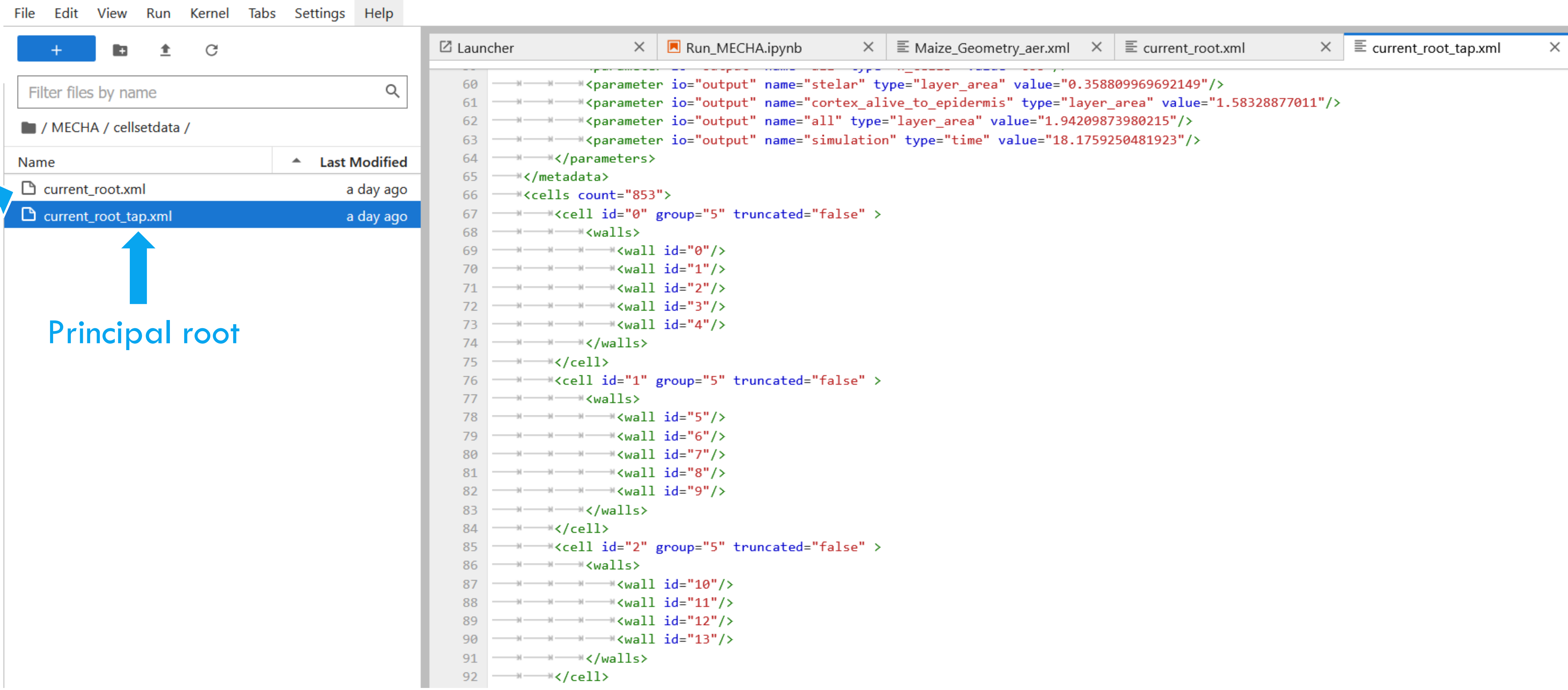
Once on Binder/Jupyter Notebook… let's run MECHA!



MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

Let us check the root anatomies available…



Lateral root

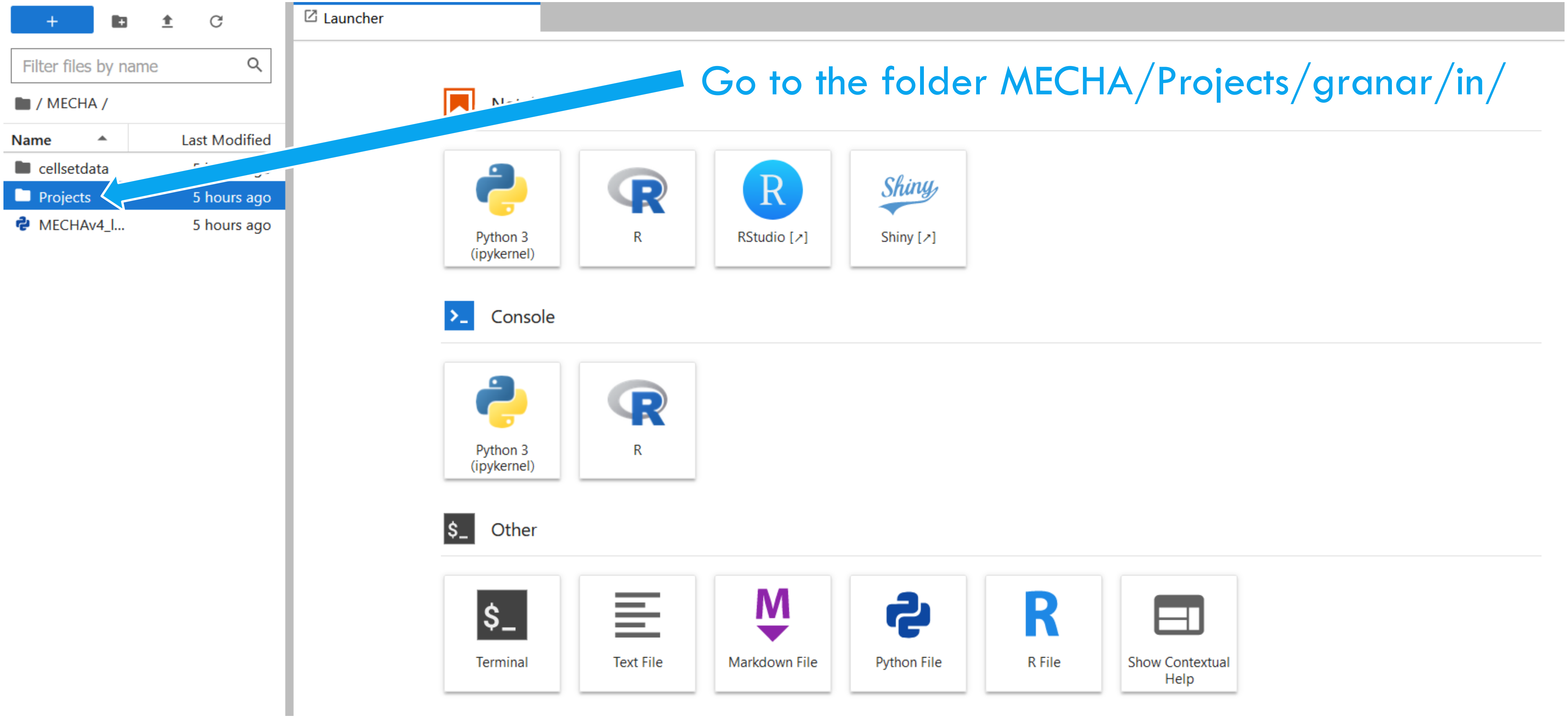
Principal root

MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

Once on Binder… let's update the root anatomy!

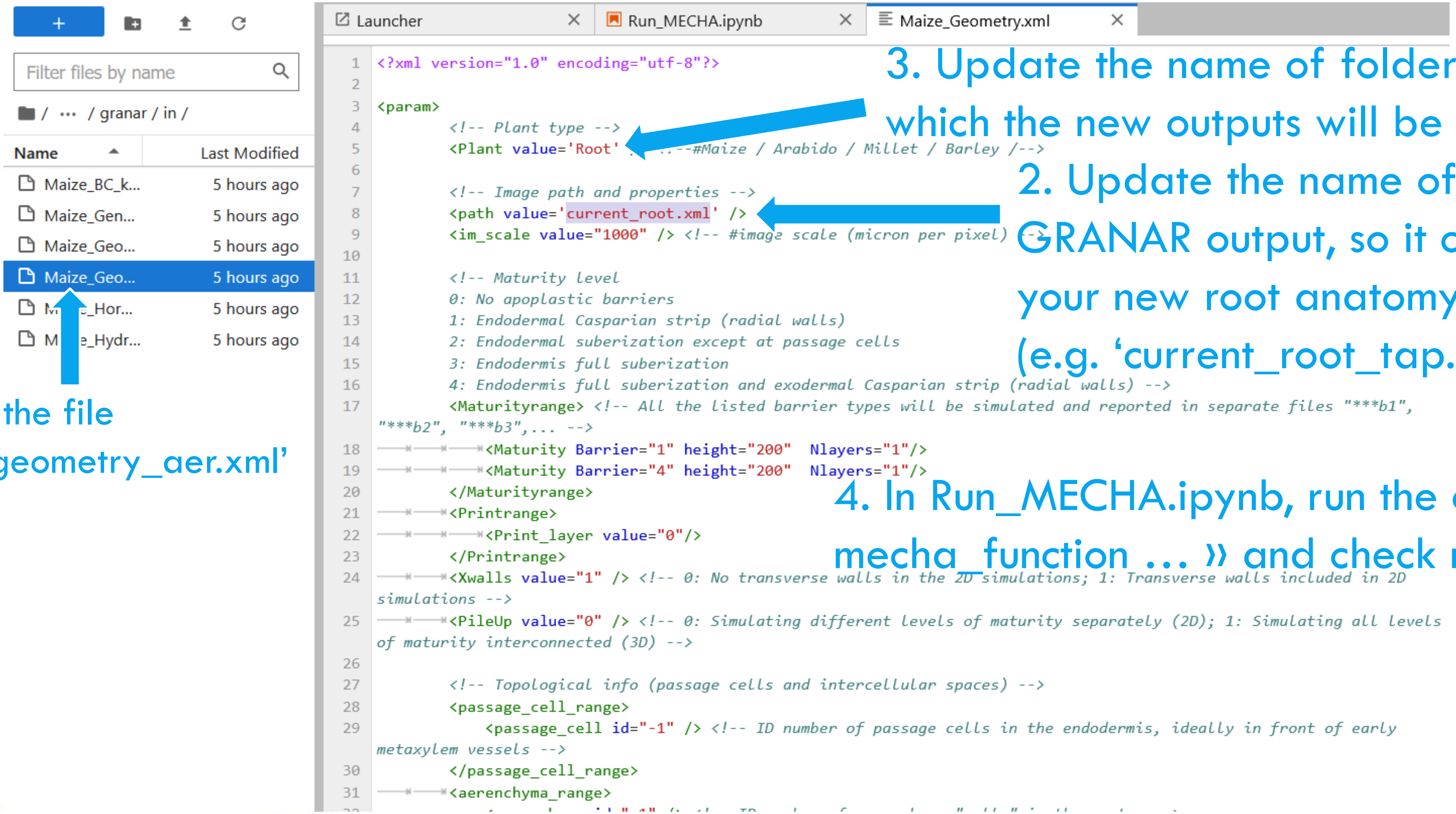
Go to the folder MECHA/Projects/granar/in/



MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

Once on Binder… let's update the root anatomy!



1. Open the file 'Maize_geometry_aer.xml'

2. Update the name of the dragged GRANAR output, so it corresponds to your new root anatomy file name (e.g. 'current_root_tap.xml')

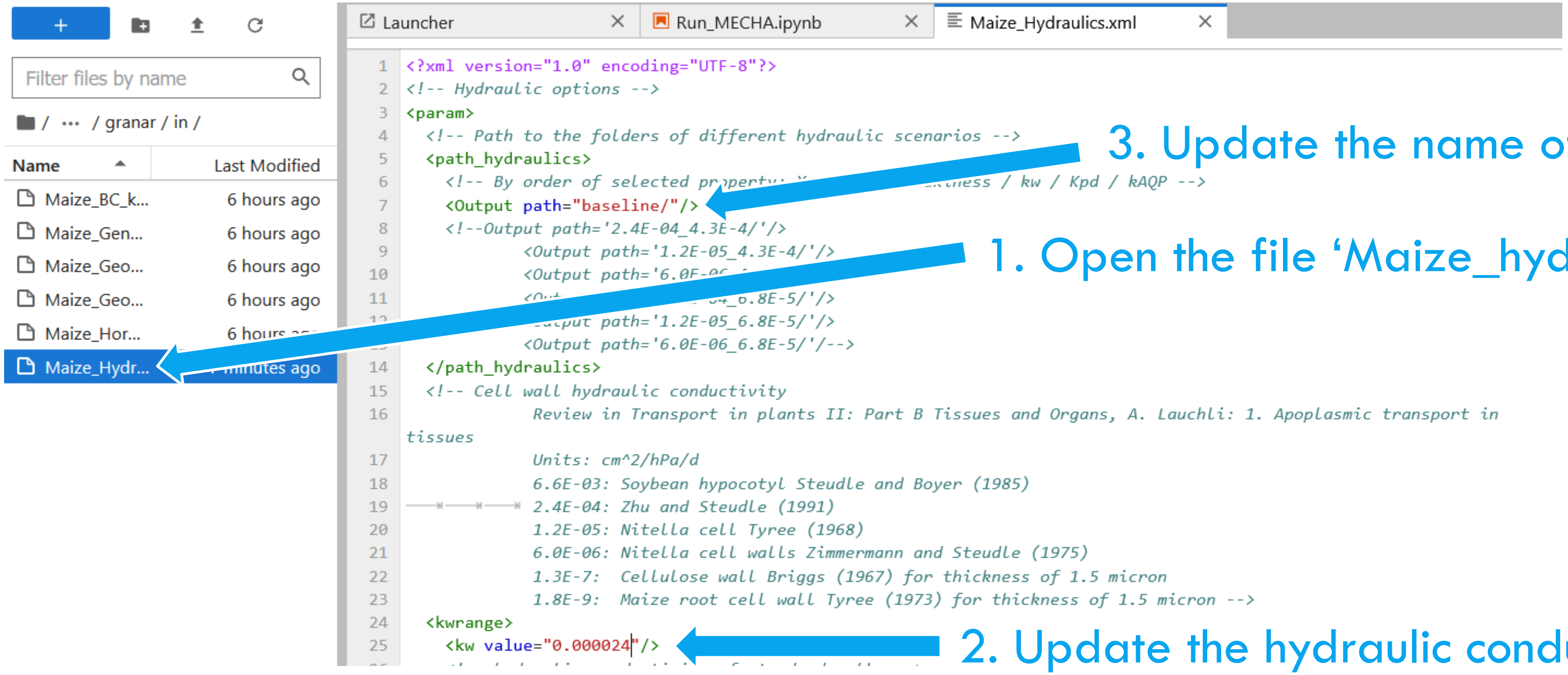
3. Update the name of folder in which the new outputs will be stored

4. In Run_MECHA.ipynb, run the cell « from mecha_function … » and check new kr values

MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

Once on Binder… let's update the cell hydraulic properties!



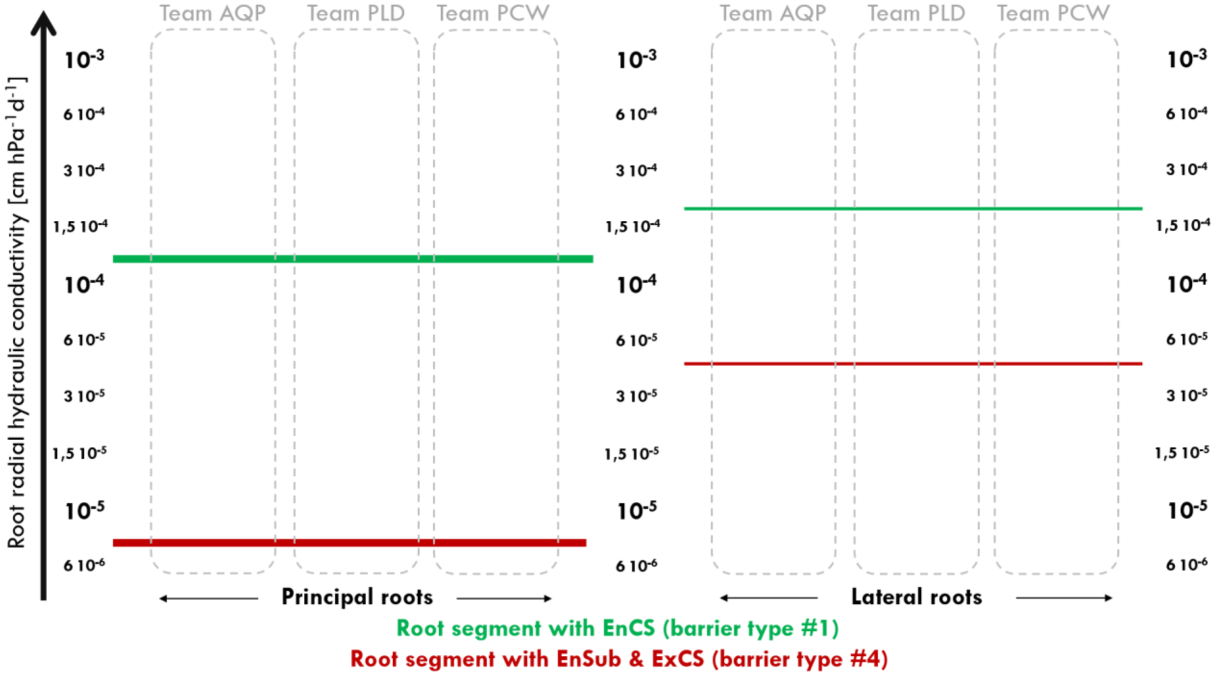
3. Update the name of the scenario

1. Open the file 'Maize_hydraulics.xml'

2. Update the hydraulic conductivity of cell walls (kw) or membranes aquaporins (kAQP), or plasmodesmata (Kpl)

4. In Run_MECHA.ipynb, run the cell « from mecha_function … » and check new kr values

Add updates radial conductivities in your team’s column !



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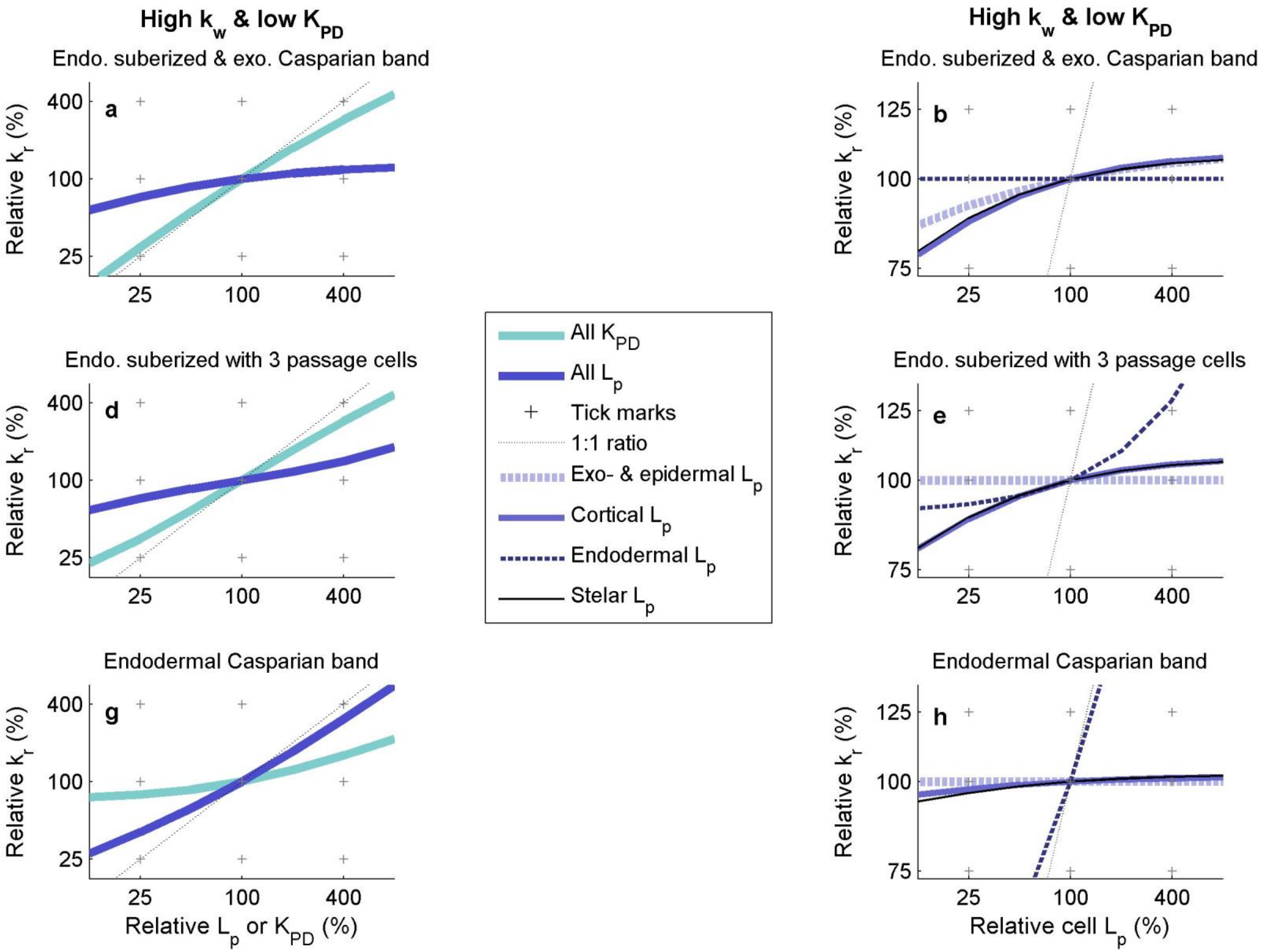
Code d'événement
MECHA2219

SENSITIVITY ANALYSIS



MODELLING WATER FLOW AT THE ORGAN SCALE

- MECHA -

https://plantmodelling.shinyapps.io/mecha/

Valentin Couvreur, Marc Faget, Guillaume Lobet, Mathieu Javaux, François Chaumont and Xavier Draye

Université catholique de Louvain, Forschungszentrum Juelich GmbH

Choose plant | Change parameters | About

Choose a simulation to visualize

1. Select a plant type

Arabidopsis1

MECHA was run for different cross section geometries and plant type. Te results were pre-processed to be easily visualised here.

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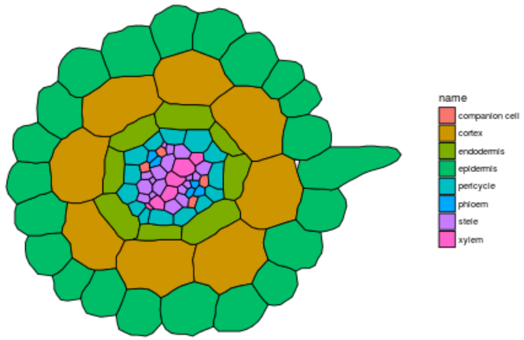
Tissue layers

Visualisation of the different cell layers used in the simulation



Select the information to visualize

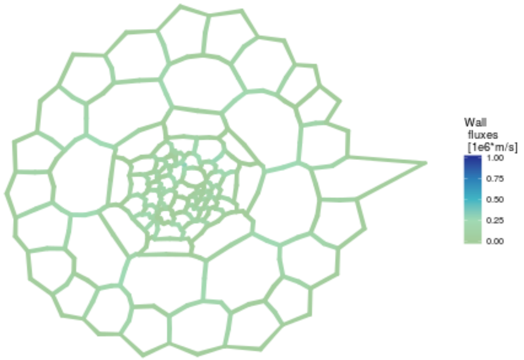
fluxes

Synthetic information about the simulation

param	value	unit
Cross-section height	0.01	cm
Cross-section perimeter	0.0304	cm
Cross-section radial conductivity	2.47e-04	cm/hPa/d
Xylem pressure potential	1100	hPa
Soil pressure potential	-100	hPa
Xylem osmotic potential	-1500	hPa
Soil osmotic potential	-200	to
Soil contact	0e+00	microns
Wall conductivity	0.0066	cm^2/hPa/d
Plasmodesmata conductivity	3.1e-11	cm^3/hPa/d
Aquaporin conductivity	4.3e-04	cm/hPa/d

Cell walls fluxes

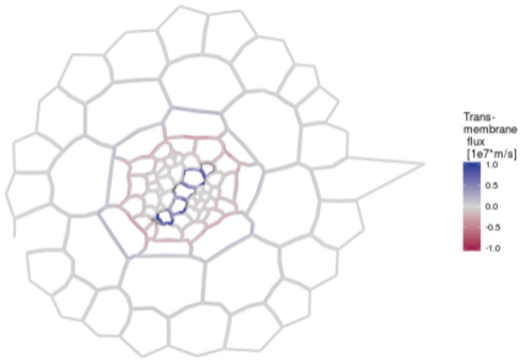
Flows with the cell walls of the cross section.



Display range:

Transmembrane fluxes

Flows with the cell membranes of the cross section. Blue color indicates when the water is entering the cell. Red color indicates when the water is leaving the cell.



Display range:

Relative contribution of water pathways

Visualisation of the relative contribution of the apolastic and symplastic pathways to the global water flow acrsoos the root crossection