

Plant root diffusional barriers: Genesis and implications for nutrient efficiency and stress tolerance

David E Salt, University of Aberdeen

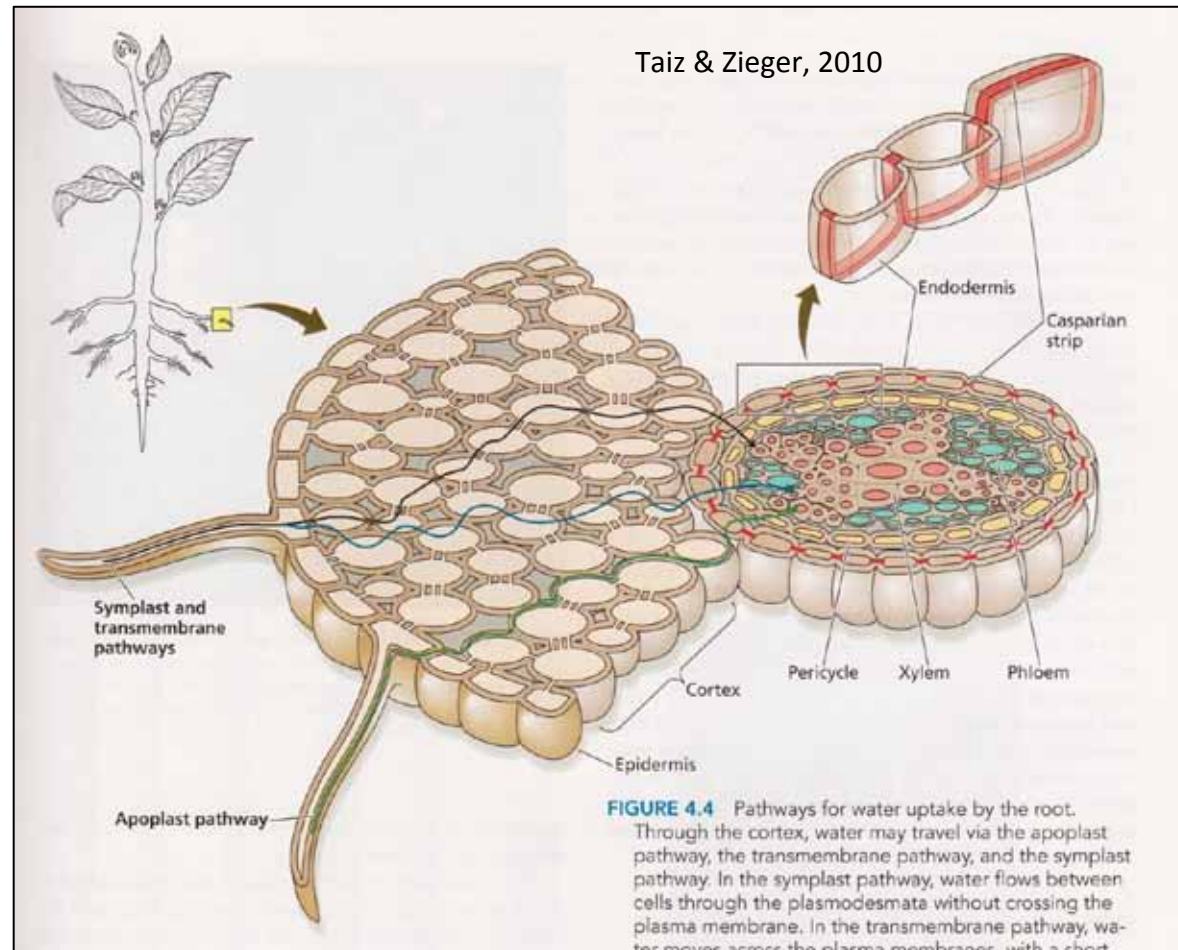


ERA-NET for Coordinating
Action in Plant Sciences



Organisation	Name of team member	Expertise
University of Aberdeen	Salt, David E., Prof. (project leader)	Molecular plant physiology including Casparian strip development
University of Bonn	Franke, Rochus B., Dr (PI)	Functional genomics of Lignin and Suberin biosynthesis.
	Grundler, Florian, Prof. (CoPI)	Plant-nematode interactions
	Siddique, Shahid, Dr (CoPI)	Plant-nematode interactions
IPK, Gatersleben	von Wirén, Nico, Prof. (PI)	Plant mineral nutrition
INRA, BPMP, Montpellier	Boursiac, Yann, Dr (PI)	Whole root and single cell hydraulics
	Maurel, Christoph, Dr (CoPI)	Whole root and single cell hydraulics & modelling
INRA, LEPSE, Montpellier	Muller, Bertrand, Dr (PI)	Analyses and modelling of plant responses to water deficit
	Simonneau, Thierry, Dr (CoPI)	Analyses and modelling of plant responses to water deficit
Wageningen University	Aarts, Mark G.M., Dr (PI)	Mineral nutrient and trace element stress (deficiency & excess)
University of Copenhagen	Schjoerring, Jan K, Prof. (PI)	Distribution and chemical speciation of mineral nutrient s and trace elements
	Husted, Søren, Prof. (CoPI)	

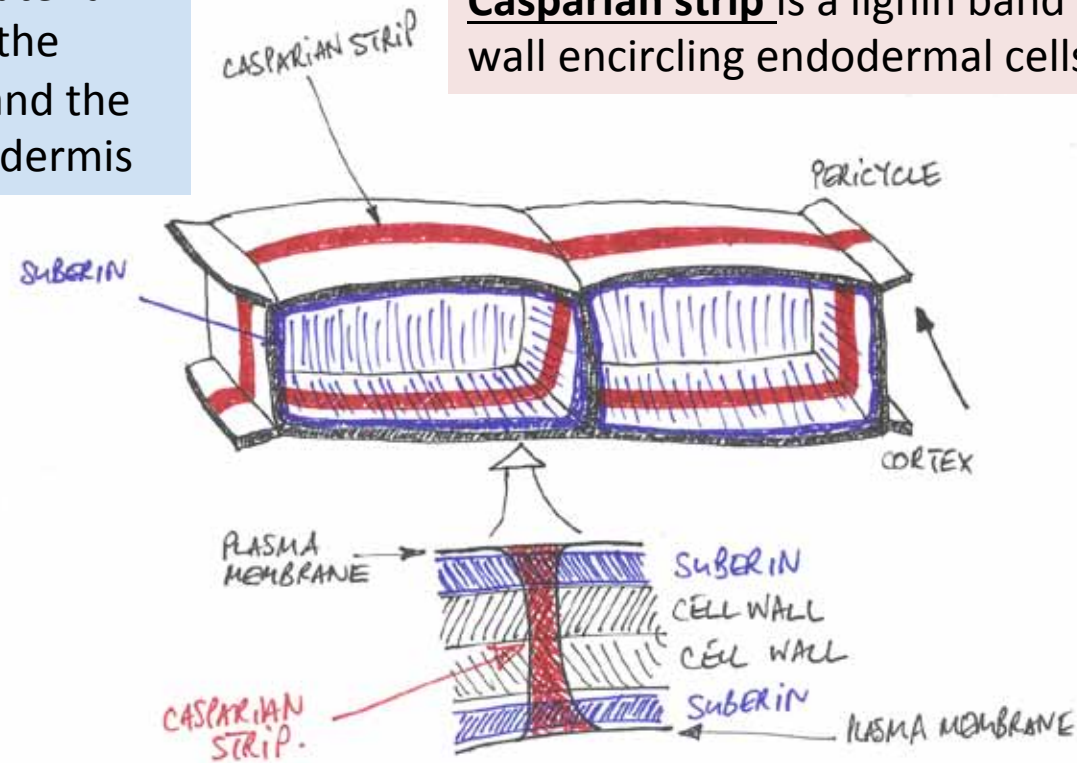
*What and where are the barriers
in the root?*



Casparian strip and suberin barriers

Suberin is a waxy material deposited between the plasma membrane and the cell wall of the endodermis

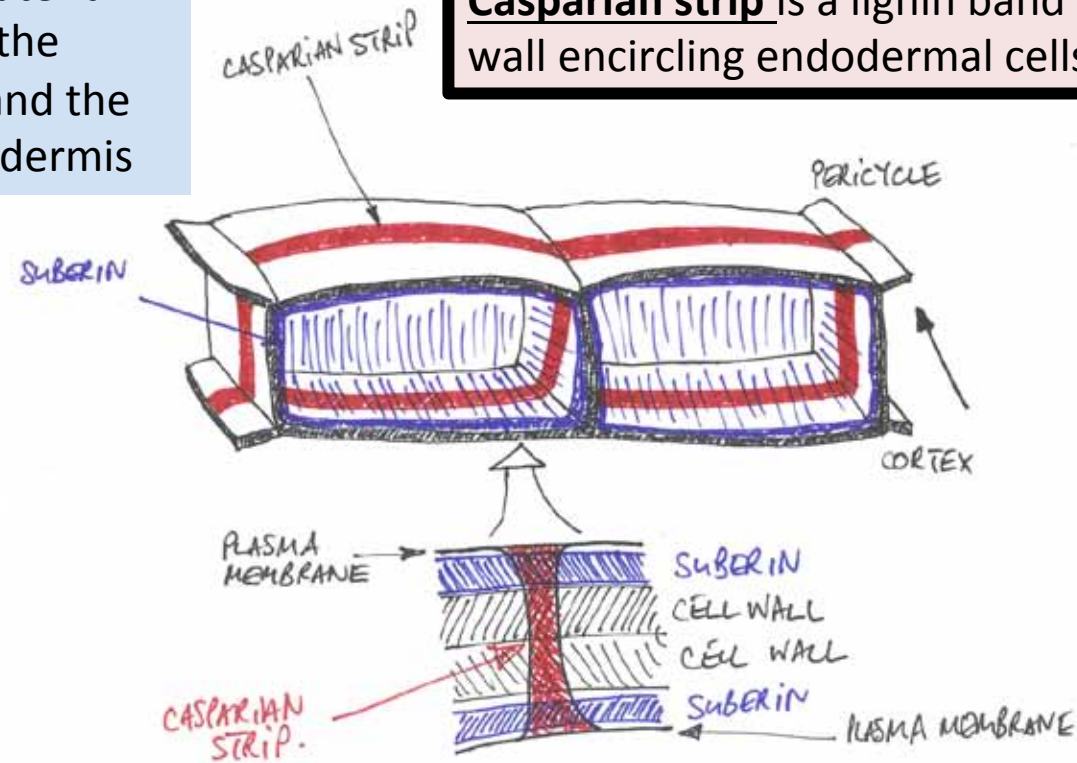
Casparian strip is a lignin band within the cell wall encircling endodermal cells



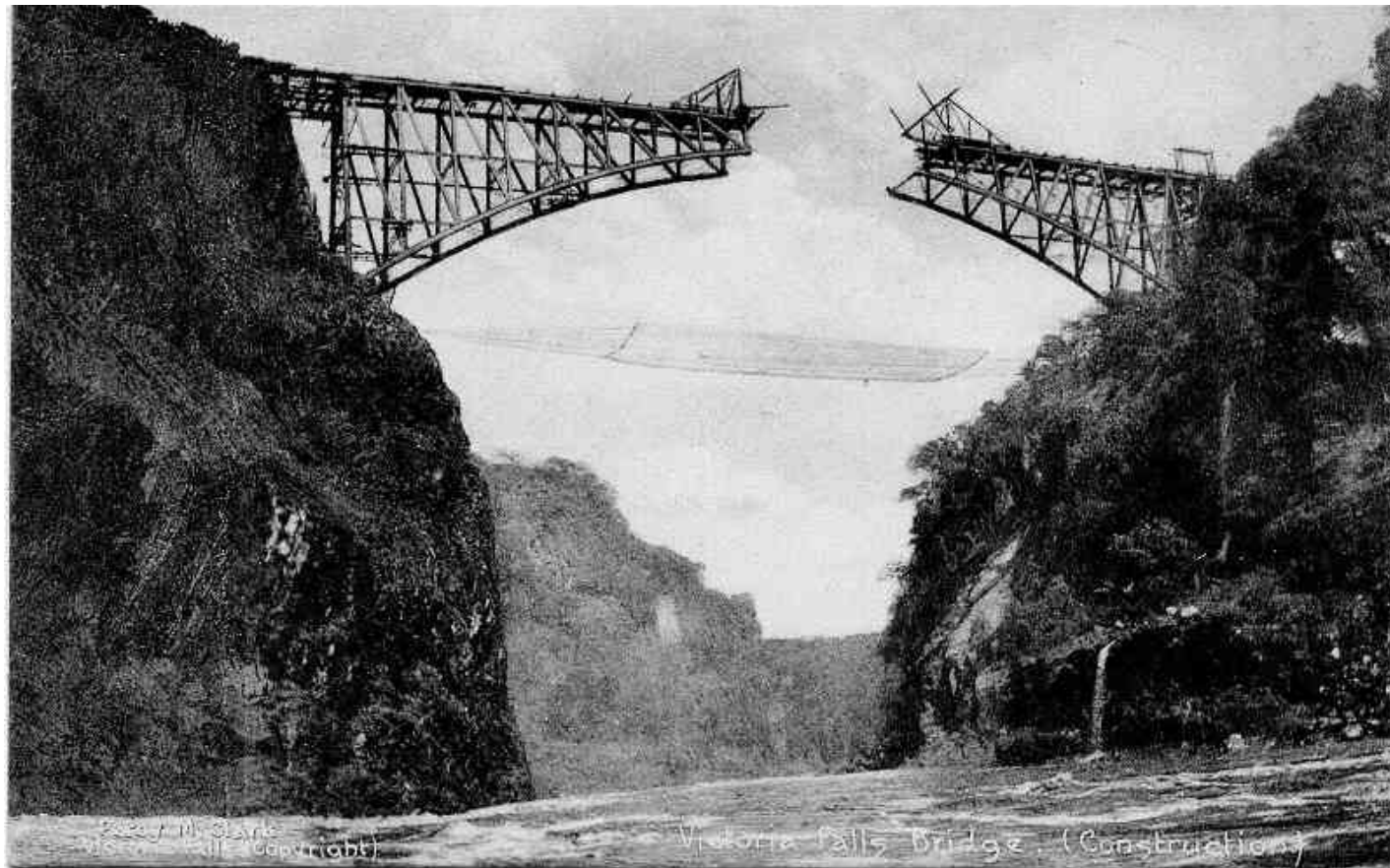
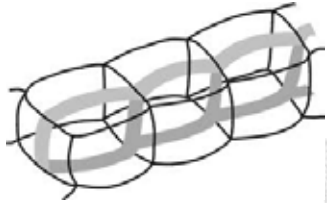
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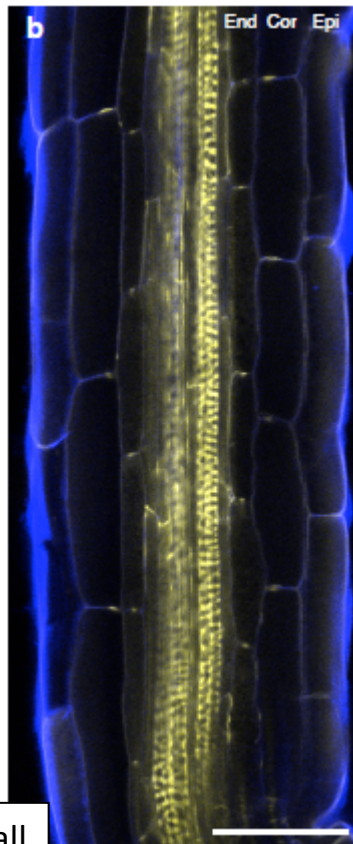
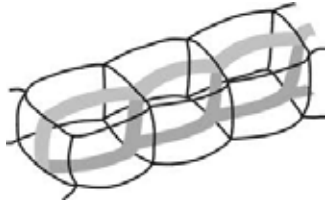
Casparian strip is a lignin band within the cell wall encircling endodermal cells



The Casparian strip problem

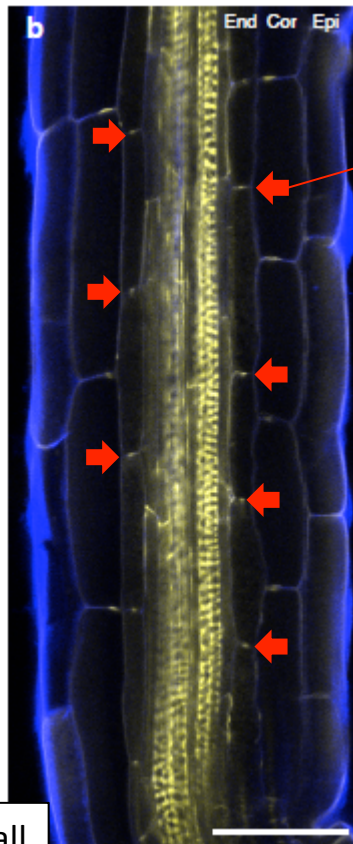
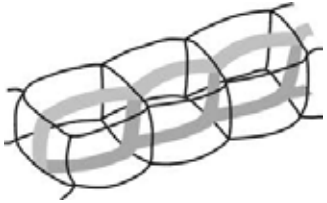


MYB36 sufficient to drive ectopic deposition of Casparian strips



Blue cell wall
Yellow lignin

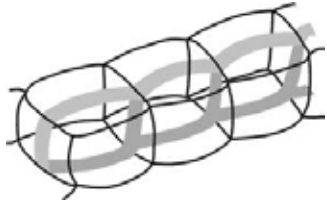
MYB36 sufficient to drive ectopic deposition of Casparian strips



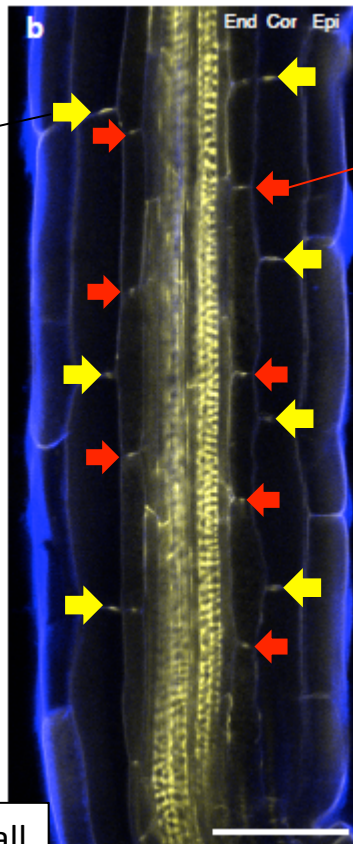
Casparian strip at endodermis

Blue cell wall
Yellow lignin

MYB36 sufficient to drive ectopic deposition of Casparian strips



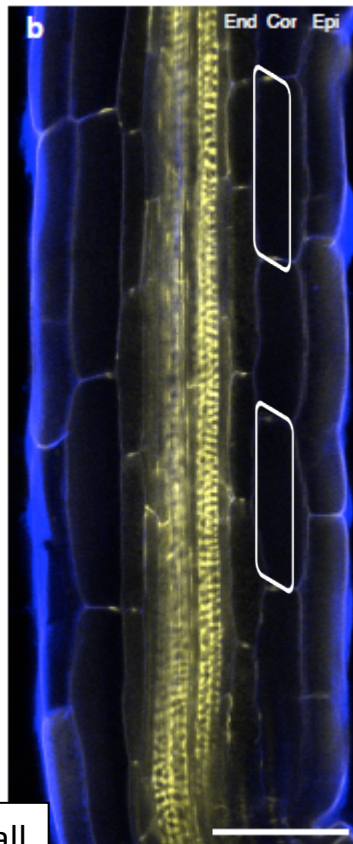
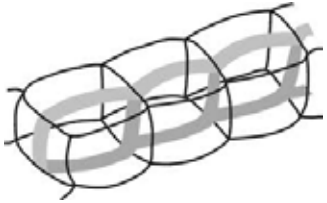
Ectopic Casparian strip
at cortex



Casparian strip at endodermis

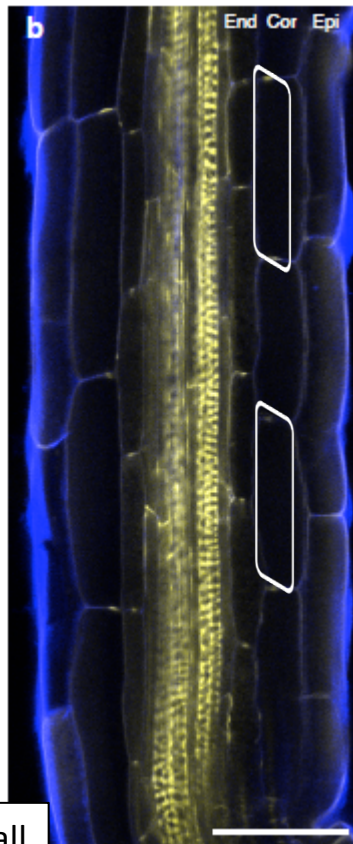
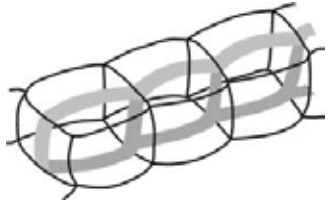
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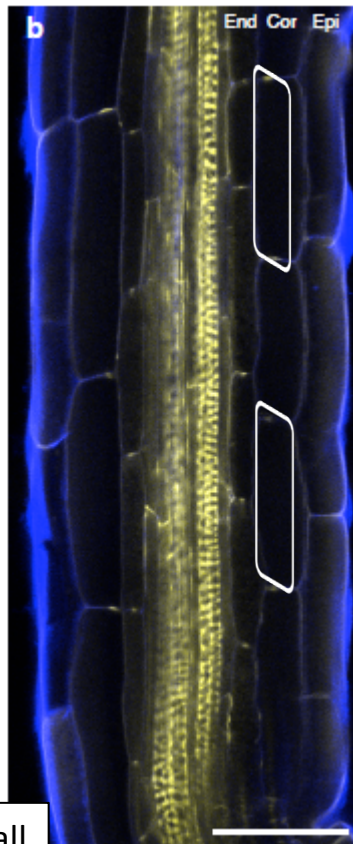
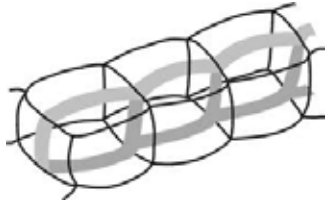
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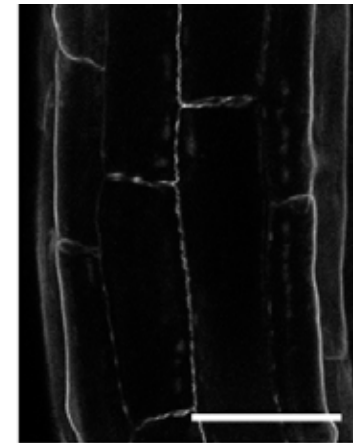


Blue cell wall
Yellow lignin

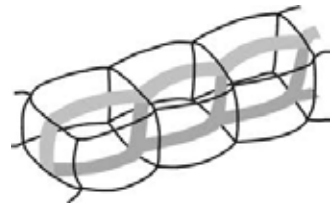
MYB36 sufficient to drive ectopic deposition of Casparian strips



Blue cell wall
Yellow lignin

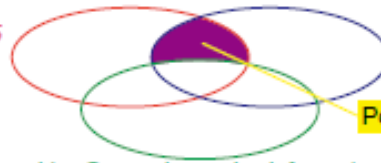


MYB36 reveals 'parts list' to make Casparian strip



a

Altered in *myb36*
(*myb36*)

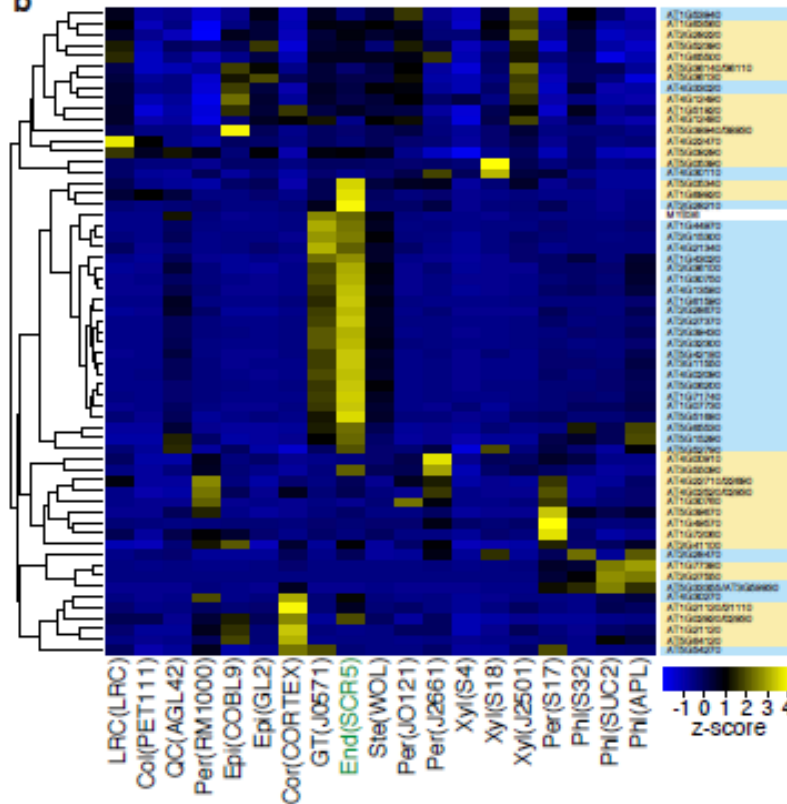


Endodermis specific
(Root tissue specific expression database)

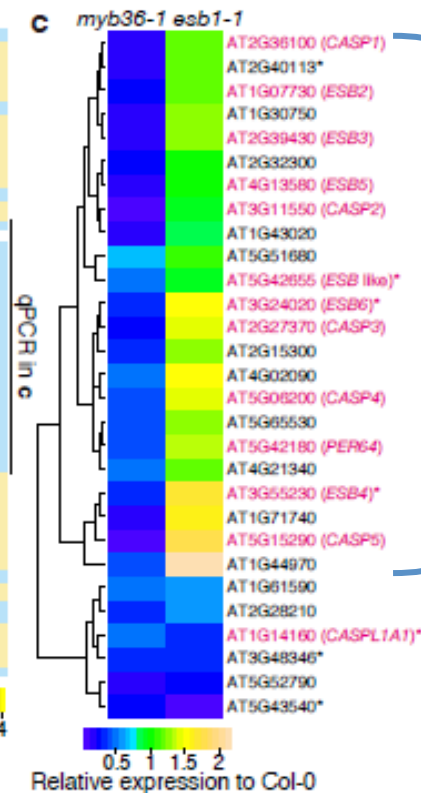
Potential target of MYB36

Altered by Casparian strip defects (*esb1-1*)

b

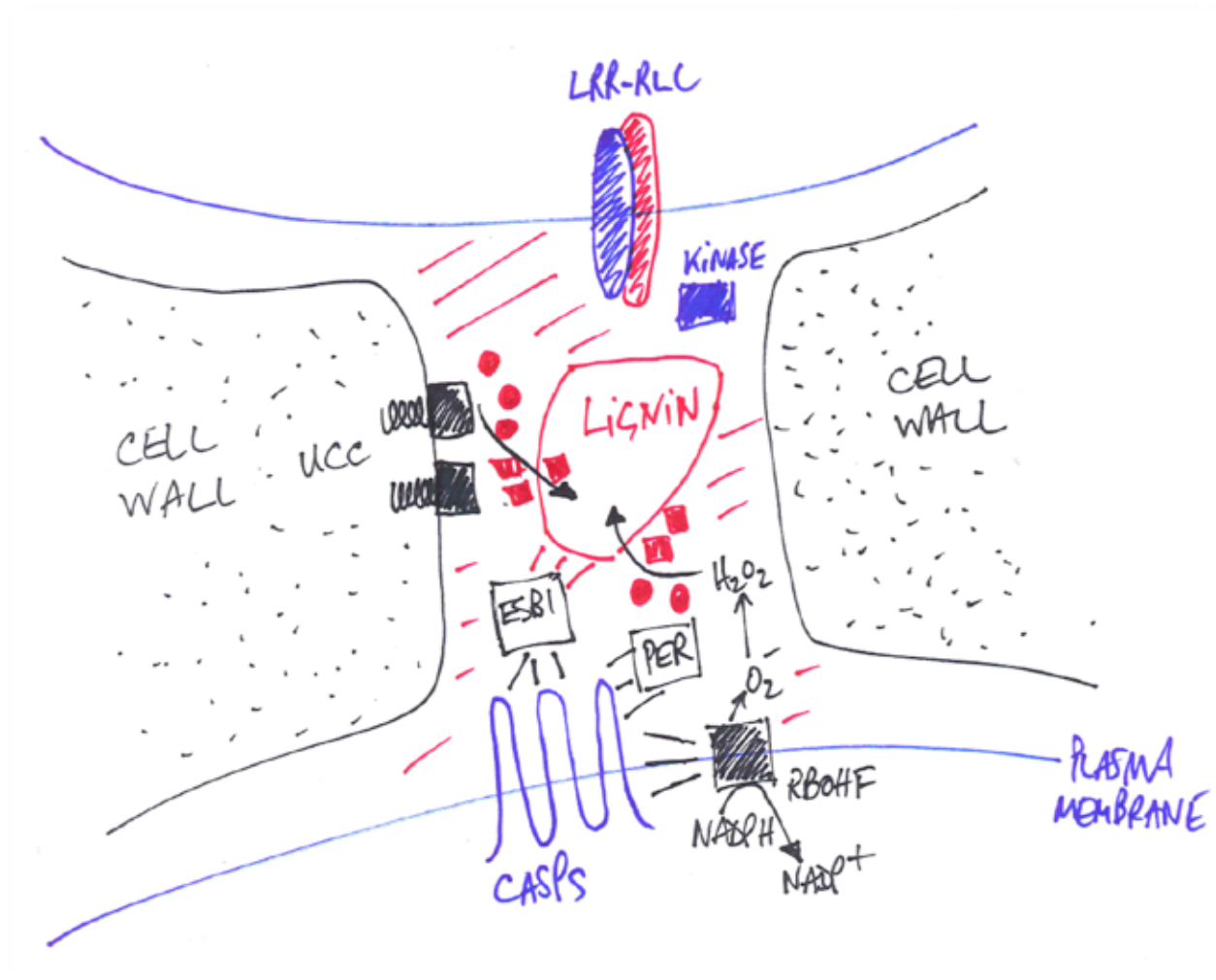
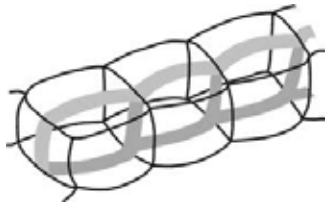


c

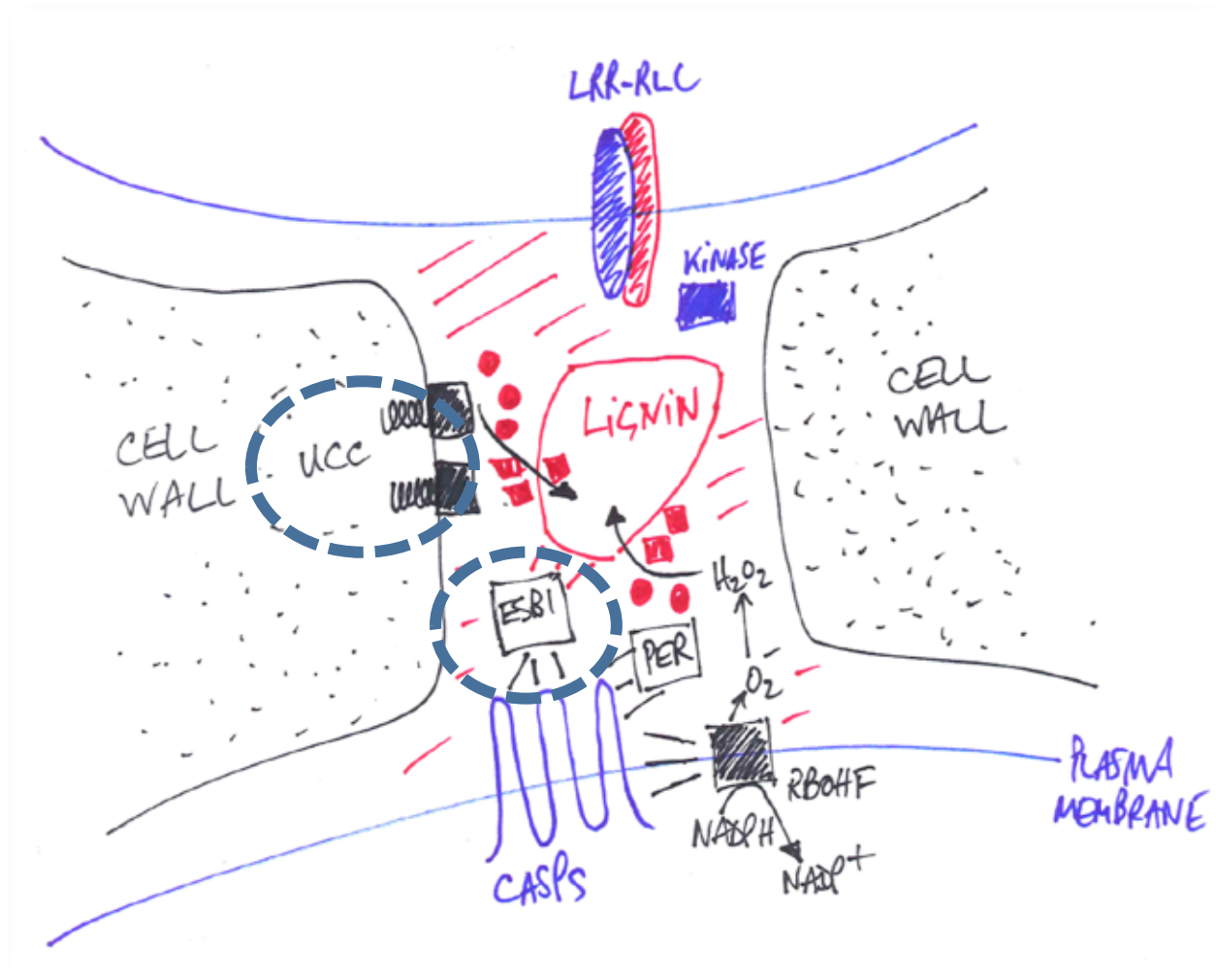
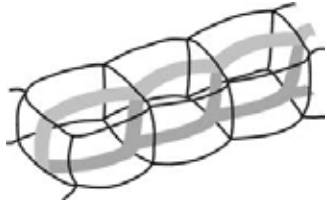


23 genes
targets for
MYB36

Current 'whiteboard' solution



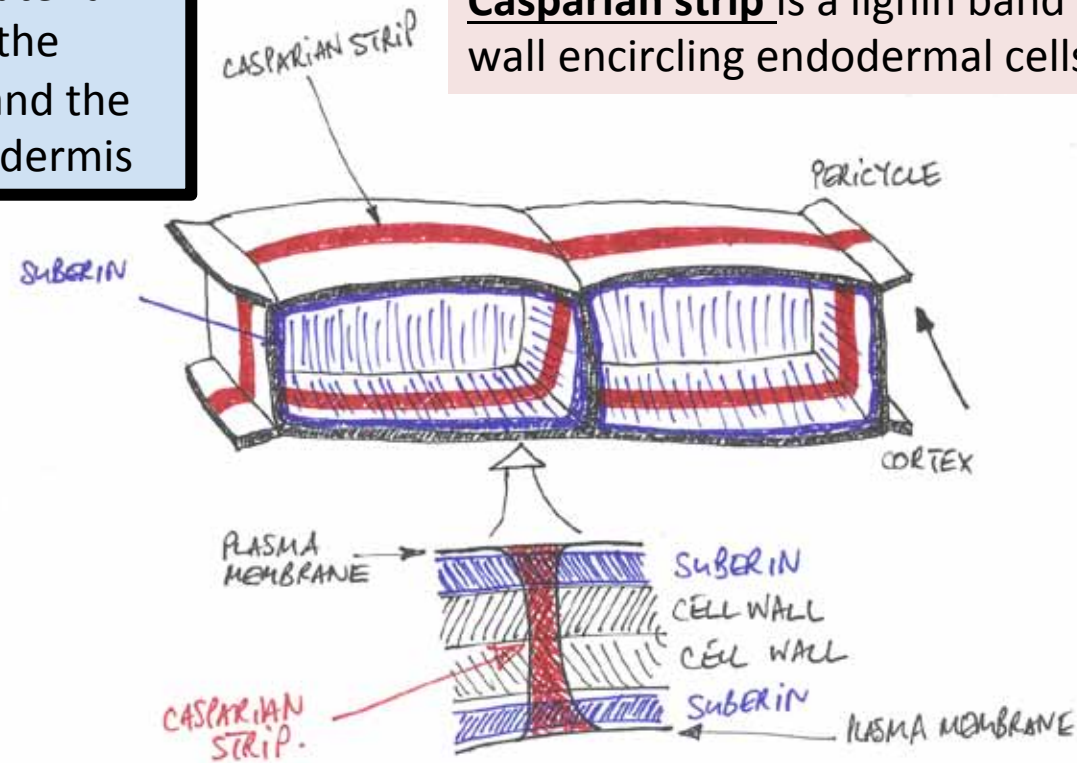
Current 'whiteboard' solution



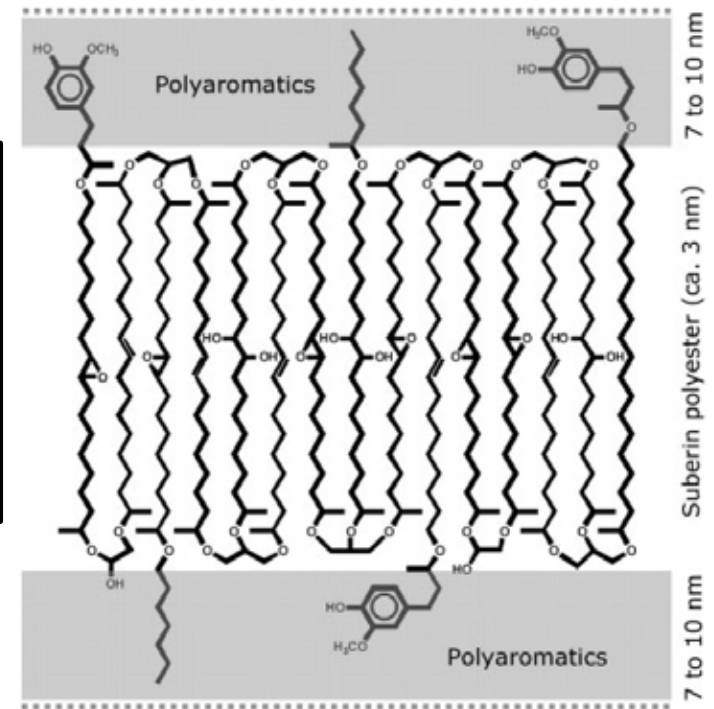
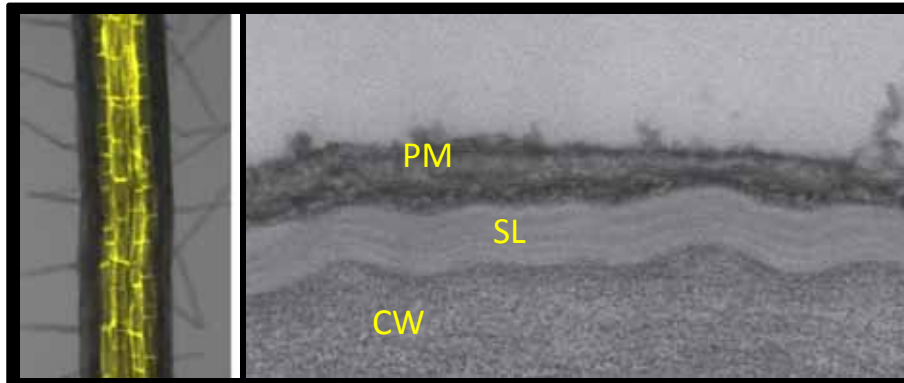
Casparian strip and suberin barriers

Suberin is a waxy material deposited between the plasma membrane and the cell wall of the endodermis

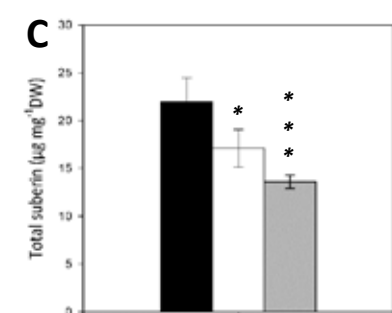
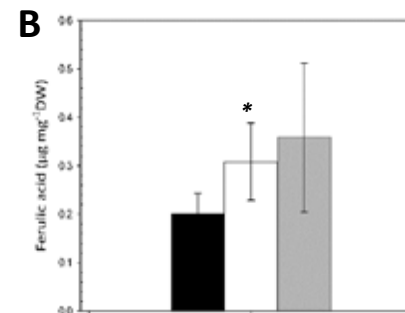
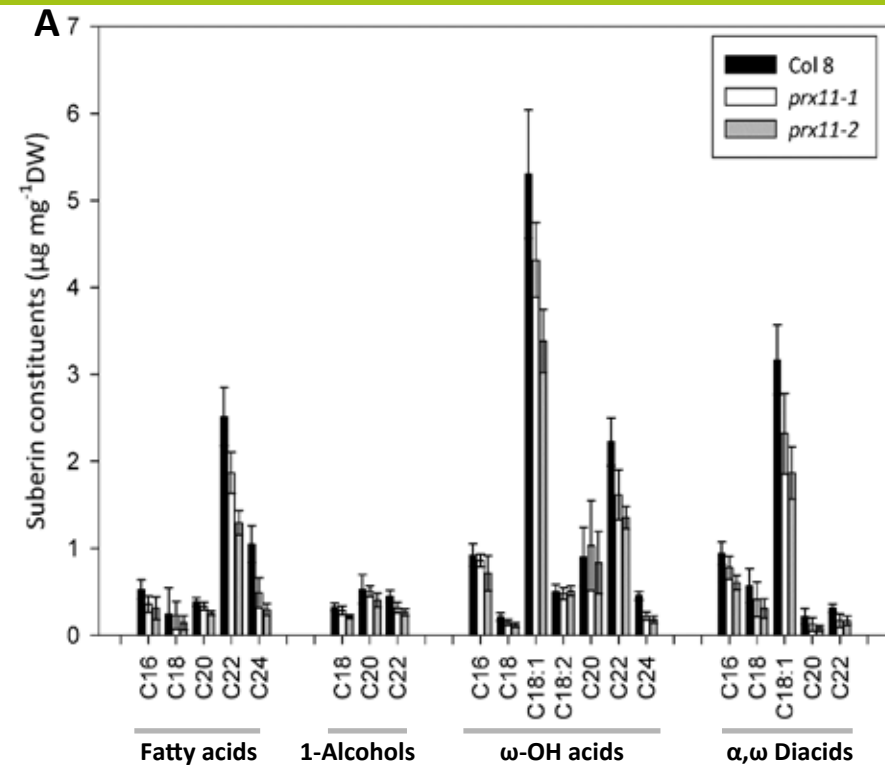
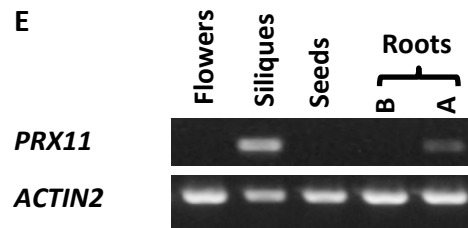
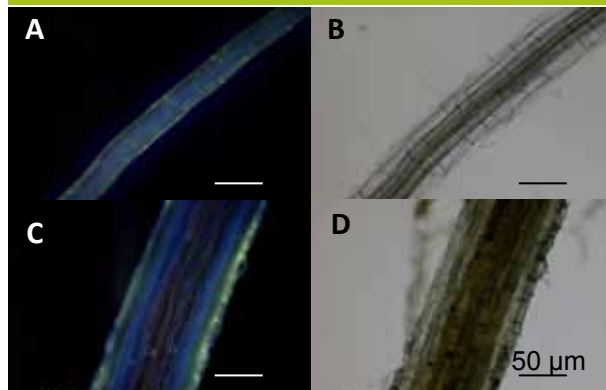
Casparian strip is a lignin band within the cell wall encircling endodermal cells



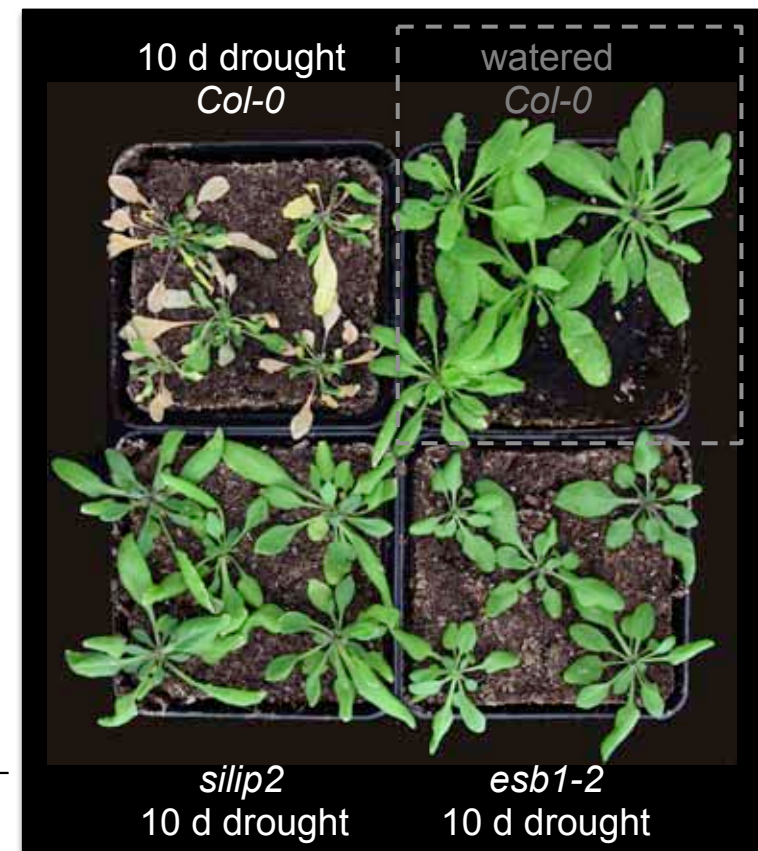
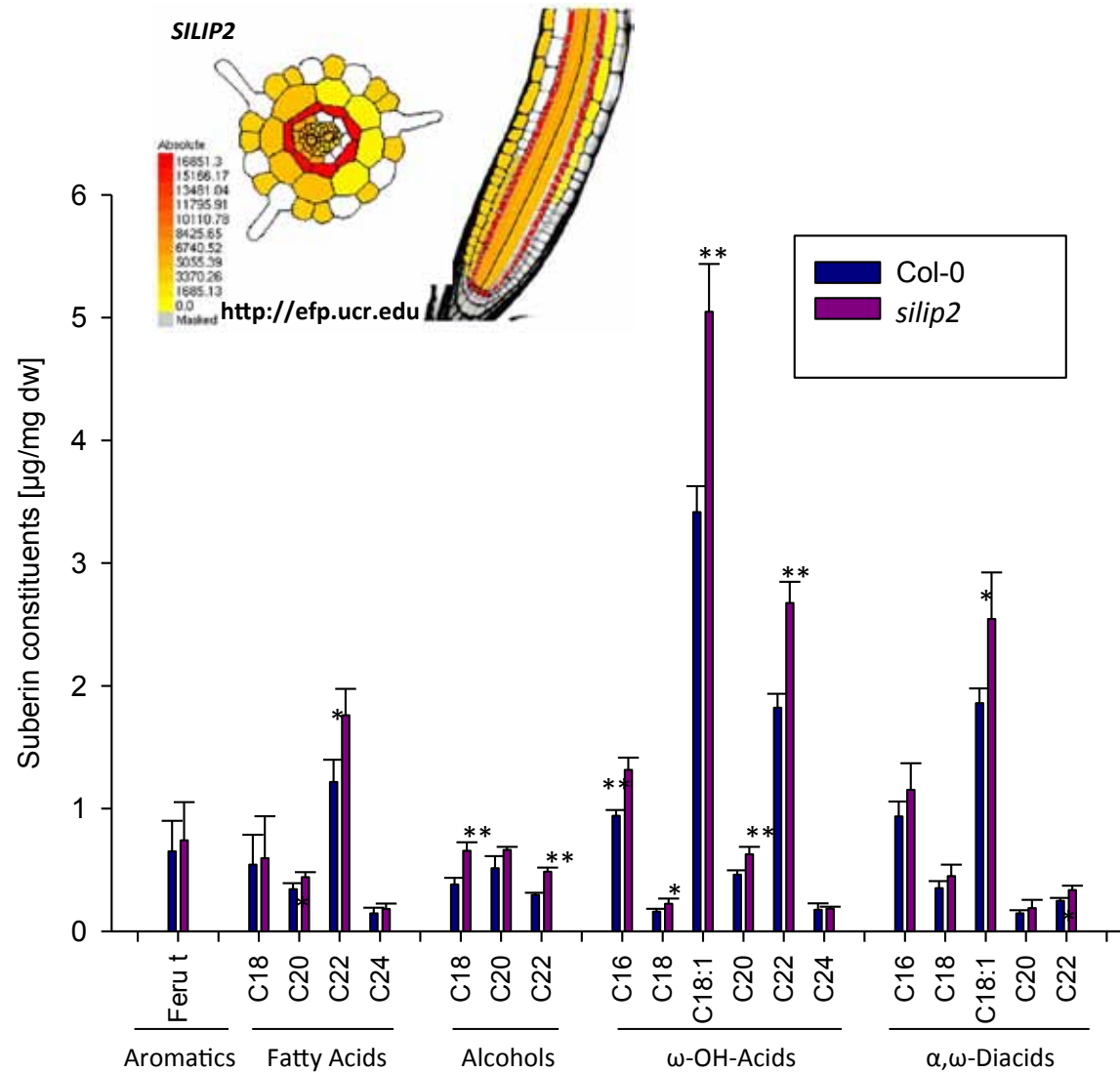
The suberin problem



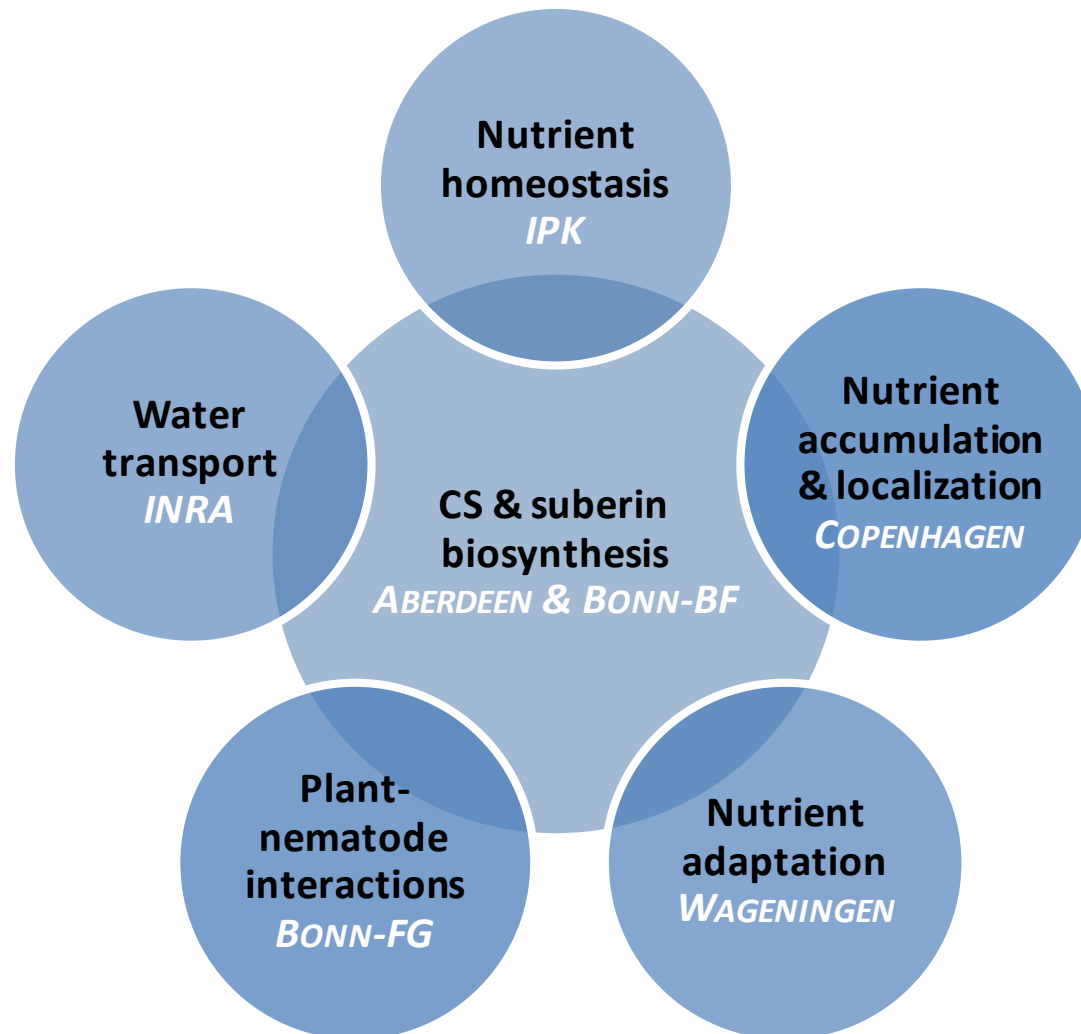
Peroxidase 11



Suberin involved GDSL-like Lipase SILIP2



What physiological role do these barriers play?

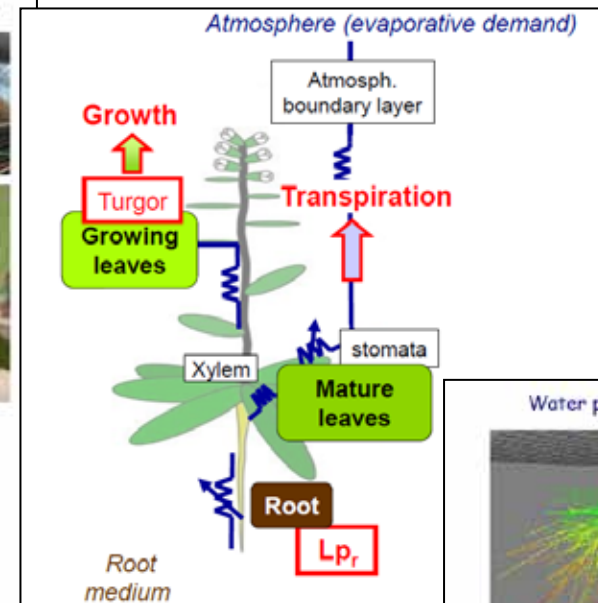
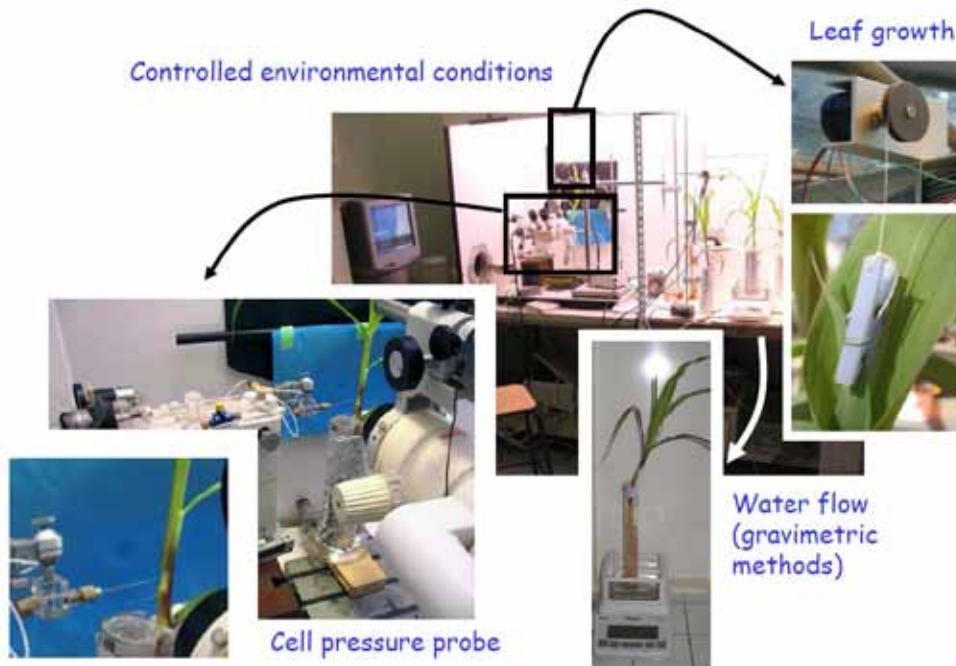


Water Transport

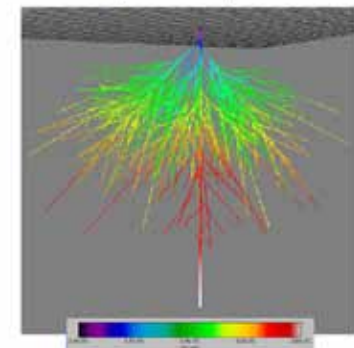
Leaf growth, cell turgor and water flow measurements

Controlled environmental conditions

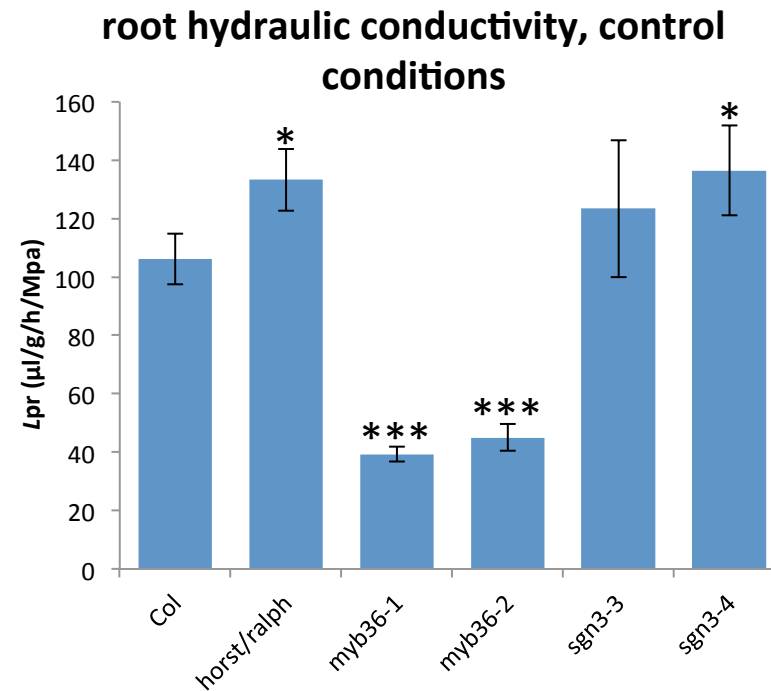
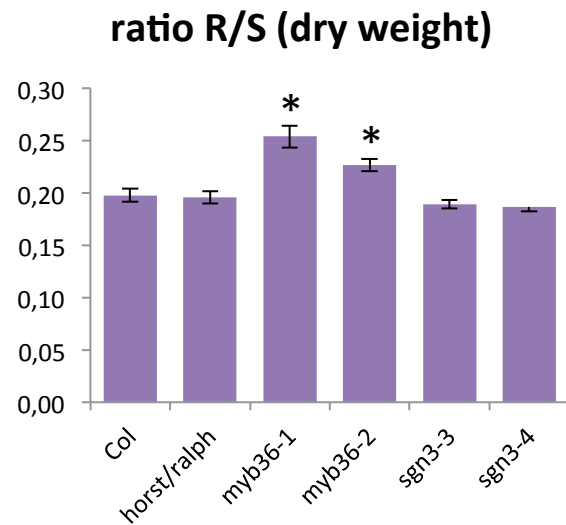
Leaf growth



Water potential representation

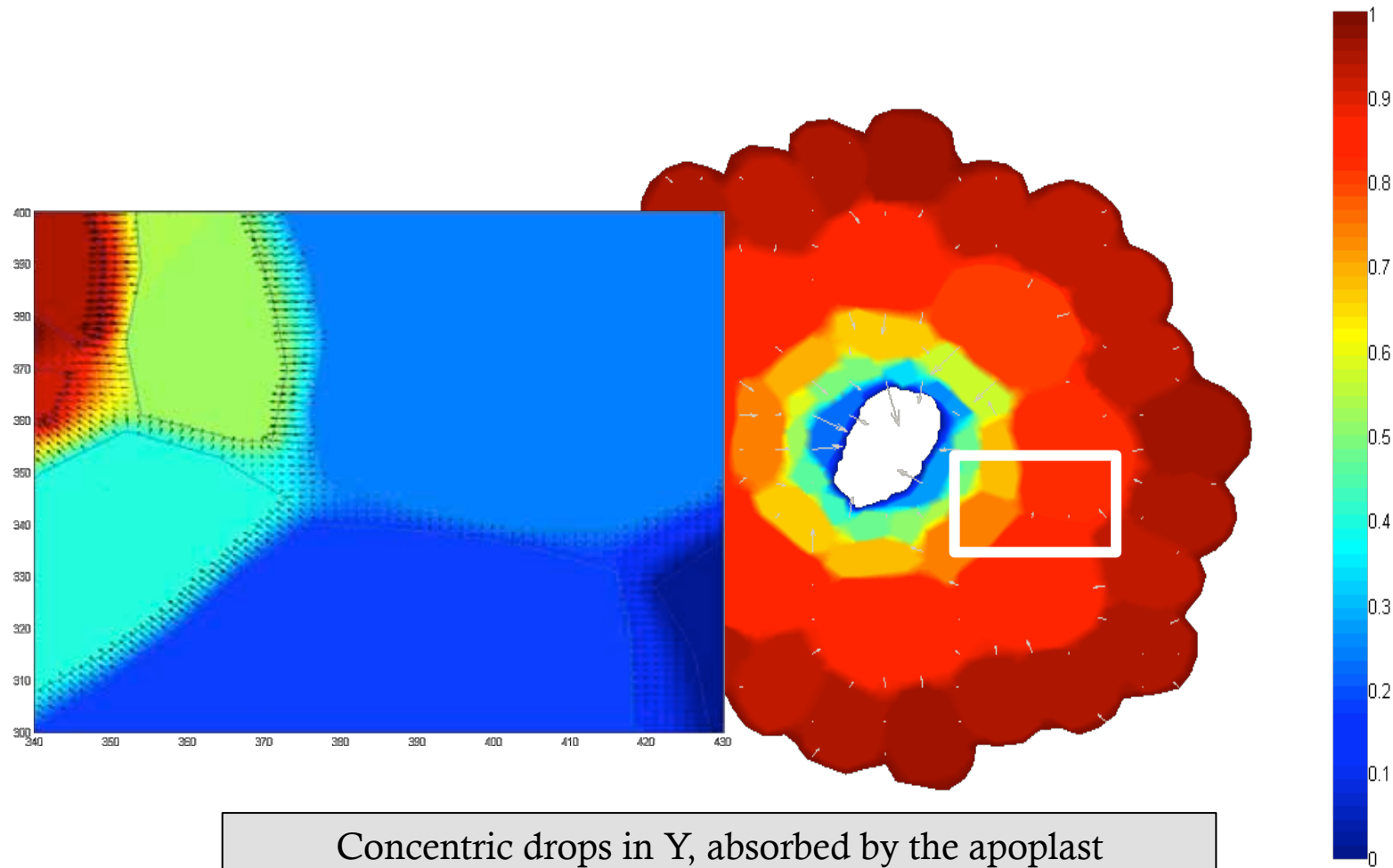


Mutants phenotyping



Hydraulic conductivity is altered in almost all genotypes tested thus far. In particular, myb mutants have a greatly reduction in Lpr, associated to a modification in root to shoot ratio

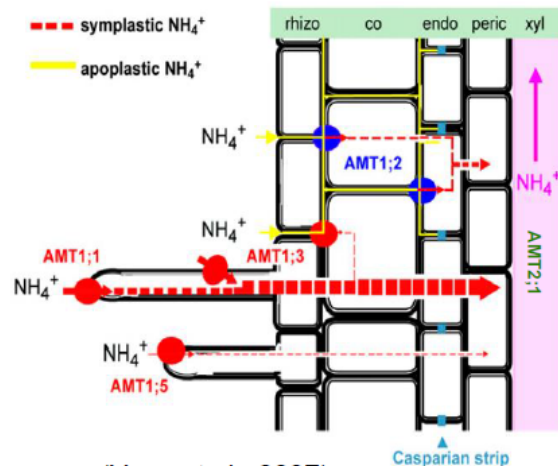
Theoretical steady state Ψ and local water flows



Concentric drops in Ψ , absorbed by the apoplast
Casparian strip remains to be integrated

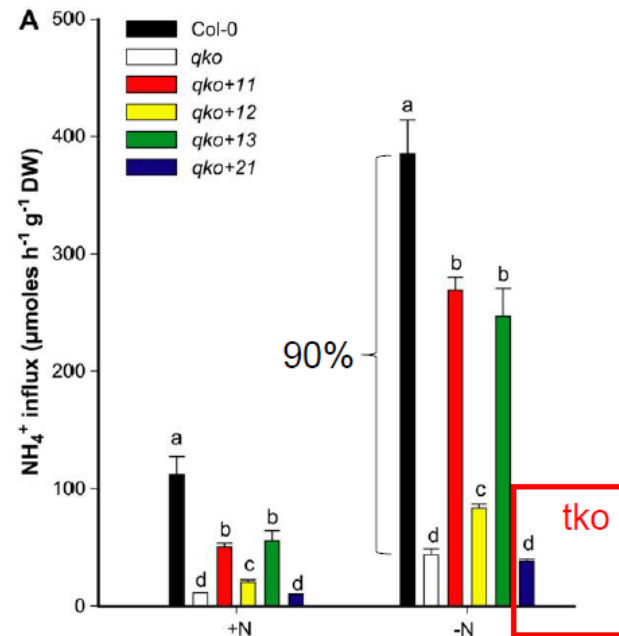
Mineral nutrient transport

High affinity ammonium transport system in Arabidopsis roots



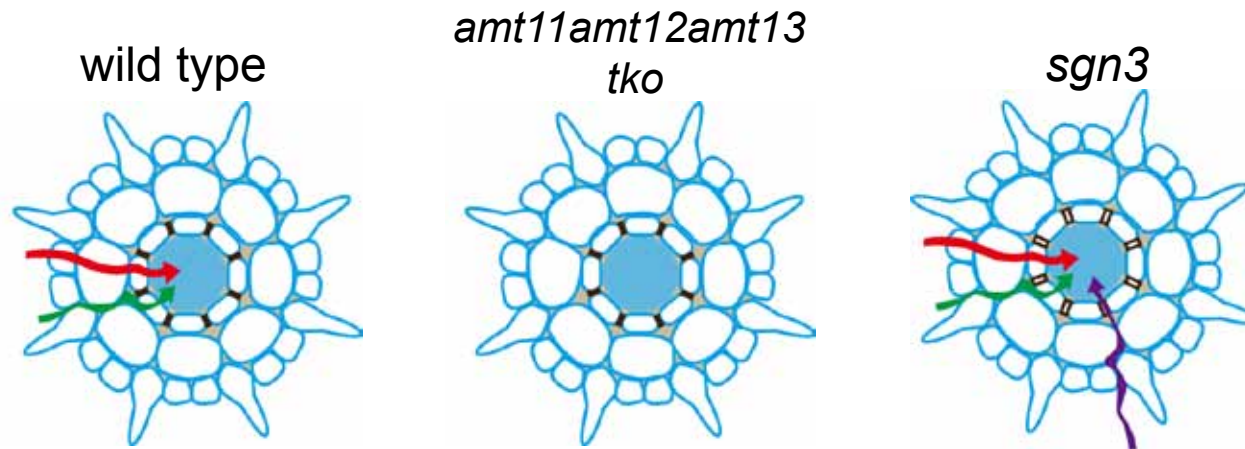
(Yuan et al., 2007)

Ammonium uptake capacity in *amt* mutants



High-affinity ammonium uptake rate decreases by 90% in *amt1;1amt1;2amt1;3amt2;1* quadruple mutant

Probing the radial transport pathways for NH_4^+ using genetic tools



NH_4^+ uptake passages :

symplastic transport pathway
(AMT1;1 and AMT1;3)
apoplastic transport pathway
(AMT1;2)

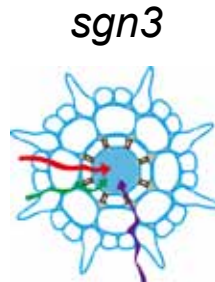
Only background, no
transport/diffusion
pathway

symplastic transport pathway
apoplastic transport pathway
apoplastic diffusion pathway
(defective CS)

Probing the radial transport pathways for NH_4^+ using genetic tools



×



mutants

NH_4^+ uptake
passages :

sgn: amt tko (tkosgn)

- - +

amt tko + amt12 (tko+12)

- + -

amt tko + amt13 (tko+13)

+ - -

How much of each passage contributes to NH_4^+ influx and translocation rate?

sgn: amt tko+ amt12 (tkosgn+12)

- + +

sgn: amt tko+ amt13/11 (tkosgn+13)

+ - +

Are there interactions between Casparian strips and sym.- and apo.- transport pathway?

Plant-nematode interaction

the plant journal

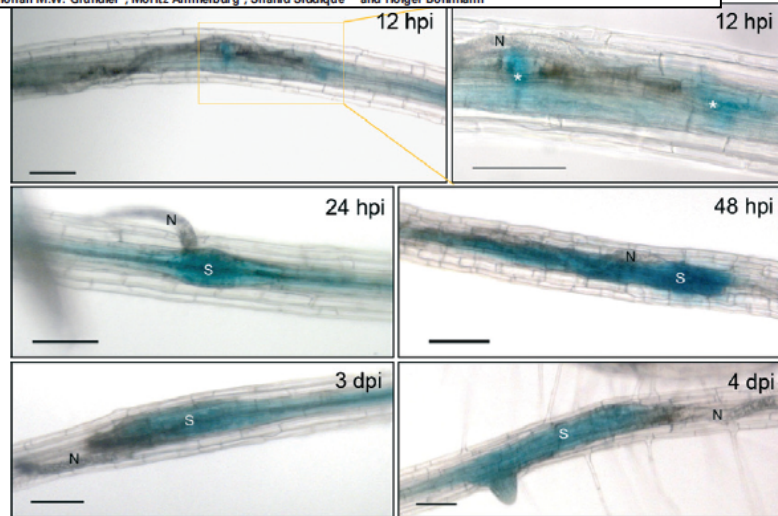


The Plant Journal (2013) 74, 852–866

doi: 10.1111/tpj.12170

An Arabidopsis ATPase gene involved in nematode-induced syncytium development and abiotic stress responses

Muhammad Amjad Ali^{1,2}, Stephan Plattner^{1,2}, Zoran Radakovic², Krzysztof Wiczelek¹, Abdelnaser Elashry^{1,2}, Florian M.W. Grundler², Moritz Ammelburg², Shahid Siddique^{1,2} and Holger Böhmann^{1*}



the plant journal

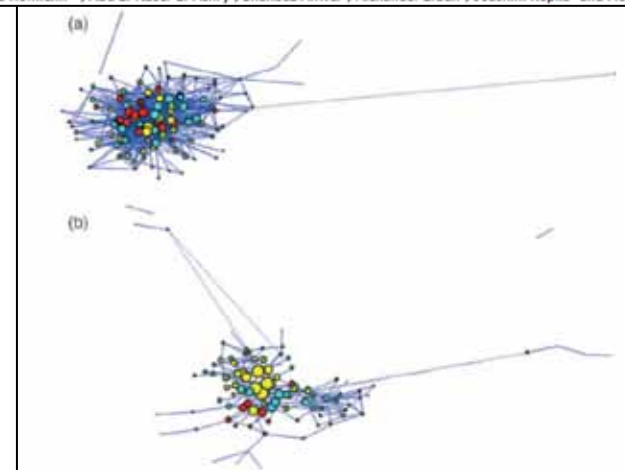


The Plant Journal (2010) 62, 1058–1071

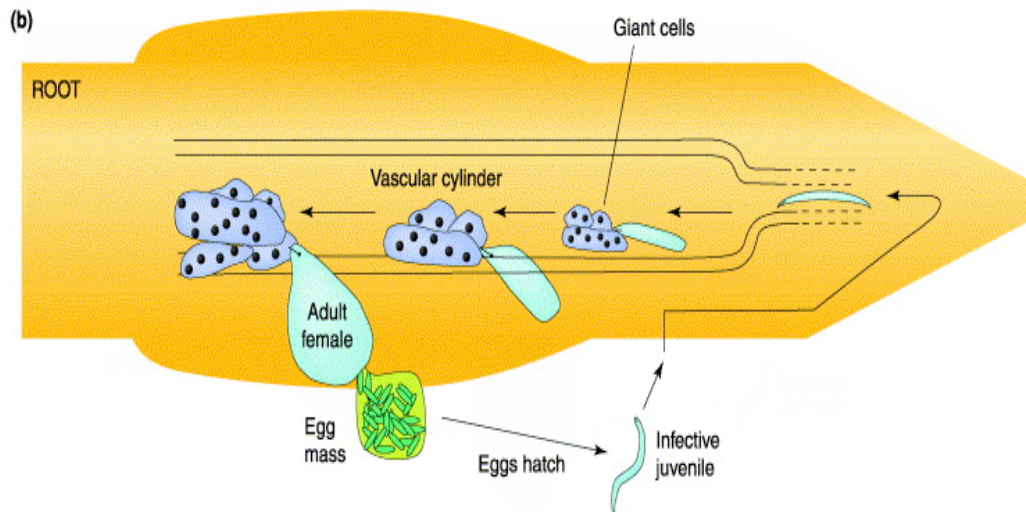
doi: 10.1111/j.1365-3113X.2010.04217.x

Metabolic profiling reveals local and systemic responses of host plants to nematode parasitism

Julia Hofmann^{1,2}, Abd El Naser El Ashry¹, Shahbaz Anwar¹, Alexander Erban², Joachim Kopka² and Florian Grundler¹



Plant-parasitic nematodes complete their life cycle in roots and roots are their sole source of nutrients



- Cyst nematode (*Heterodera schachtii*)
- Root-knot nematode (*Meloidogyne incognita*)

Different approach to cross the endodermis

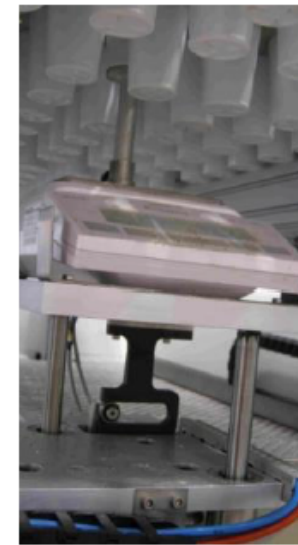
Conclusions

- Defective CS and/or increased suberin impair nematode development
- It can lead to smaller females, and galls
- This might be due to a reduced expansion of the feeding site and/ or an impeded nutrient uptake
- However, the effect varies between different nematode species

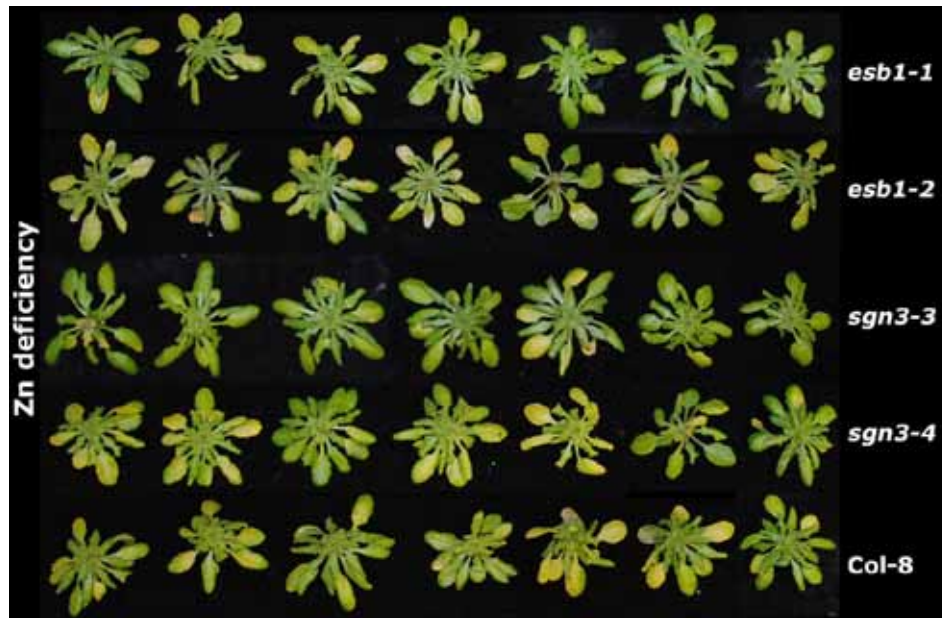
Analysis of nematode parasitism in further mutants in Casparian strip and suberin deposition are in progress

Nutrient adaptation

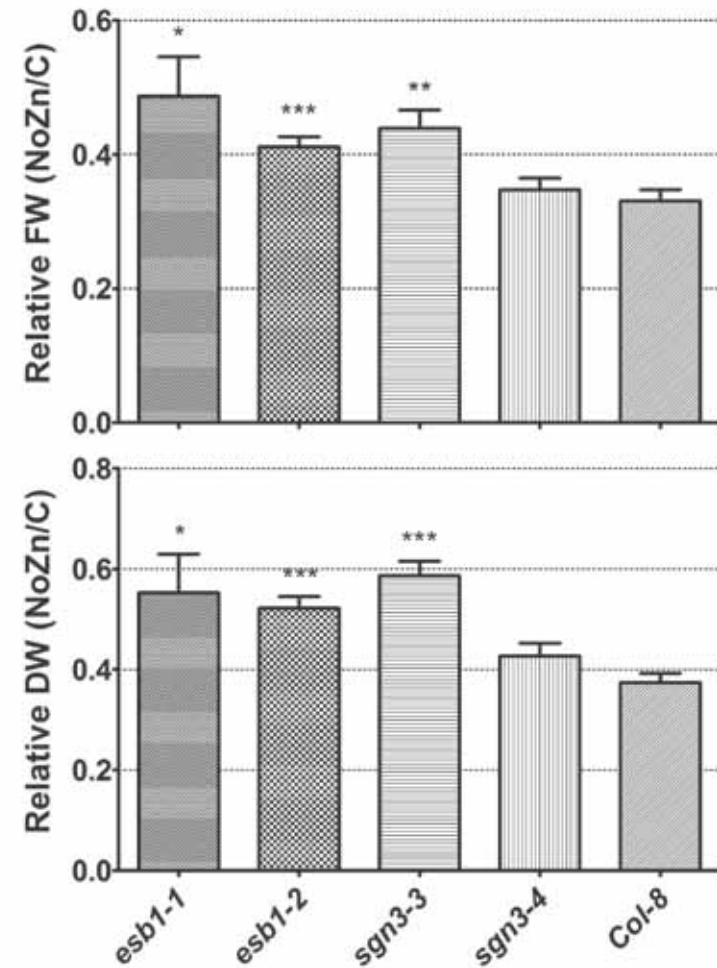
Determine the effect of the barriers on mineral nutrient efficiency and toxicity using high throughput phenotyping



esb1 and sgn3 growth is less affected under zinc deficiency

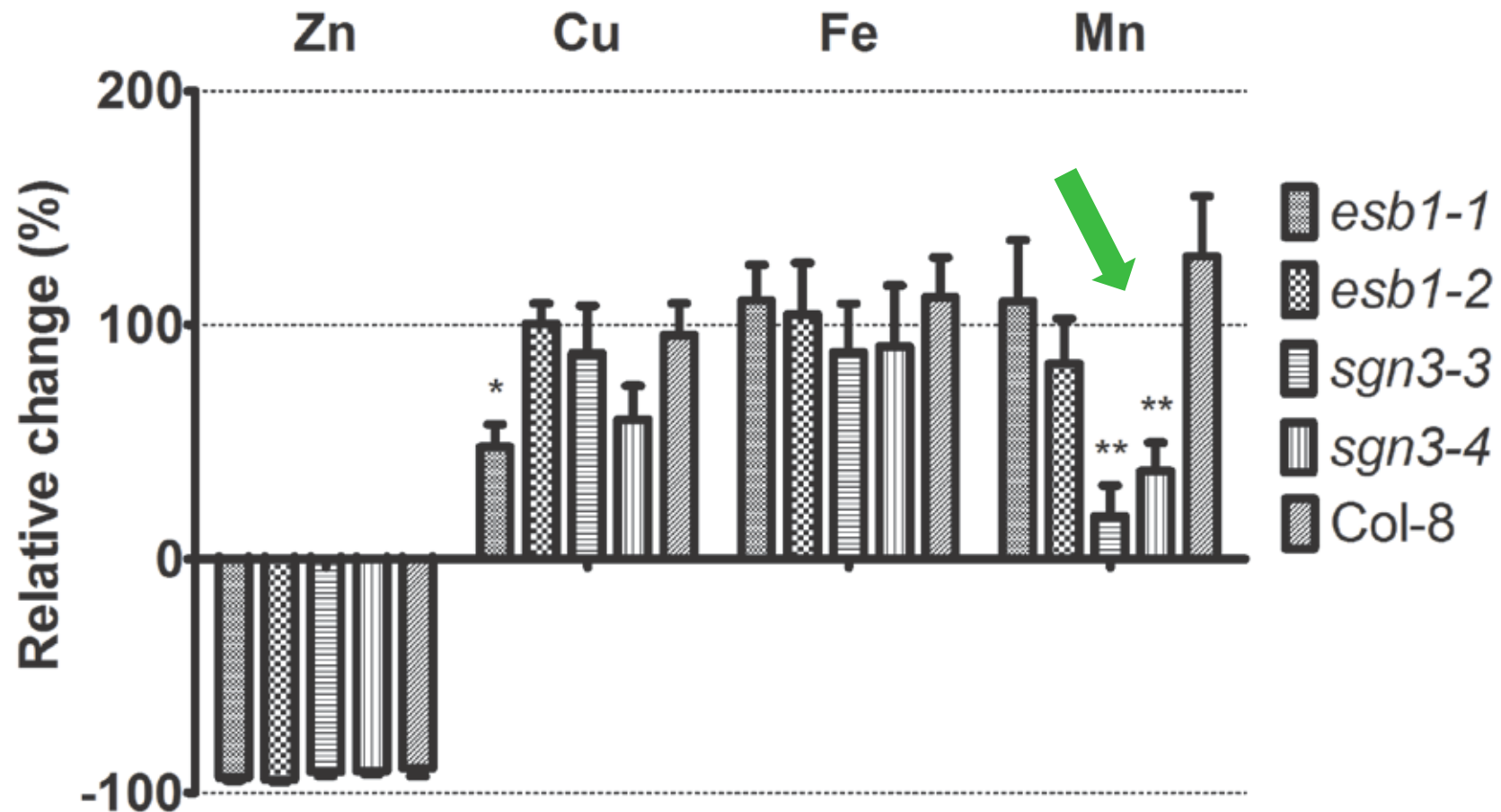


Thirty seven-days old plants grown in hydroponic conditions and subjected to zinc deficiency for 23d.



n=10 to 31; (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$;
Error bars: SE

Mn concentration is less affected in sgn3 mutants under zinc deficiency



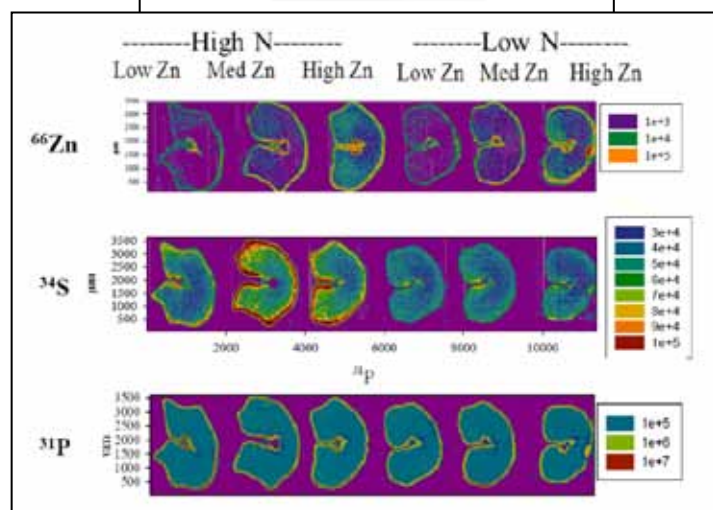
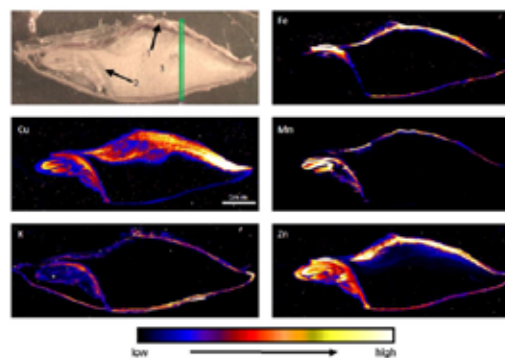
n=6; (*) p< 0.05; (**) p< 0.01; Error bars: SE

Analytical approaches

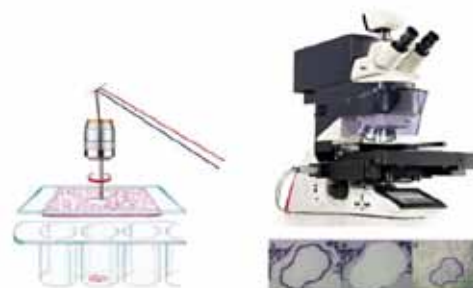
NWR Eximer Laser System



Synchrotron XRF, nano-SIMS



Laser (capture) micro dissection (LMD)





ERA-CAPS

ERA-NET for Coordinating
Action in Plant Sciences

