XYLEM HYDRAULIC CONDUCTIVITY MEASUREMENTS DURING FLOW-CONTROLLED EXPERIMENTS SUGGEST THE PRESENCE OF GAS BUBBLES THAT MOVE WITH THE FLOW AND ACCUMULATE AT VESSEL ENDS

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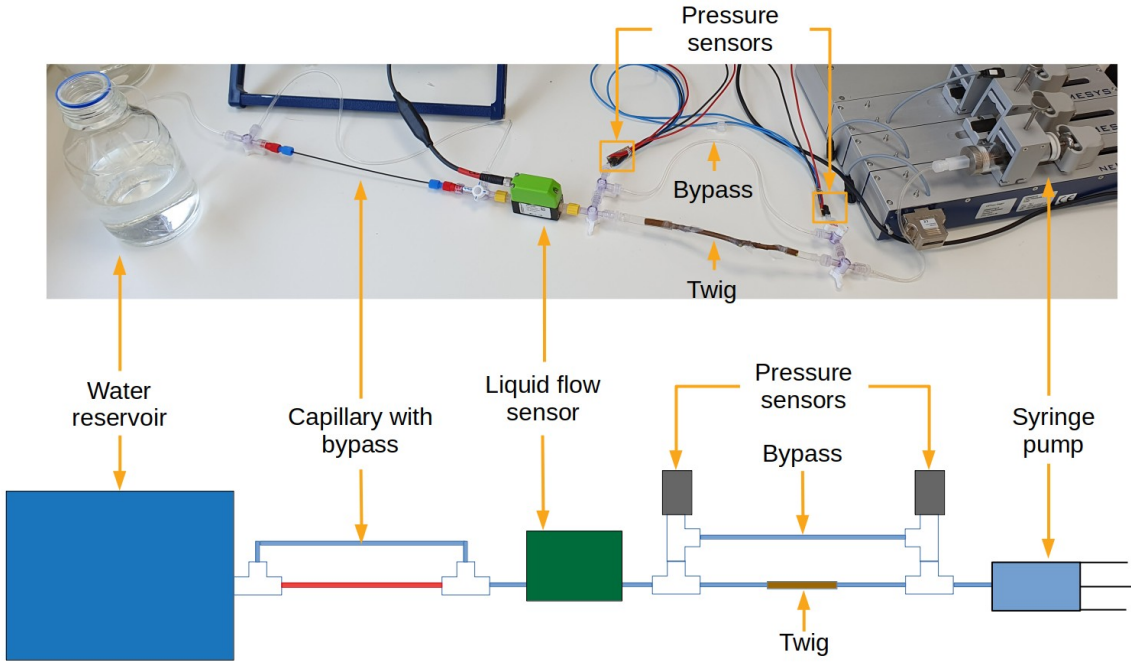
MOTIVATION

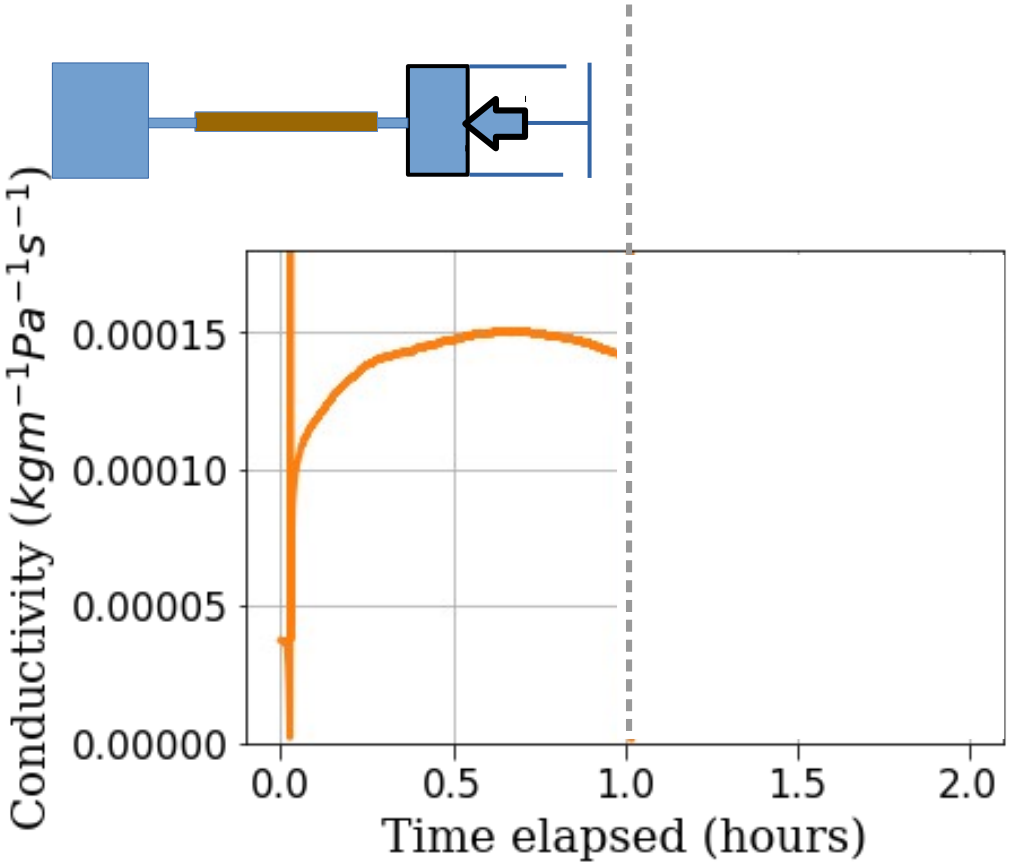


Built a new setup to measure under more natural conditions

Key features

- Control flow rate
- Control flow direction

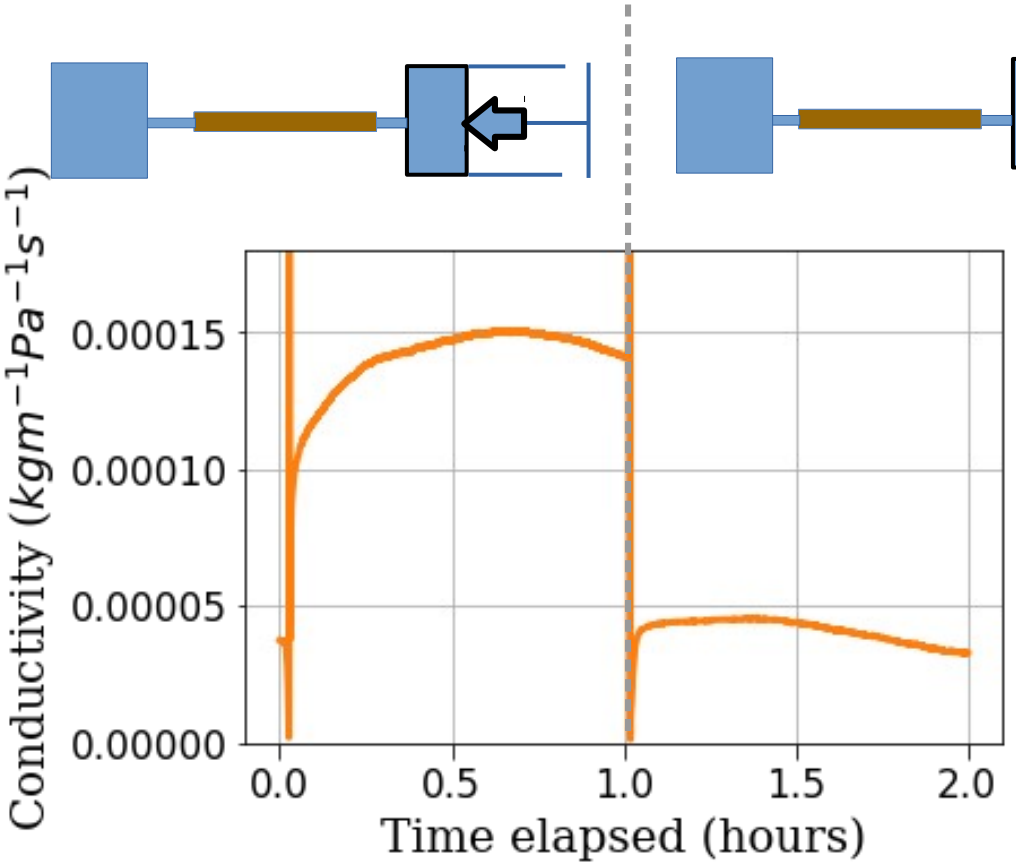
CURIOUS RESULT



Water is pushed then pulled at 25µL/min

Beech
L = 5.7cm
Ø = 4mm

CURIOUS RESULT



Water is pushed then pulled at 25µL/min

Conductivity **2-3 times** higher when pushing compared to pulling

Beech
L = 5.7cm
Ø = 4mm

OBJECTIVE

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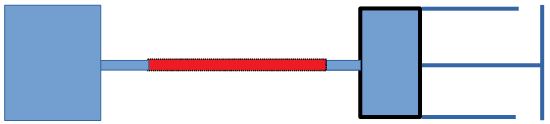
Understand the reason for the difference in hydraulic conductivity:

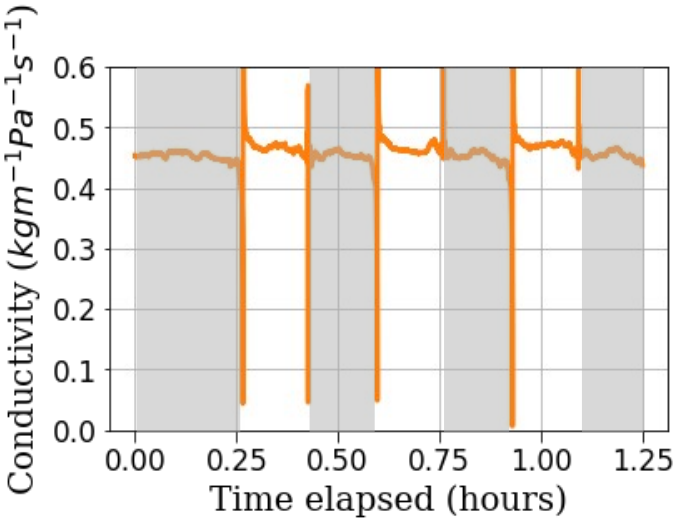
- Due to direction?
- Due to pulling vs pushing? (low vs high pressure)
- Due to setup?

RESULTS

NOT AN ARTIFACT



Capillary shows no difference in conductivity between push and pull

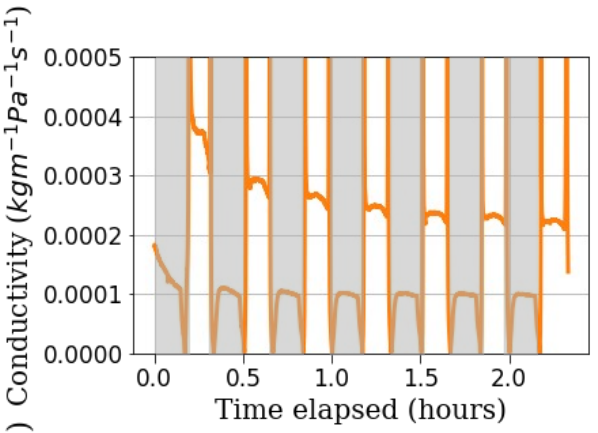


Capillarius minimus
L = 20.0cm
Ø = 0.1mm

Pull Push

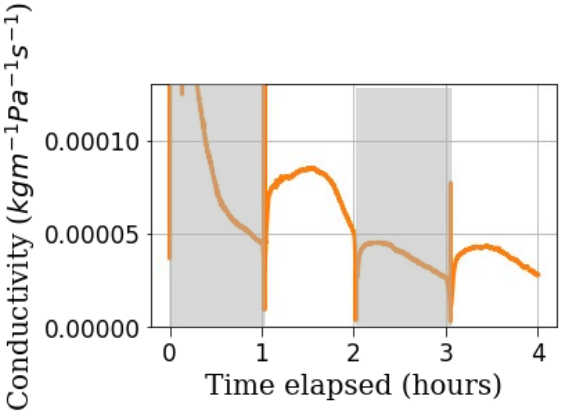
RESULTS

REPRODUCIBLE

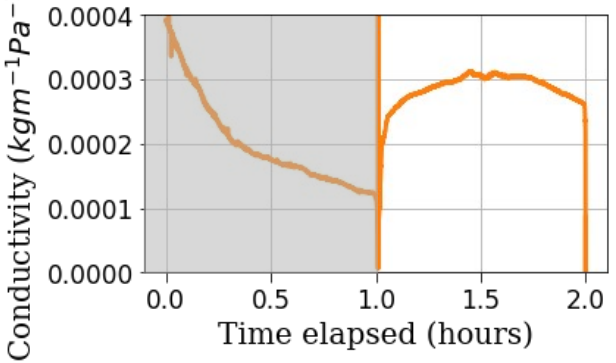


Fagus sylvatica
L = 7.0cm
Ø = 4mm

Pull Push



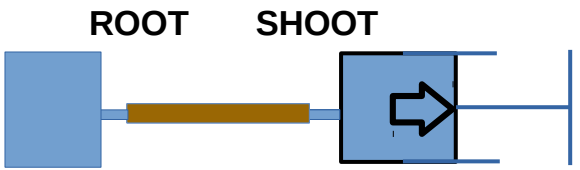
Carpinus betulus
L = 8.9cm
Ø = 4mm

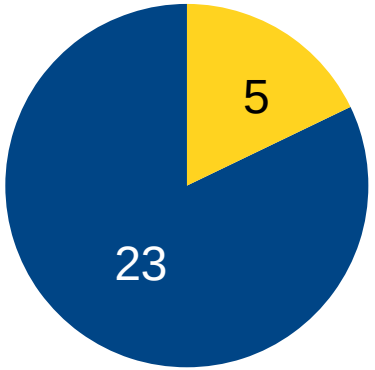


Tilia cordata
L = 12.2cm
Ø = 4mm

Increased conductivity during pushing reproduced consistently

RESULTS





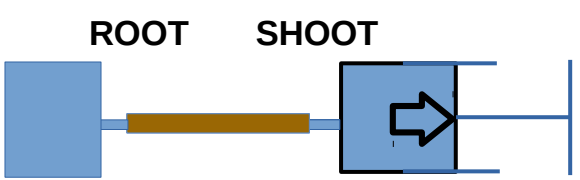
Pull Root-Shoot

Push Shoot-Root

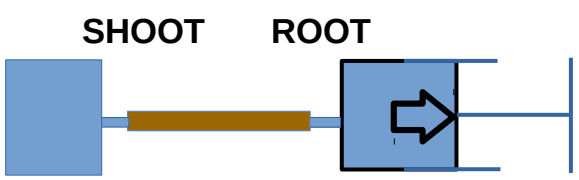
Higher conductivity while :

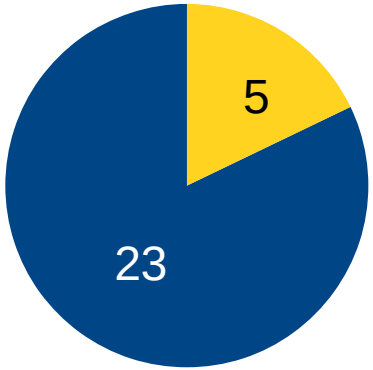
- Pushing
- Pulling
- Neither

RESULTS



Flip twig





Pull Root-Shoot

Push Shoot-Root

Higher conductivity while :

- Pushing
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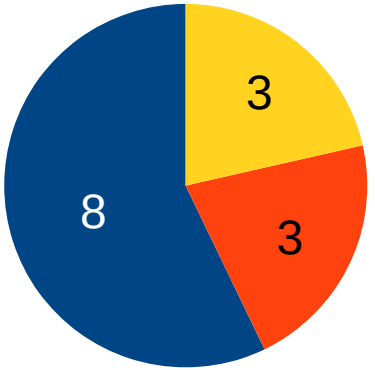
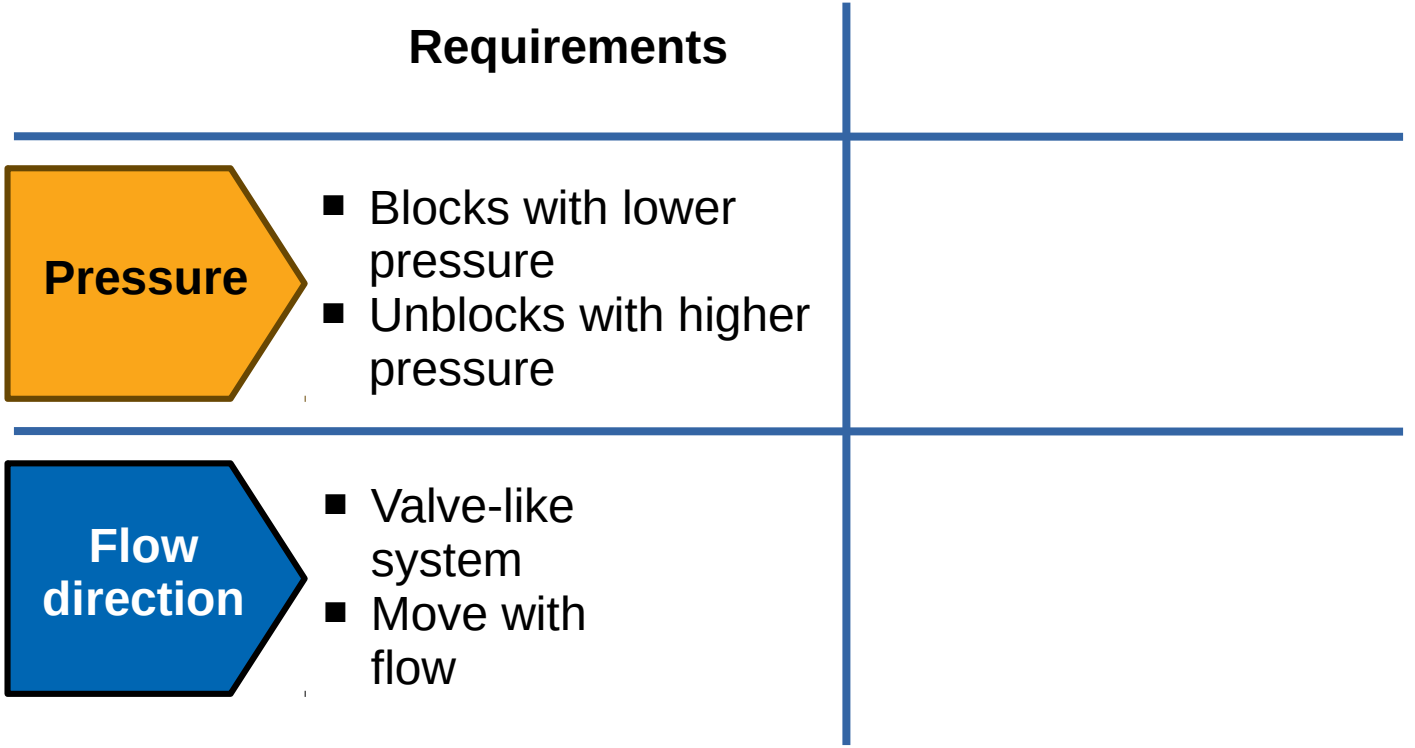


Pull Shoot-Root

Push Root-Shoot

THEORY



THEORY

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	Requirements	Nanobubbles (Schenk et al. 2017)
Pressure	■ Blocks with lower pressure ■ Unblocks with higher pressure	✔ Grow with lower pressure ✔ Shrink with higher pressure
Flow direction	■ Valve-like system ■ Move with flow	✔ Move with flow ✔ Stop at vessel ends

Schenk et al. 2017 Plant Physiology, Volume 173, Issue 2

THEORY

PULLING ROOT-SHOOT DIRECTION

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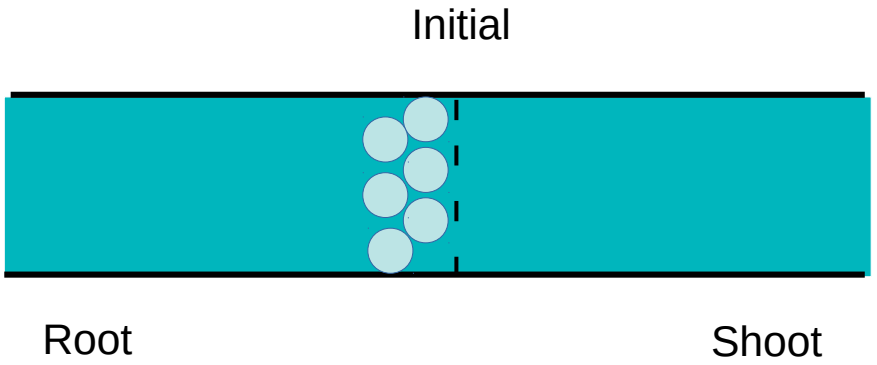

THEORY

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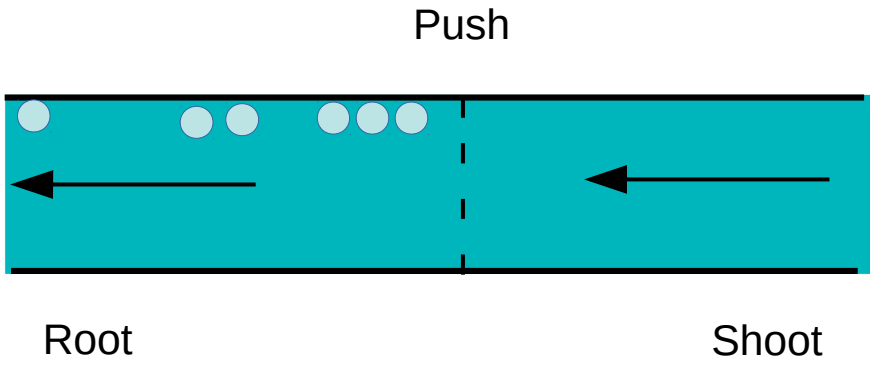

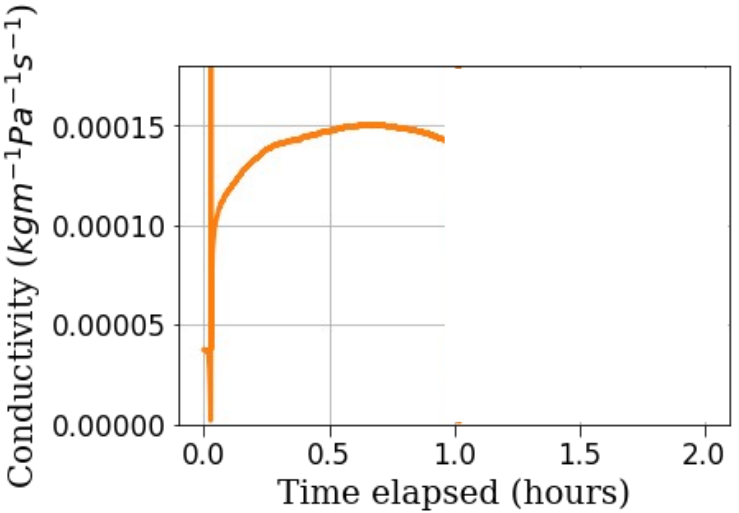

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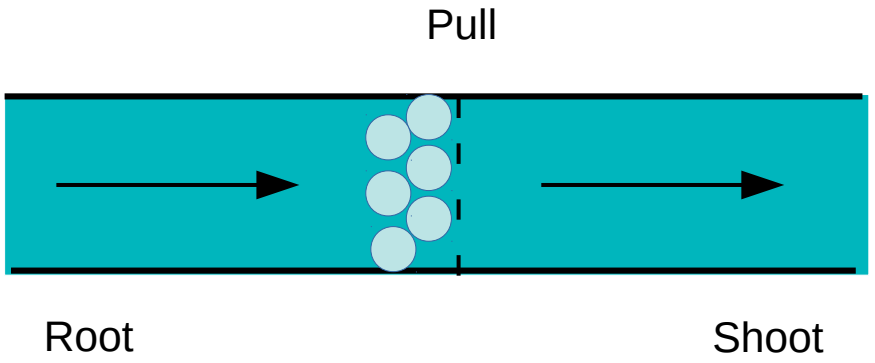

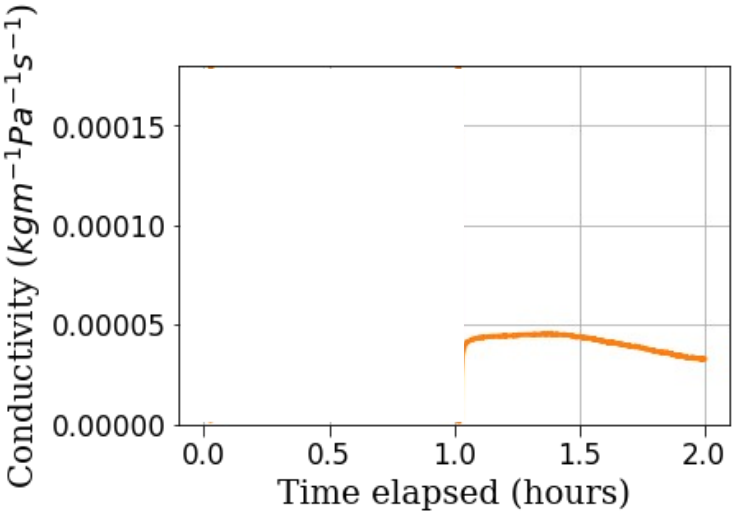

THEORY

PULLING SHOOT-ROOT DIRECTION

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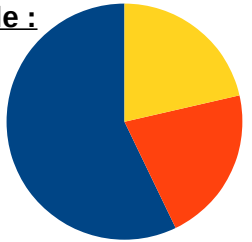
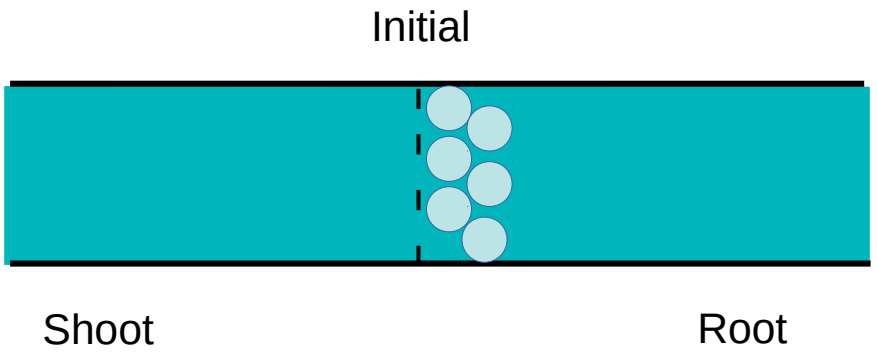
Higher conductivity while :

- Pushing
- Pulling
- Neither





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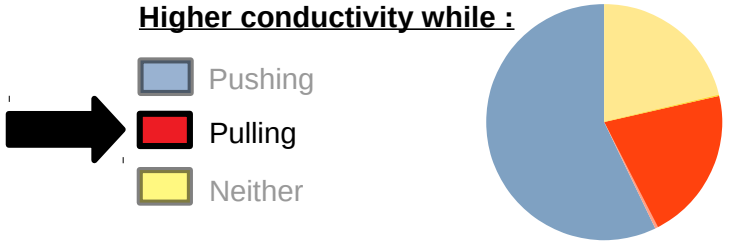

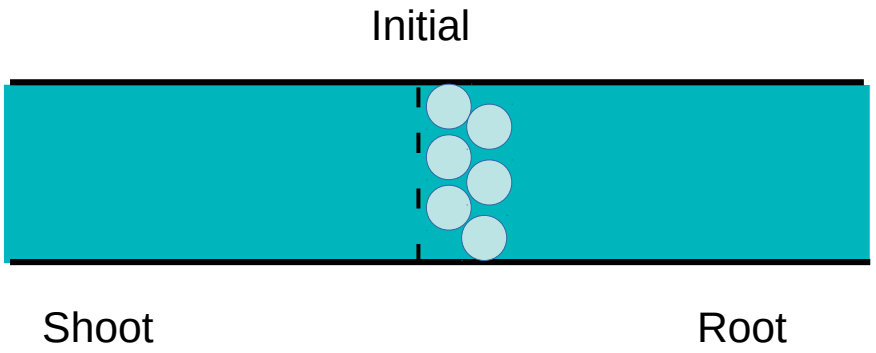

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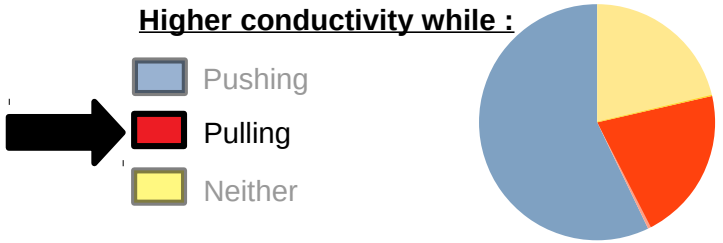

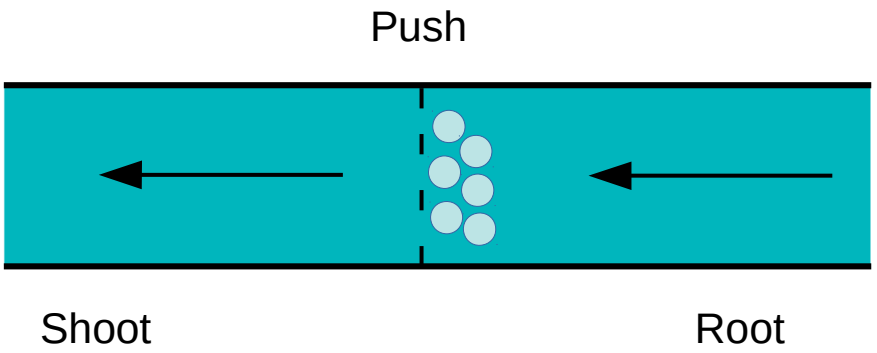

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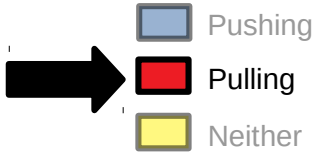

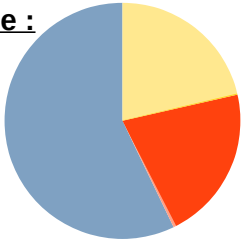

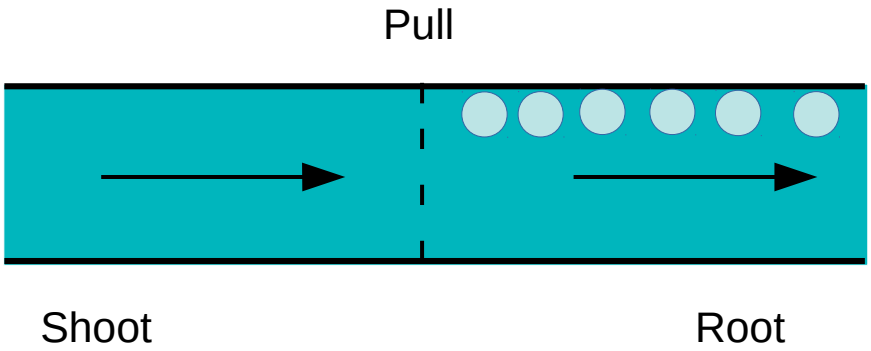

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PULLING SHOOT-ROOT DIRECTION

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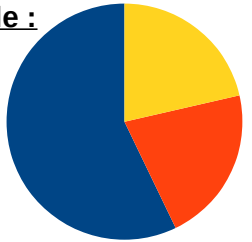
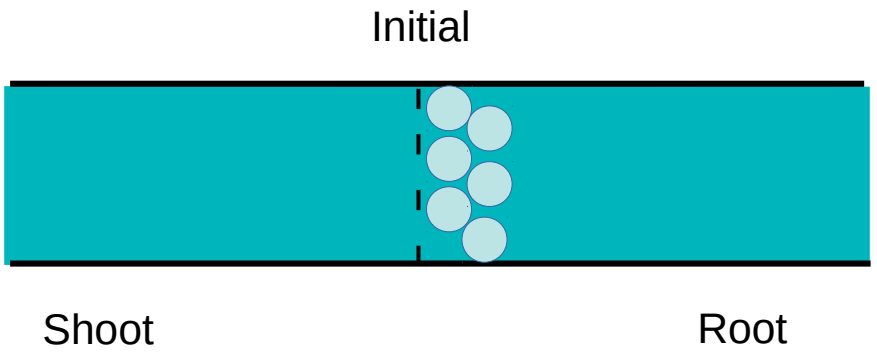
Higher conductivity while :

- Pushing
- Pulling
- Neither





THEORY

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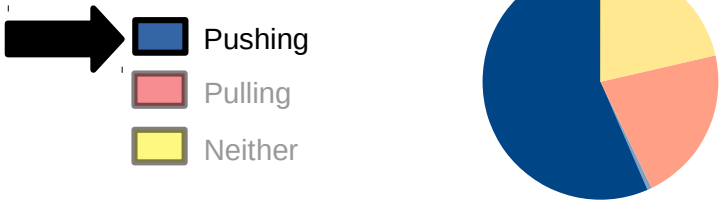

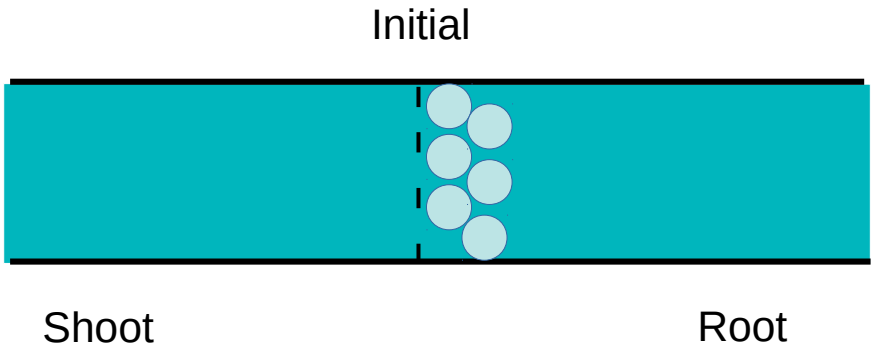

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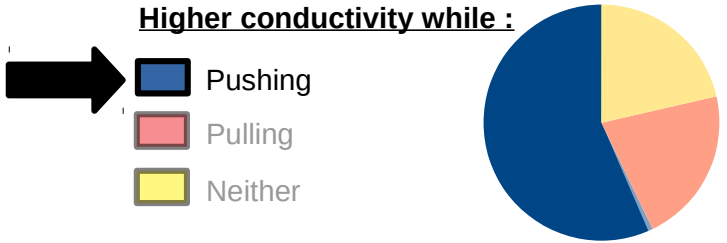

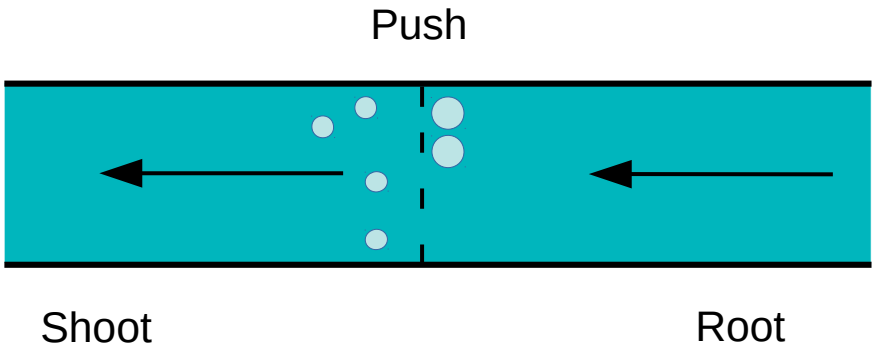

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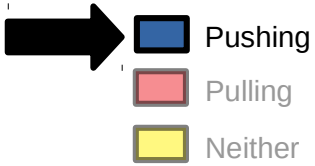

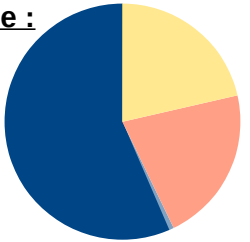

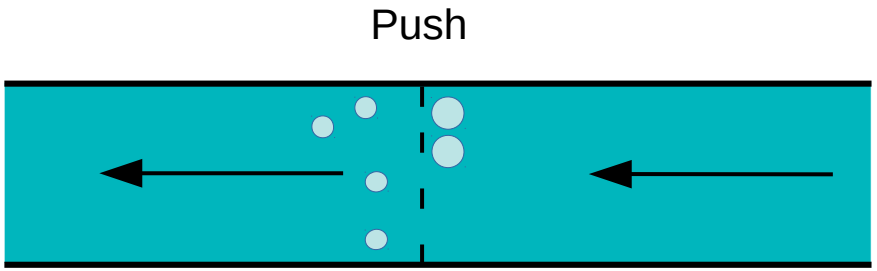

Cannot be explained by particles

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PULLING SHOOT-ROOT DIRECTION

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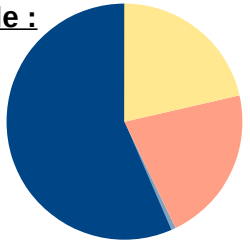
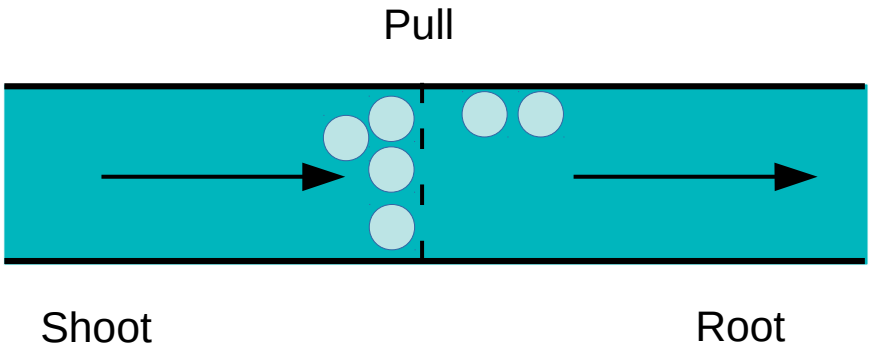
Higher conductivity while :

- Pushing
- Pulling
- Neither





THEORY

TWIGS WITH 2 VESSEL ENDS

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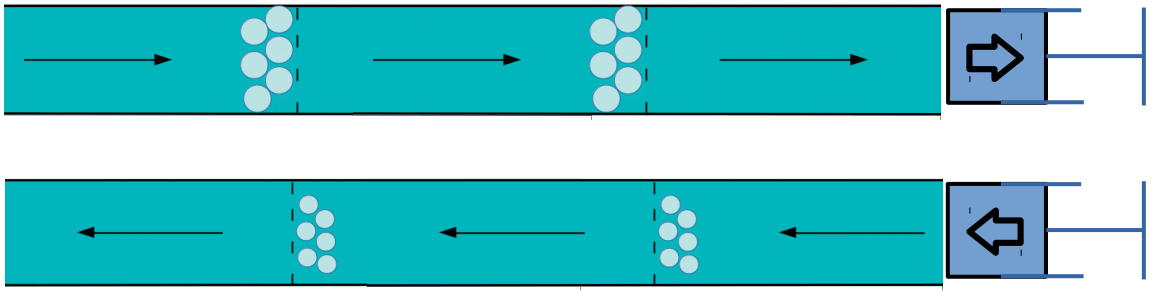
Long twig with at least 2 vessel ends

Expect the same conductivity



THEORY

TWIGS WITH 2 VESSEL ENDS

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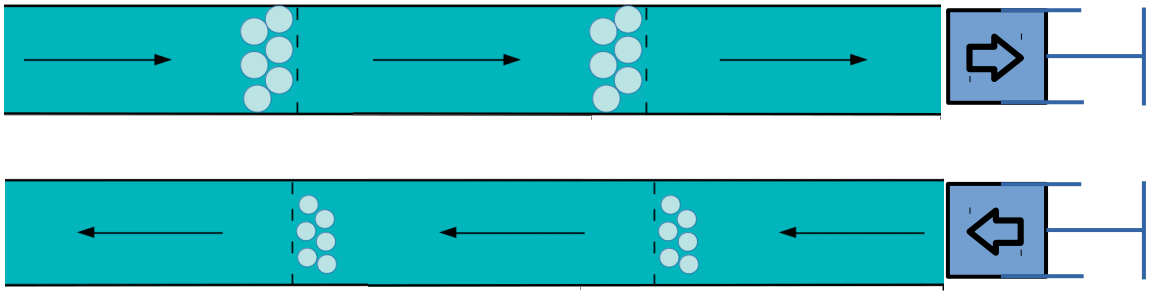
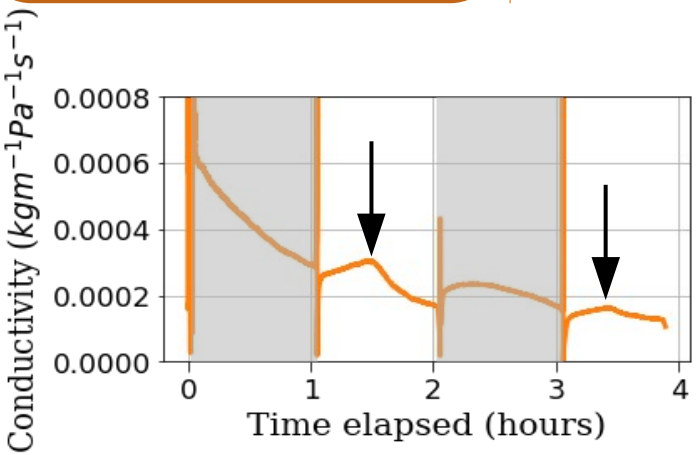
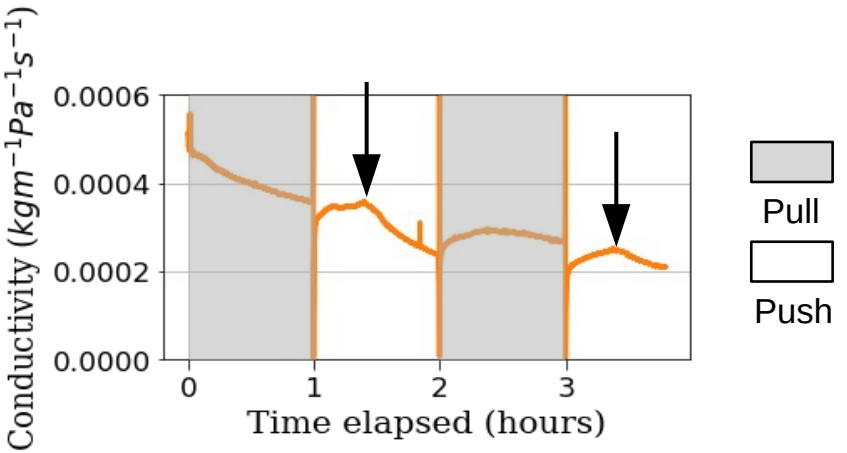
No large fluctuation in conductivity

Can see movement from one vessel end to another







CONCLUSION

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Experimental results suggest:

- Accumulation of **nanobubbles** on upstream sides pit membranes, which:
  - Expand and reduce conductivity at low pressure
  - Contract and partially pass through pit membranes at high pressure
  - Unblock pit membranes when flow is reversed
  - Move with the flow until they reach next vessel end