Hydropatterning:
Water Availability Regulates Lateral Root Branching

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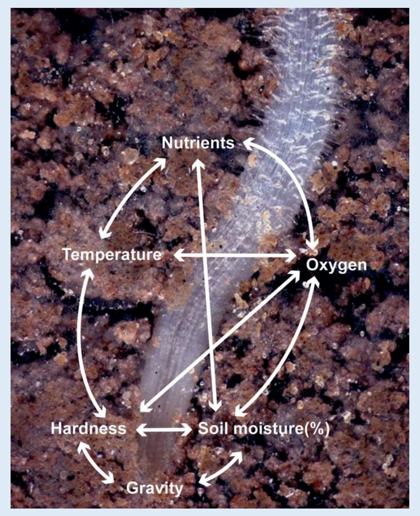
Plant Roots Navigate Complex Soil Environments

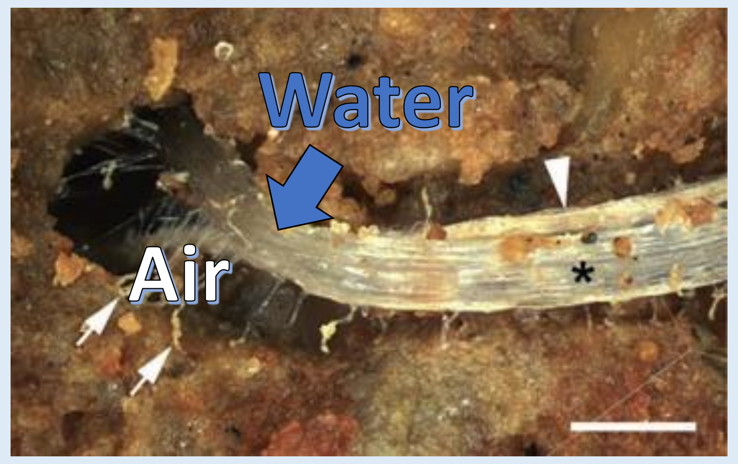
Roots navigate a heterogeneous environment to capture resources such as water and nutrients. To aid foraging, plants have evolved roots whose growth and development are highly responsive to soil signals. As a result, 3D root architecture is shaped by the soil it grows in[1].

A feature of soil that contributes to its complexity is the presence of macropores, created by worms, previous root growth or drying soil. When a root grows down a macropore lateral roots (LRs) only form on the side of the root in contact with soil. Experiments show the response is stimulated by differences in water availability[2]. This bias in branching is called hydropatterning. It is hypothesised that this is an adaptation to improve water uptake and save energy.

I am using X-ray computed tomography (CT) to observe hydropatterning in the soil and genetic tools in *Arabidopsis thaliana* to investigate how water movement could trigger the bias in branching.



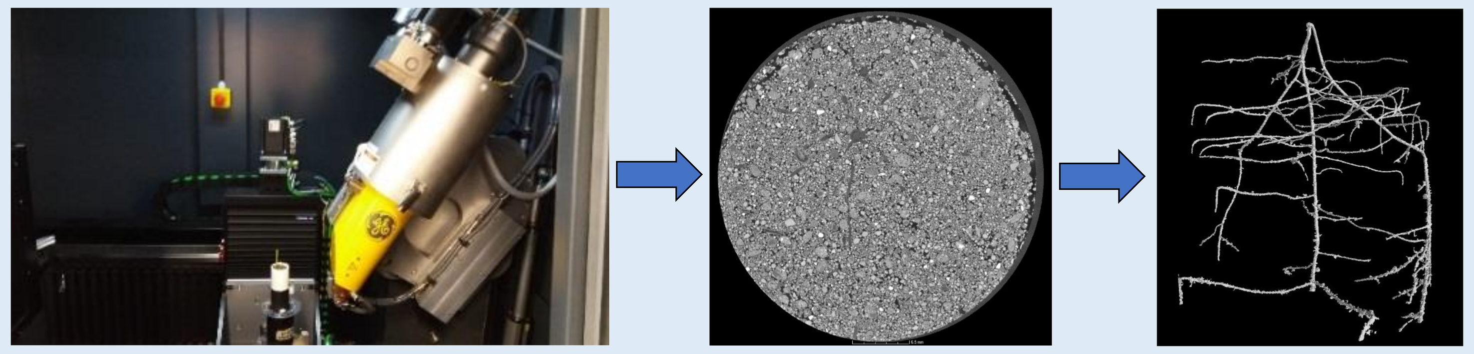
Interacting soil conditions[3]



A wheat root growing in a macropore[4]

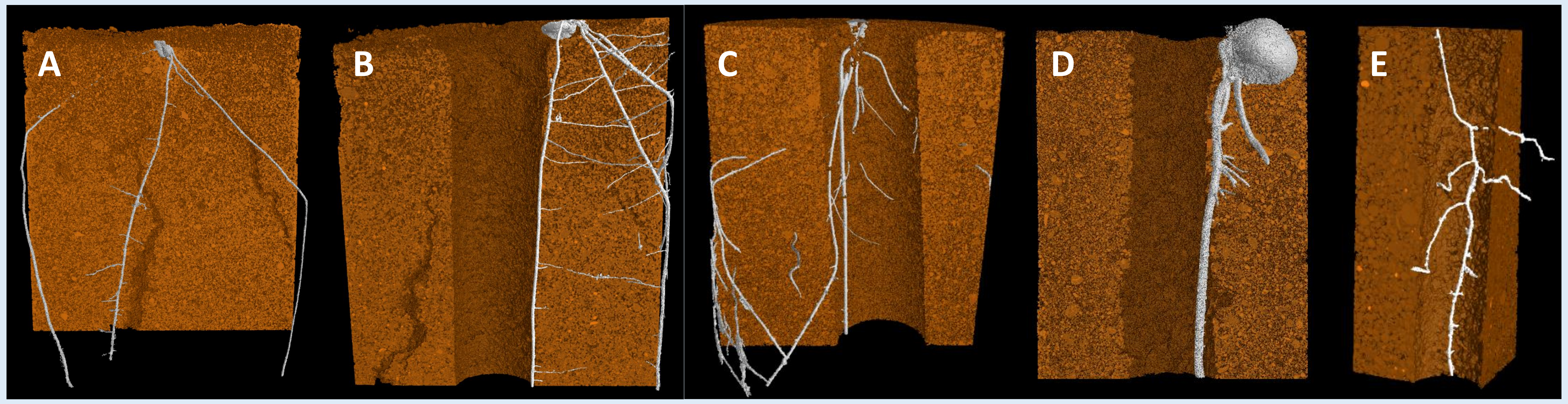
Hydropatterning is a Striking Response Observed in Many Species

Method
3-D plant root systems can be imaged non-destructively using X-ray CT scanning. X-rays are fired through the sample as it rotates. Root, soil and air differ in X-ray attenuation so the root structure can be picked out of the soil.



No macropore

Macropore

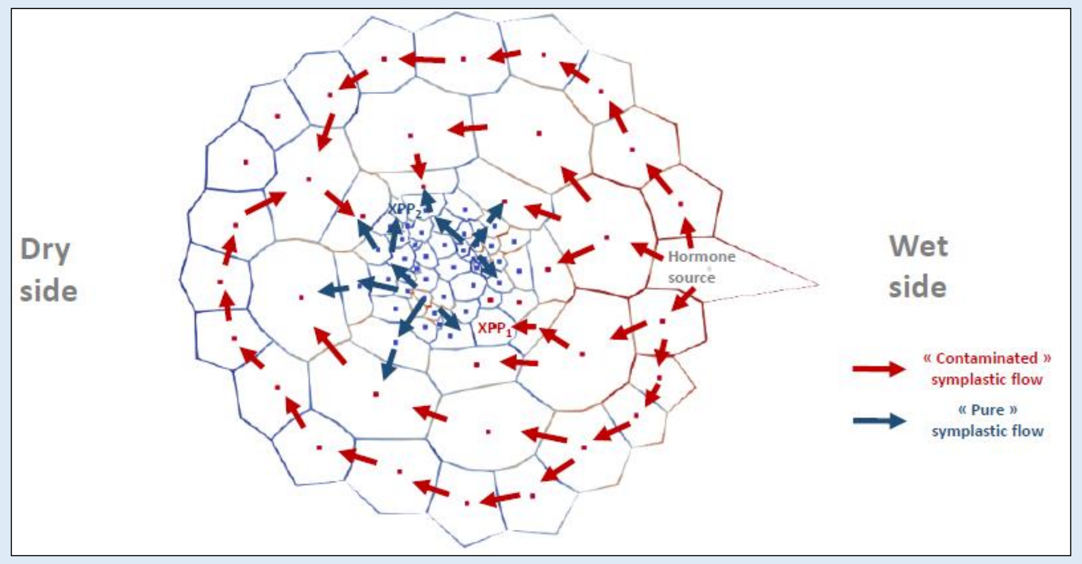


Roots of 4 different species –wheat (A+B), barley (C), maize (D) and arabidopsis (E)- were grown down an artificial macropore in soil and the direction of initiating LR's was quantified. All species show strong patterning of LR initiation towards the soil. Interestingly the strength of patterning differs between species. Results confirm that hydropatterning is a conserved response supporting the hypothesis that this is a key adaptation to improve water and nutrient resource capture.

Modelling Reveals Water Moves Asymmetrically During Hydropatterning

Method
Water movement during hydropatterning was modelled using a model of explicit cross-section hydraulic architecture (MECHA). Root anatomical descriptions, experimental data on the permeability of cell walls and membranes and plasmodesmata (PD) conductance are used to predict horizontal water movement in the root.

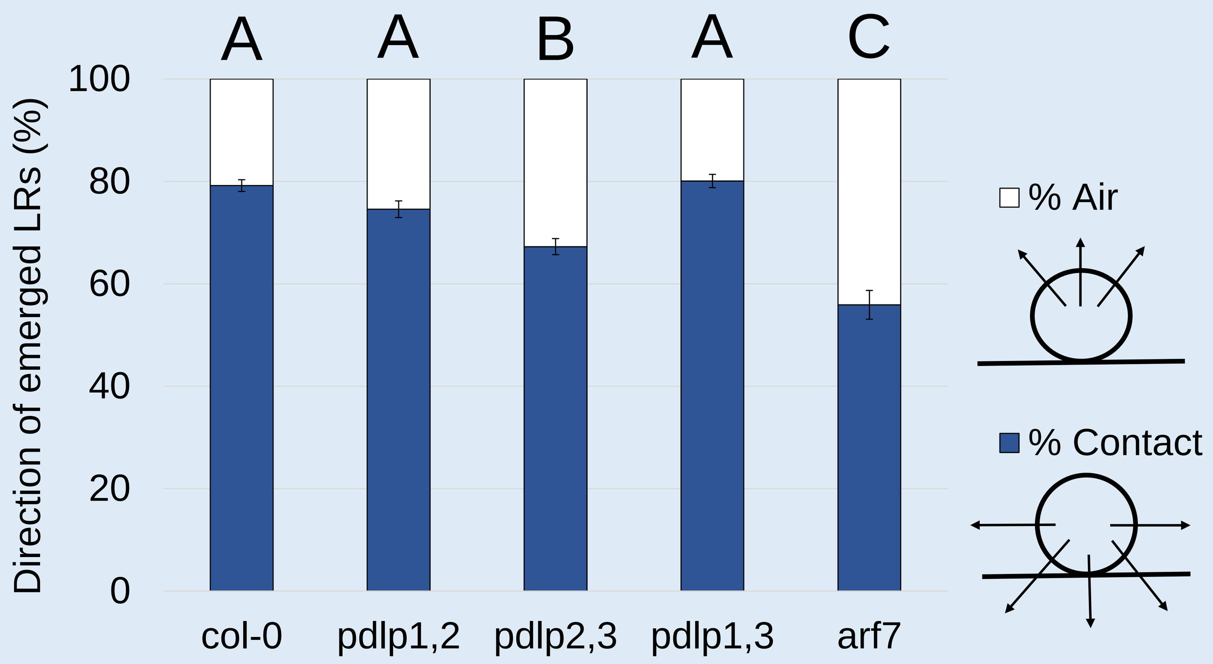
The elongating cells on the dry side of the root pull soil water through the outer layers of the root from the wet side, creating asymmetric water movement. Water is also sourced from the phloem on the dry side of the root to maintain elongation. LR initiation sites on the dry and wet side of the root are likely to be reached first by different sources of water. Increased PD conductance surrounding the phloem, causing more water to leak out, could disrupt the asymmetry of water movement.



Red arrows illustrate water flow from the soil across the root

Altering Plasmodesmata Permeability Disrupts Hydropatterning

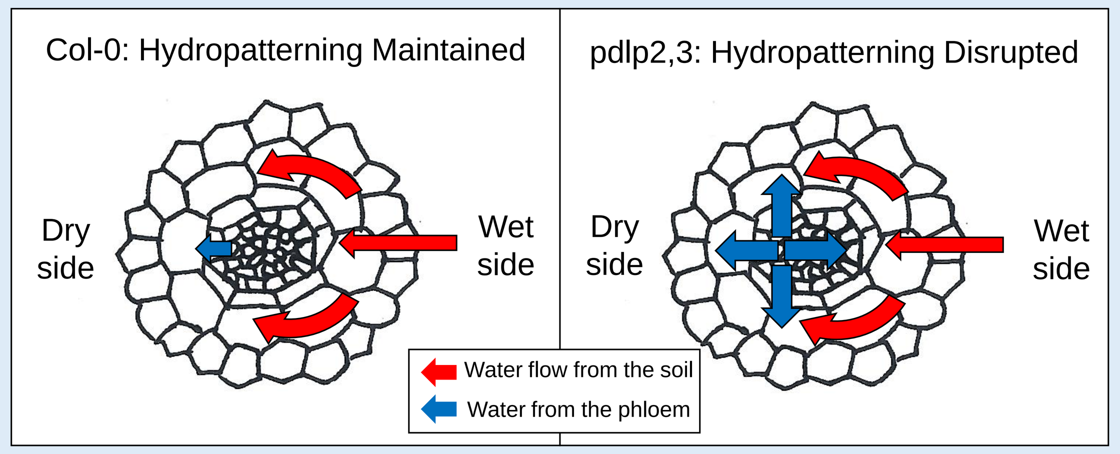
Method
Root growth on agar mimics growth down a macropore as part of the root is in contact with wet agar and the other part is exposed to air. Arabidopsis roots display hydropatterning by initiating most, ~80%, of LRs into the contact side. This assay was used to explore whether lines with altered PD conductance had a disrupted hydropatterning response.



Plasmodesmata localised proteins (PDLPs) are receptor like proteins that block PD. Double knock outs in the PDLP family show increased PD permeability[5]. Plants without pdlp2,3, normally acting to block PD in cells surrounding the phloem, have a hydropatterning defect. Taking in to account the MECHA model it can be hypothesised that pdlp2,3 has a reduced ability to hydropattern due to the increased flow of water from the phloem disrupting which source of water reaches which LR initiation site.

Asymmetric water flow from the soil is required for hydropatterning

X-ray CT scanning has revealed the striking patterning of LR's towards water. Modelling the movement of water has provided vital clues to understand this branching pattern. Interrupting the flow of soil water towards LR initiation sites by altering PD can disrupt hydropatterning. The asymmetric flow of water from the soil, and/or a signal contained in the flow, appears necessary for roots to pattern LRs towards water.



Citations: 1. Morris et al, Curr Bio (2017) 2. Bao et al, PNAS (2014) 3. Rich & Watt, J Exp Bot (2013) 4. White & Kirkegaard, Plant Cell Environ (2010) 5. Thomas et al, PLoS Biol (2008)