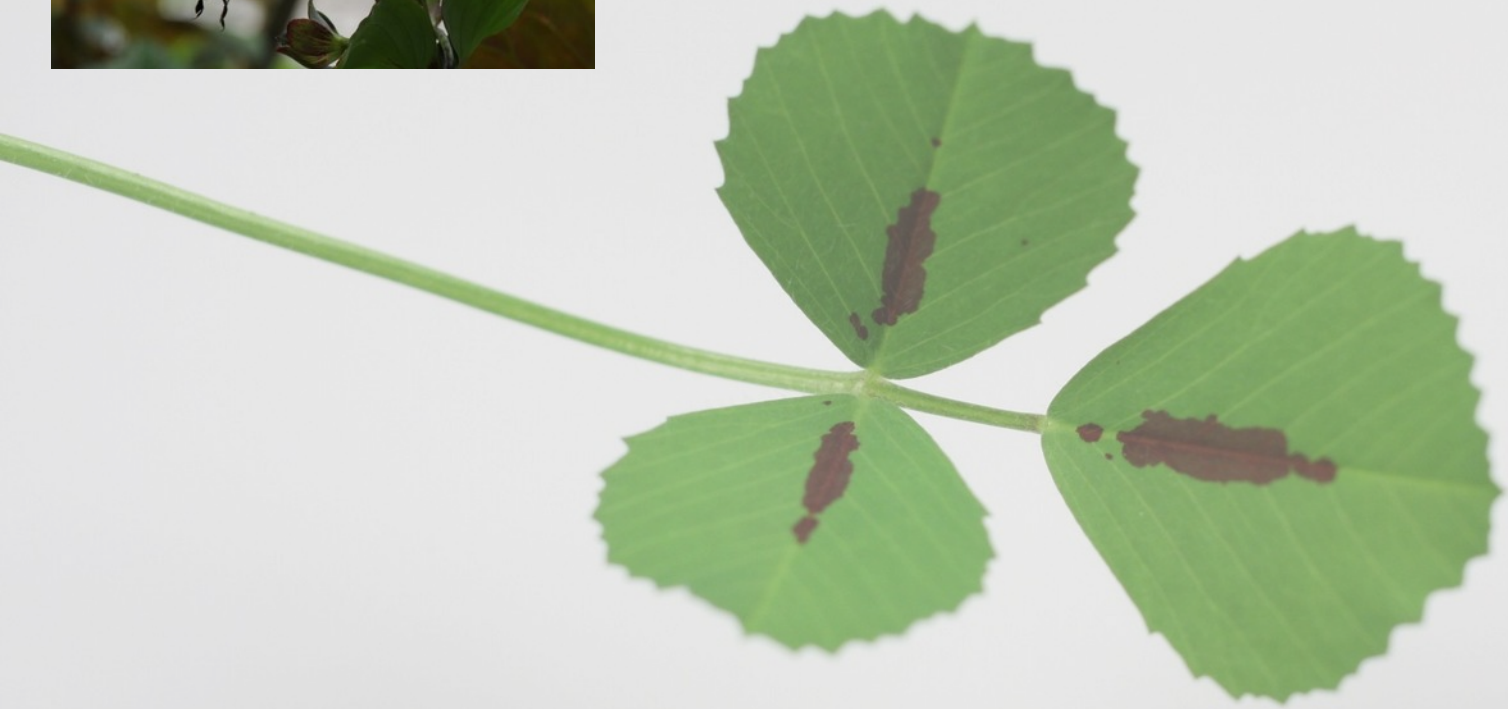


Moleculare Ecology of Plants

MOLECULARE CELL BIOLOGY

Stefanie Wienkoop, Gert Bachmann
Molecular Ecology of Plants - 300409

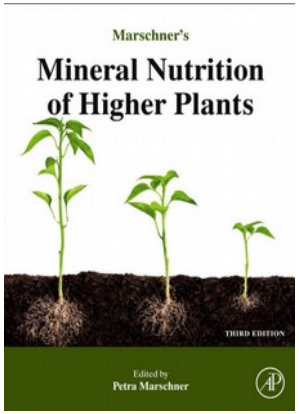
universität wien

Schedule

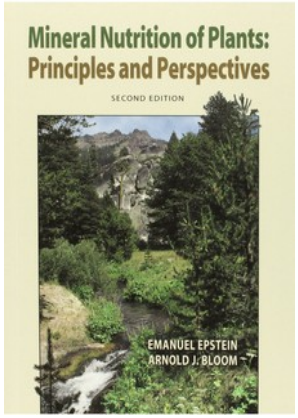
Every Wednesday 12:30 am

Kurs/Datum	Thema
1/ 07.10.	**Moleculare Cell Biology of Plants – towards systems biology**
2/ 14.10.	Autecology I - Transport and Nutrition
3/ 21.10.	Photosysnthesis
4/ 28.10.	C3/C4/CAM
5/ 04.11.	Autecology II - Plant-Microbe Interaction
6/ 11.11.	Stressphysiologie I – BIOTIC STRESS
7/ 18.11.	Autecology III – ABIOTIC STRESS
8/ 25.11.	Stressphysiologie II – ABIOTIC STRESS – temperatur
9/ 02.12.	Stressphysiologie III – ABIOTIC STRESS – drought, salt
10/ 09.12.	GREEN SYSTEMS BIOLOGY – Importance of integrating „omics“ techniques to phenotyping for tolerant varieties

Literatur

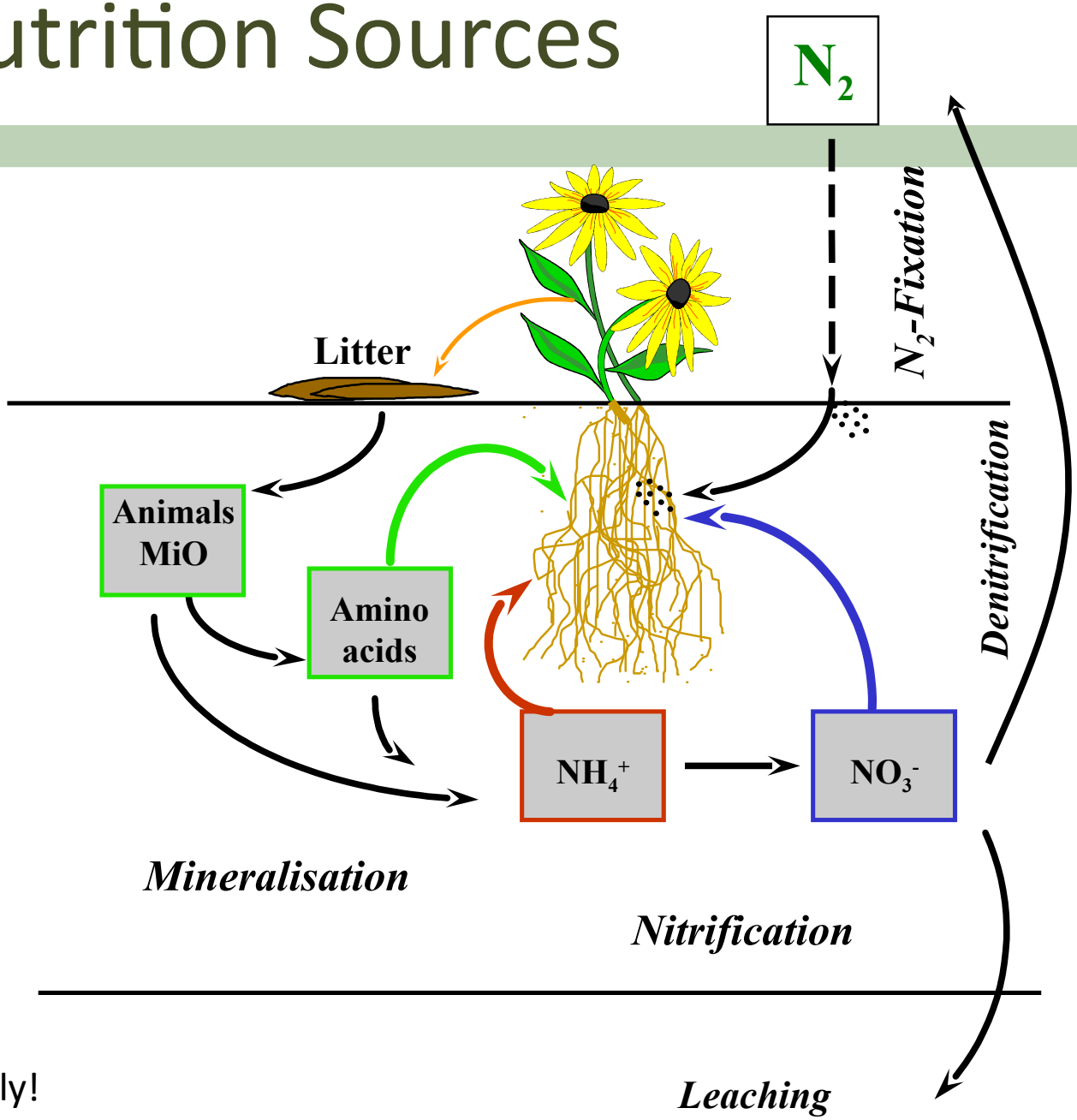


Petra Marschner/ Horst Marschner
Mineral Nutrition of Higher Plants
ISBN-10: 0123849055
ISBN-13: 978-0123849052

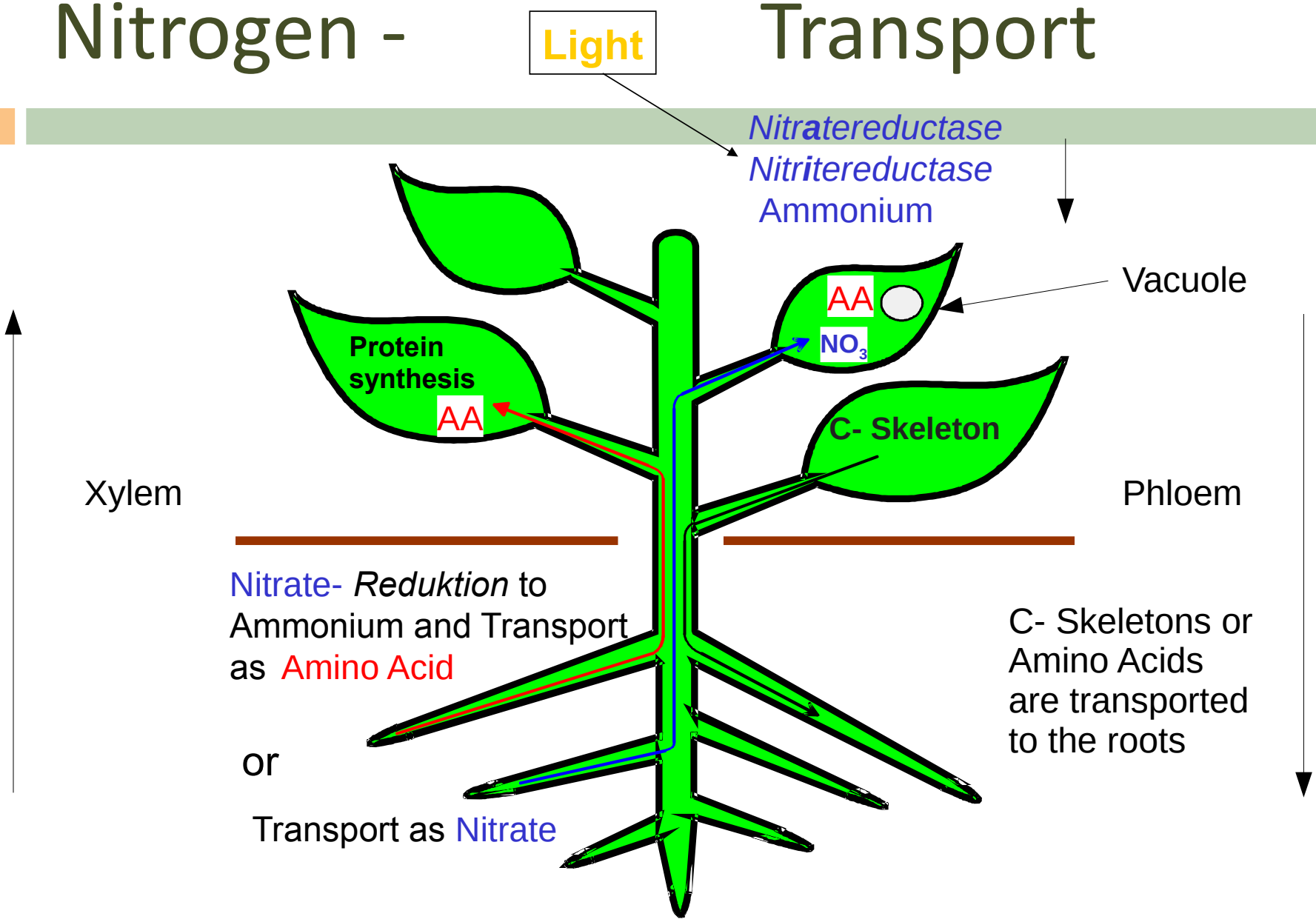


Emanuel Epstein, Arnold J. Bloom
Mineral Nutrition of Plants: Principles and Perspectives
ISBN-10: 0878931724
ISBN-13: 978-0878931729

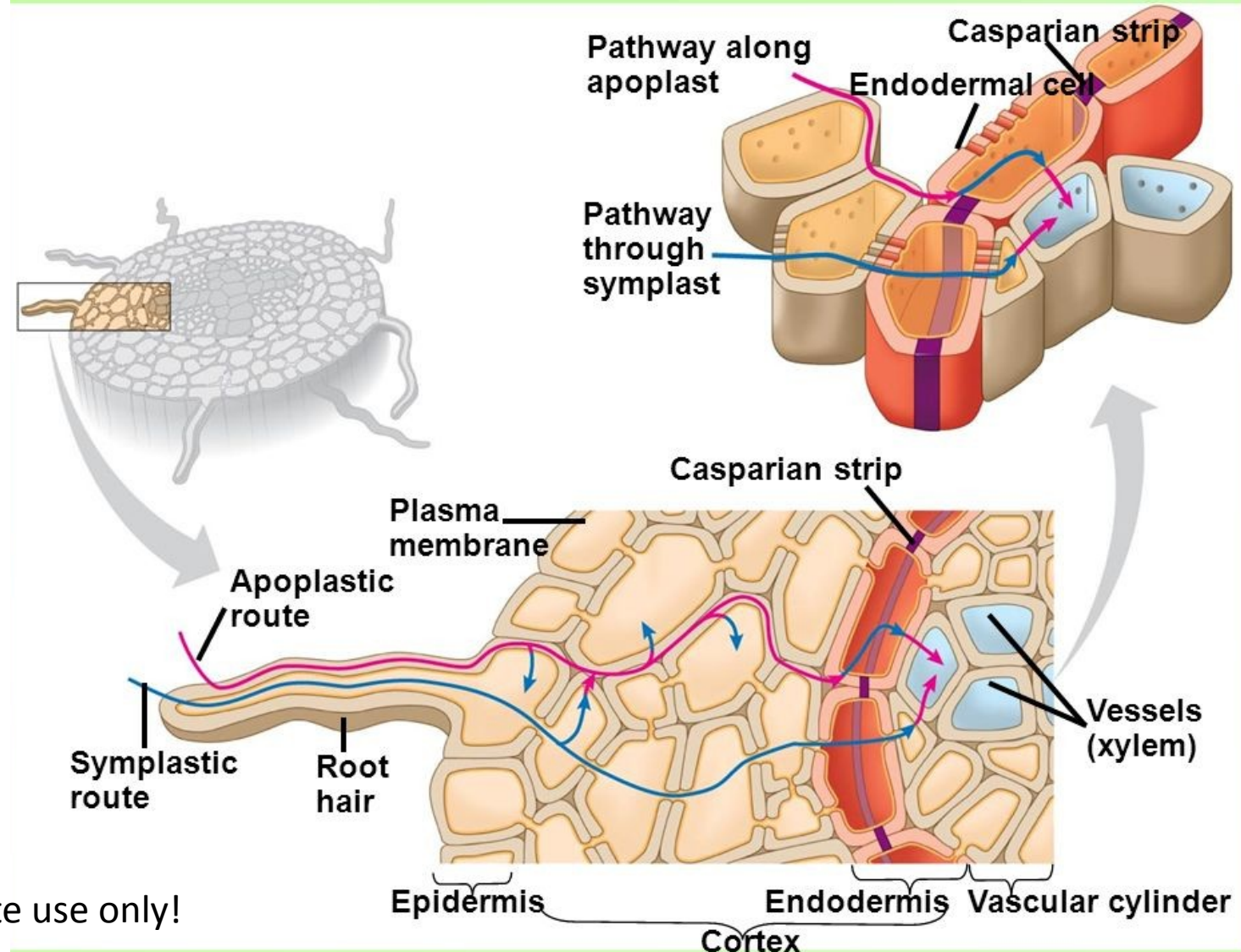
N- Nutrition Sources



Nitrogen - Transport



Cation Uptake



Nutrient Uptake of vascular Plants

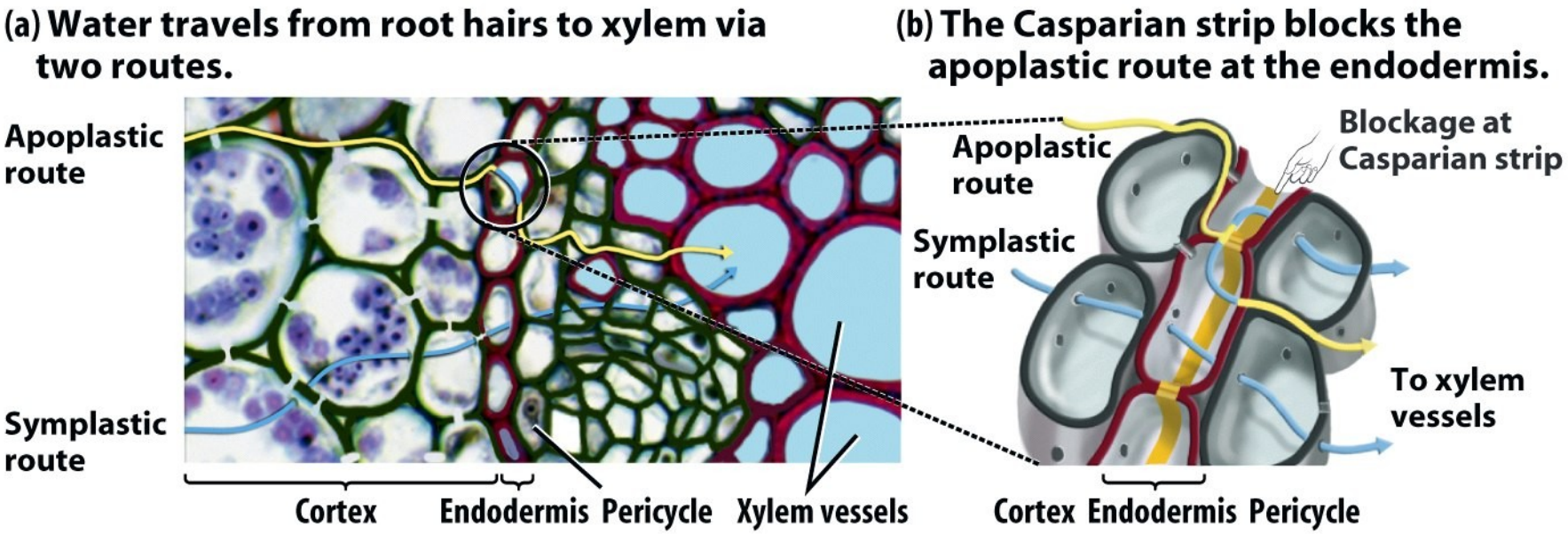
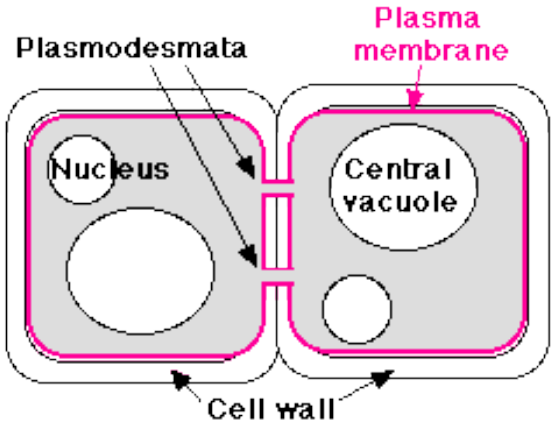
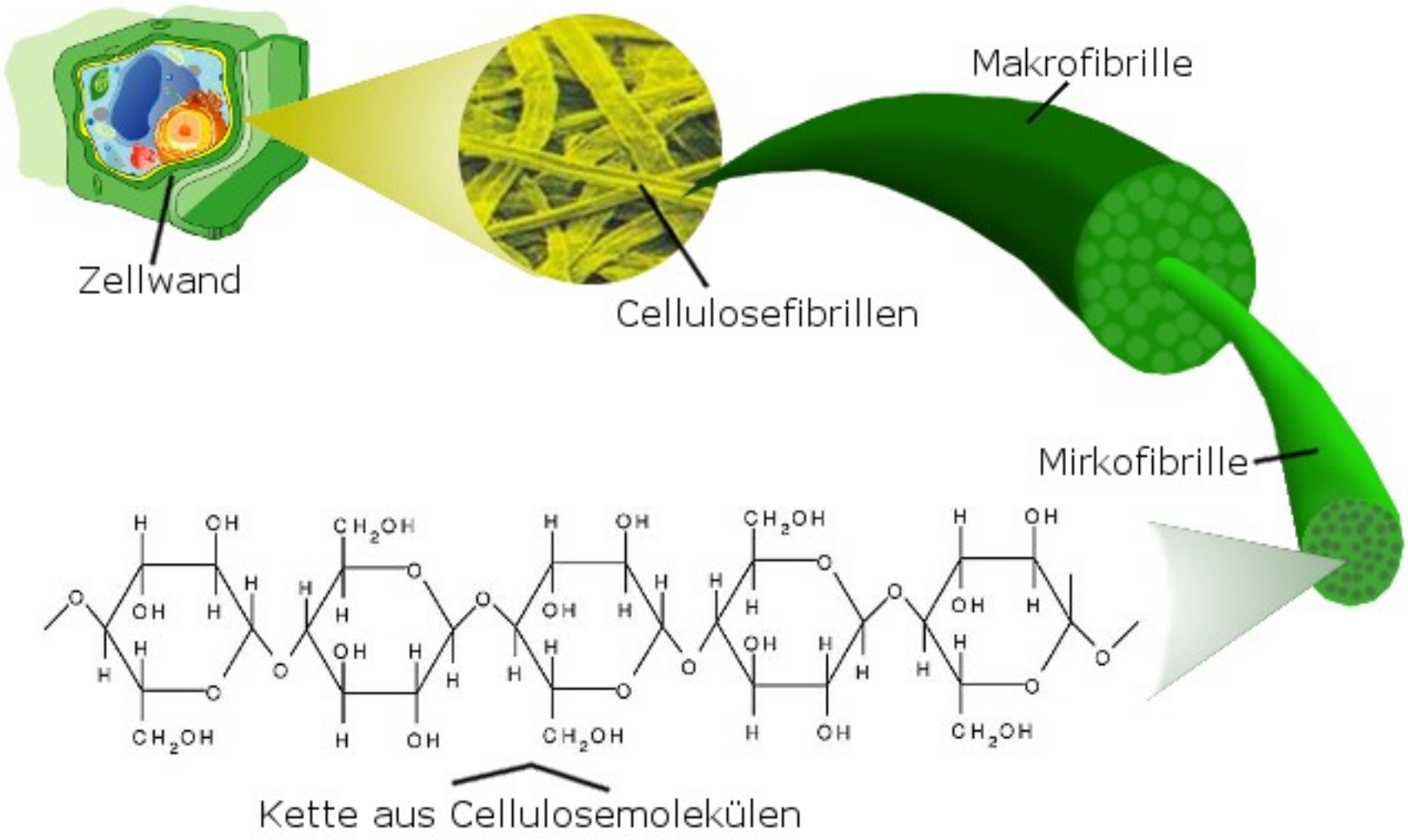


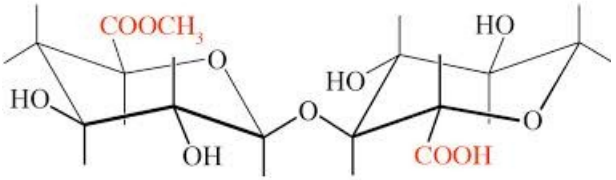
Figure 36-8 Biological Science, 2/e



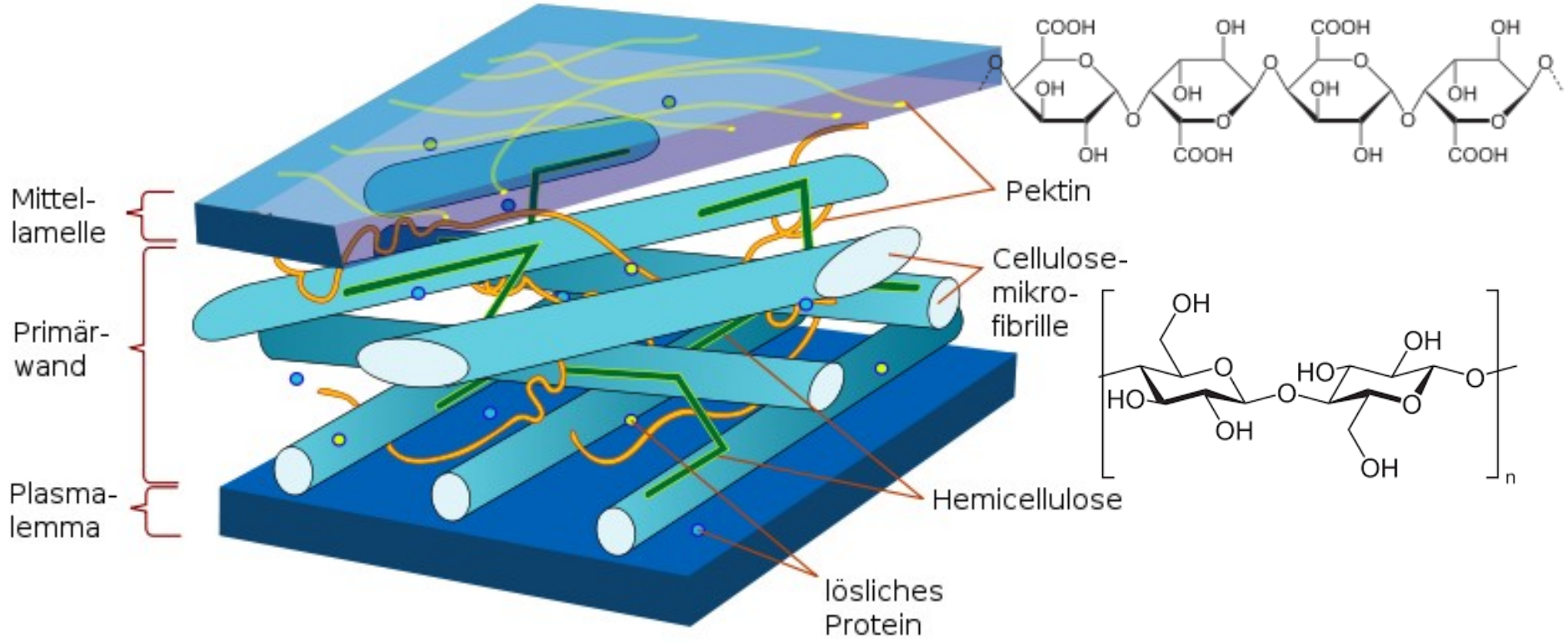
Cell Wall – Cellulose Fibers



Apoplast



polygalacturonic acid

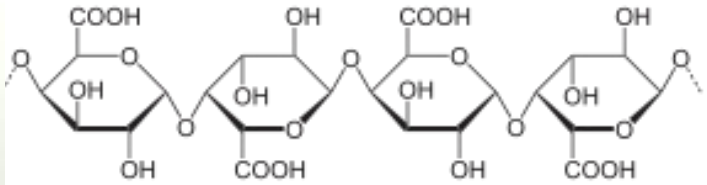


cellulose is a piezoelectric macromolecule !

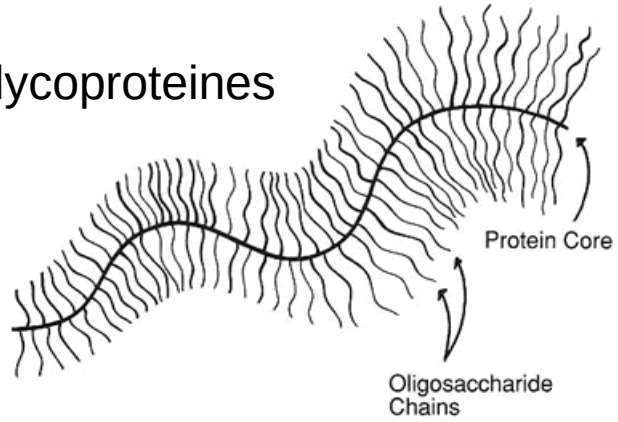
Synplast

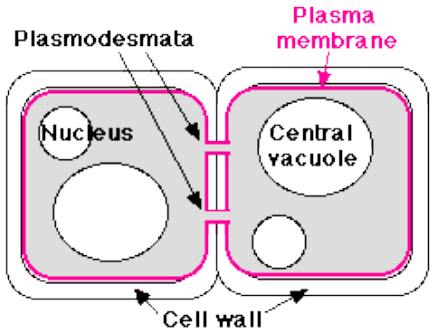
… no communication without slime!

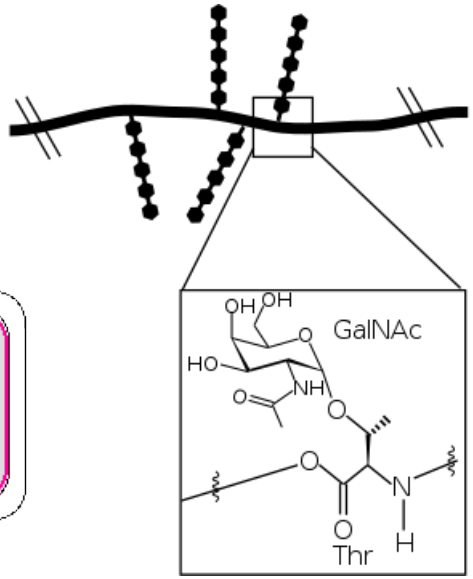
polygalacturonic acid



glycoproteines







mucines (slimes) are also colloidal, piezoelectric macromolecules !

Mucus/Mucigel

known traits

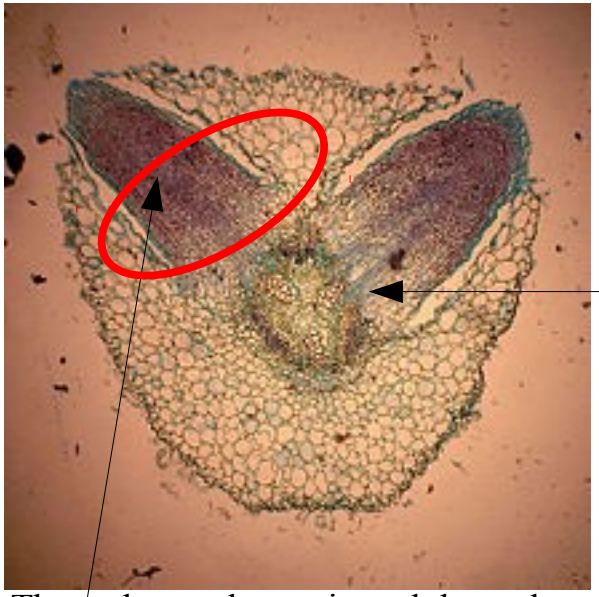
- Colloidal + nano-properties
- vegetation specific composition (root exudates)
- lubricant for growing roots
- humidity conserving and pH/RP buffering
- soil aggregate stabilising and cytostatic environment
- self organizaton of membranes and tubuli
- regenerated/ing habitat for microorganisms

hypothesized Mucigel Functions

- root exudates control nutrient uptake
- root exudates facilitate MiO succession

Root structure

- The Casparyan Strip (red) constitutes the main barrier aginst the “chemically hostile environment” of vascular plants.



The embryonal root tip and the endogenous root branches are the weak points of the system: this is where the water stream may circumvent the endodermis and the casparian strip !

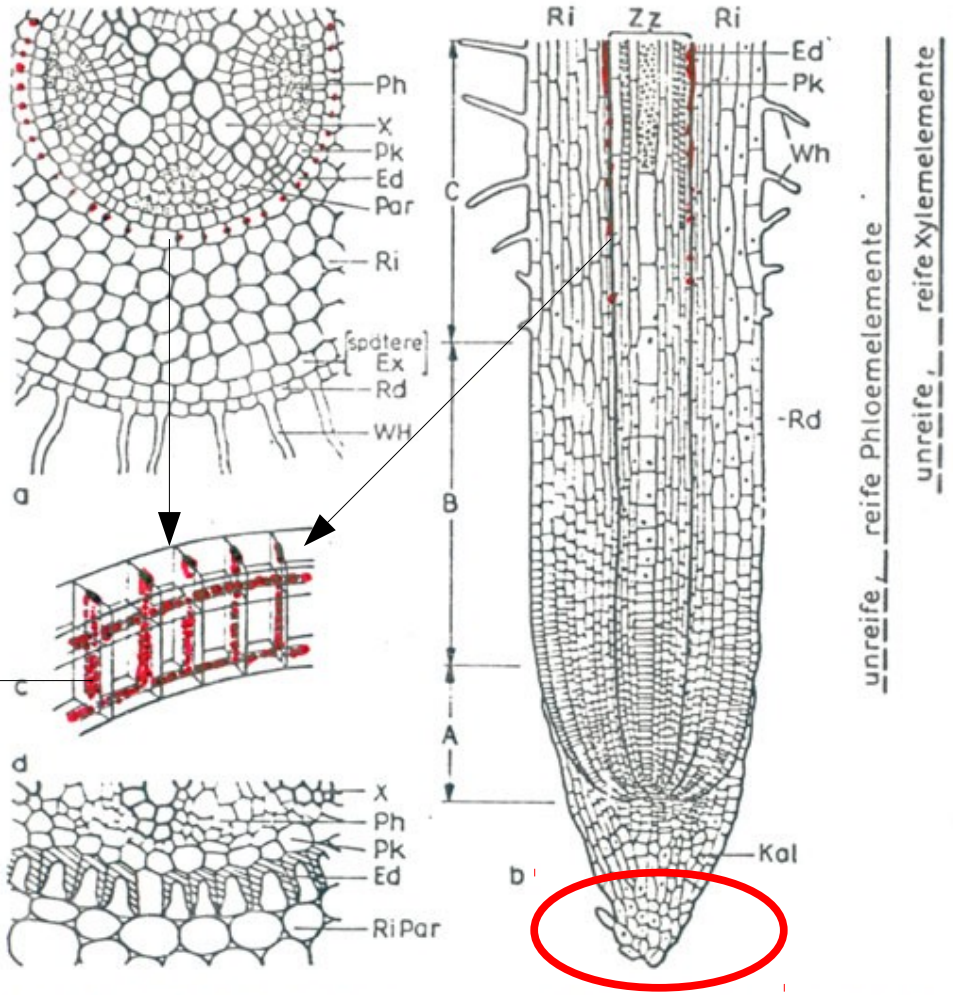


Abb. 5.20. Aufbau der Wurzel. a Schema eines Wurzelquerschnittes, b eines Wurzellängsschnittes mit A Zellteilungszone, B Zellstreckungszone, C Wurzelhaarzone. c Zellen der Endodermis mit Casparyschen Streifen (Primärendodermis), schematisch. d Tertiärendodermis bei *Iris germanica*, Ausschnitt. *Ed* Endodermis, *Ex* Exodermis, *Kal* Kalyptra (= Wurzelhaube), *Par* Parenchym, *Ph* Phloem, *Pk* Perikambium, *Rd* Rhizodermis, *Ri* Rinde, *Ri*? *r* Rindenparenchym, *WH* Wurzelhaar, *X* Xylem, *Zz* Zentralzylinder. – a nach Stocker, b nach Holman und Robbins, verändert, d nach Braune, Leman und Taubert.

Hostile Soil

… a cytostatic environment ?

- polyphenols
- radicals
- heavy metals
- salt
- bacteria
- hyphae

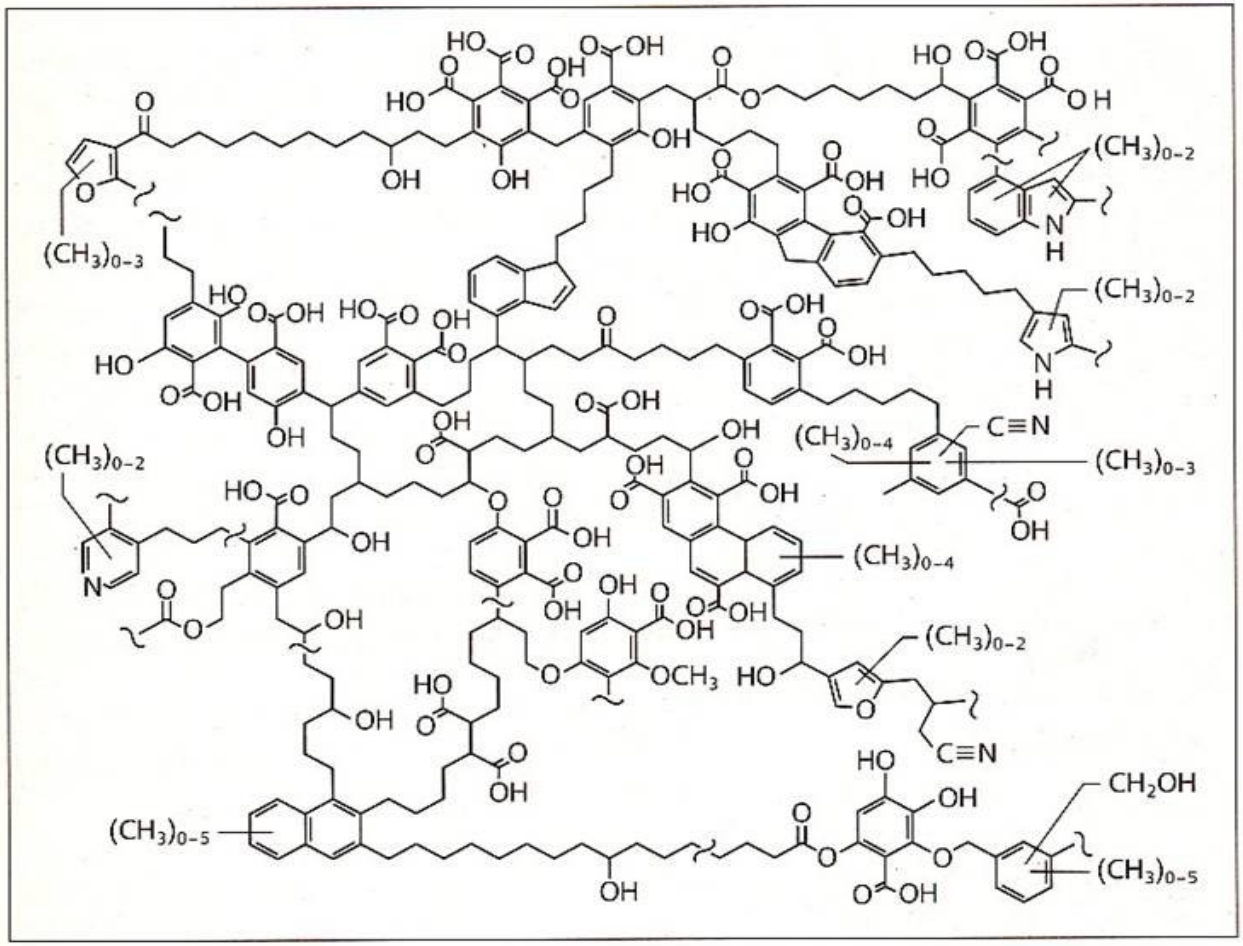
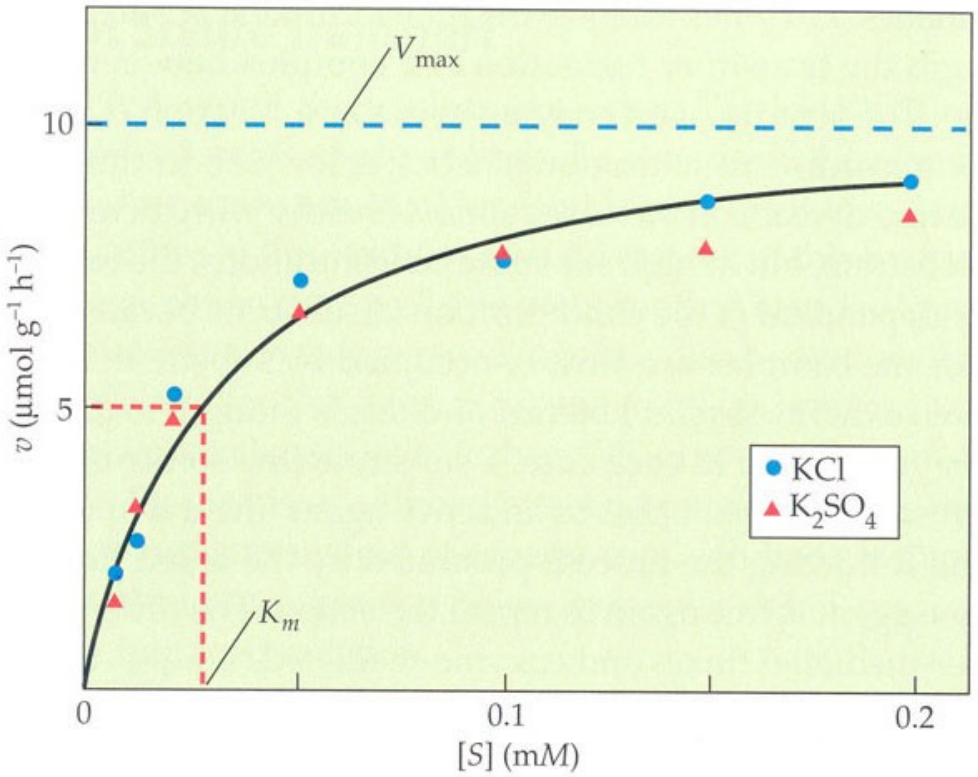


Abb. 2.**15** Hypothetische Struktur von Huminsäure mit verknüpften aromatischen Kernen, funktionellen Gruppen und aliphatischen Seitenketten (nach Schulten u. Schnitzer 1993)

Ion Uptake



V_{max} A capacity factor denoting the maximal transport rate when all available carrier sites are loaded, that is, the maximal transport rate.

K_m The Michaelis constant, equal to the substrate ion concentration giving half the maximal transport rate.

Figure 4.10 Potassium Absorption (v) by Barley Roots as a Function of K^+ Concentration ([S]). The rates of K^+ absorption (v), when offered in the form of KCl and K_2SO_4, are shown as a function of solute concentration [S]. The solid line is the best fit of the Michaelis-Menten equation to the data. The dashed blue line shows the V_{max}, or maximum velocity. The red dashed line shows the calculation of K_m, or concentration at half maximum velocity, which is inversely related to the affinity of the transport system for K^+. K_m = 0.023 mM; V_{max} = 10.0 mmol g^{-1} root fresh weight h^{-1}.

Ion Uptake

multi stage
Ion uptake due to different mechanisms

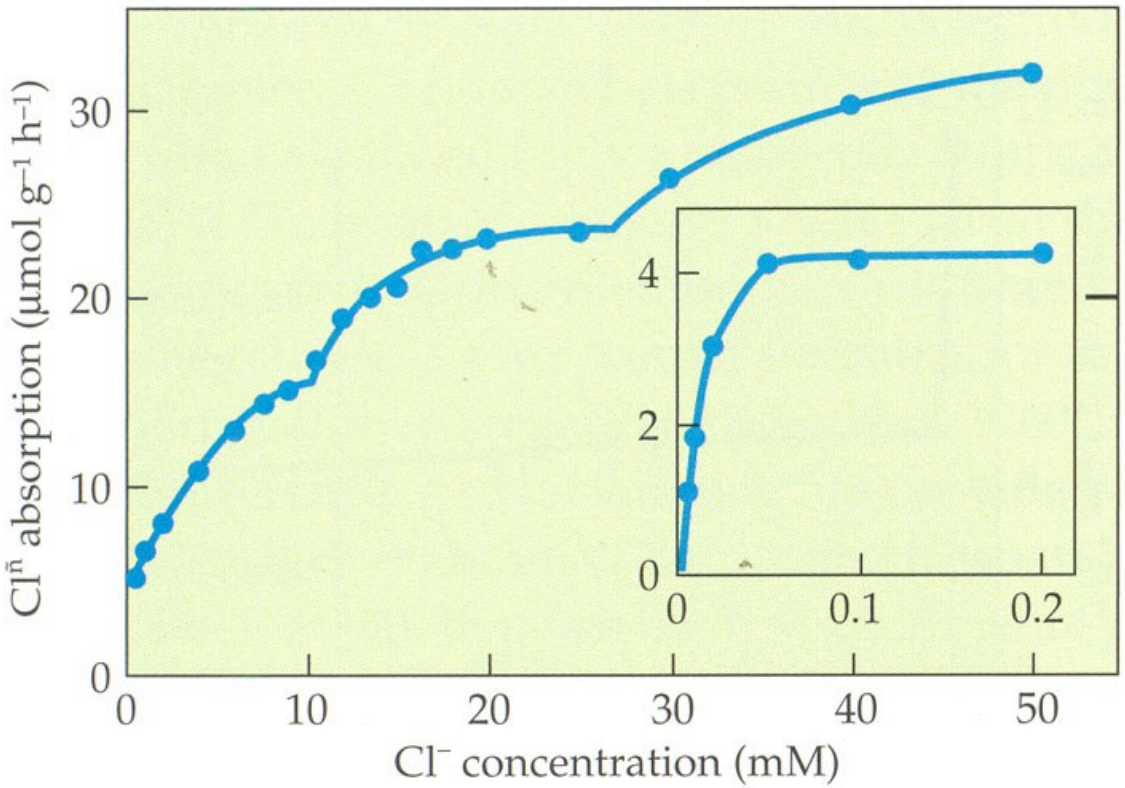
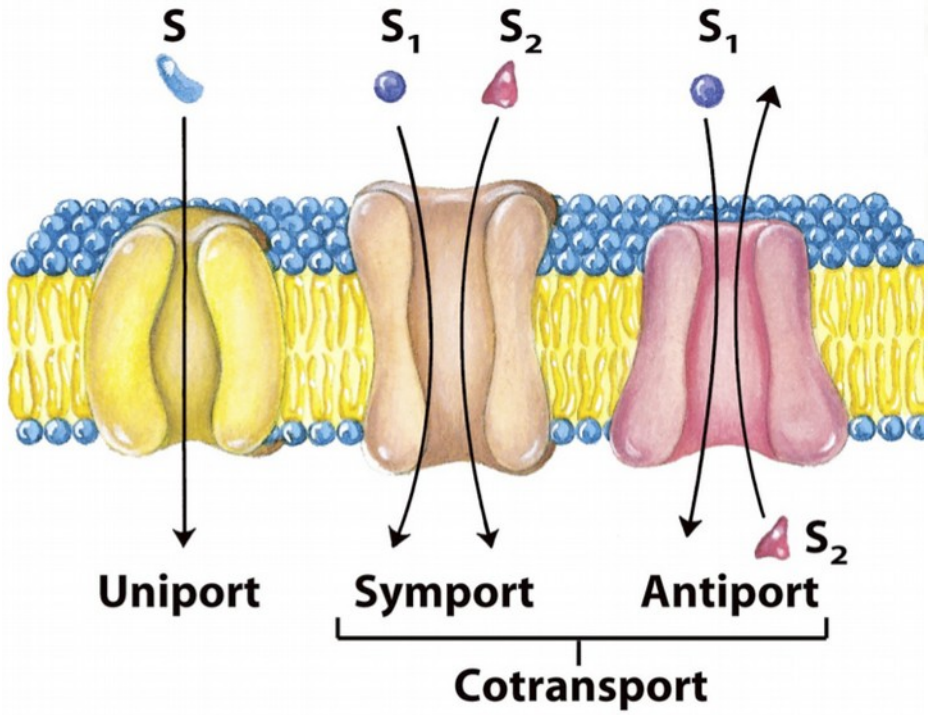
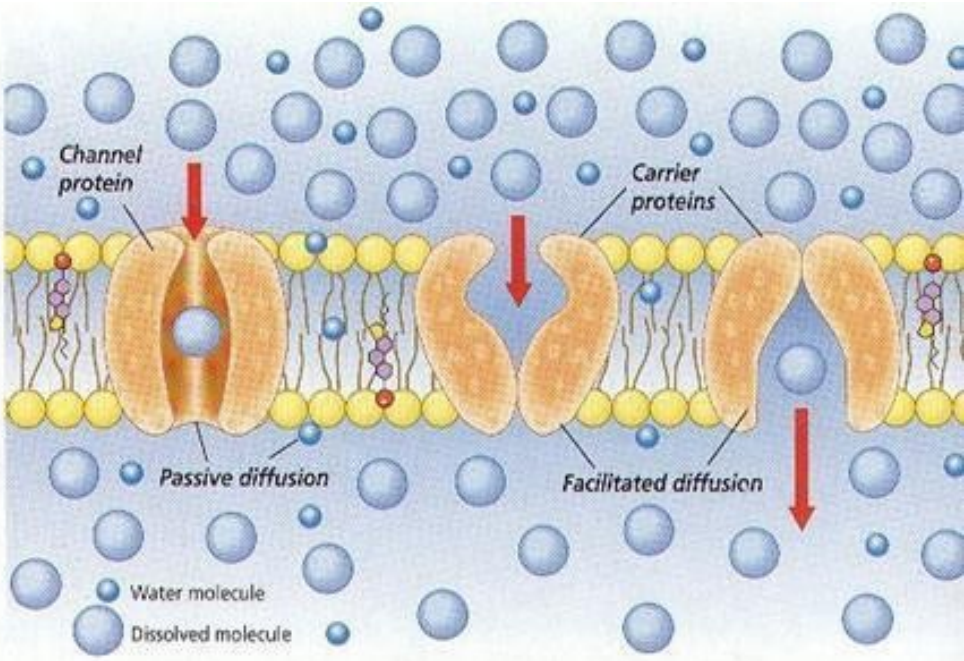


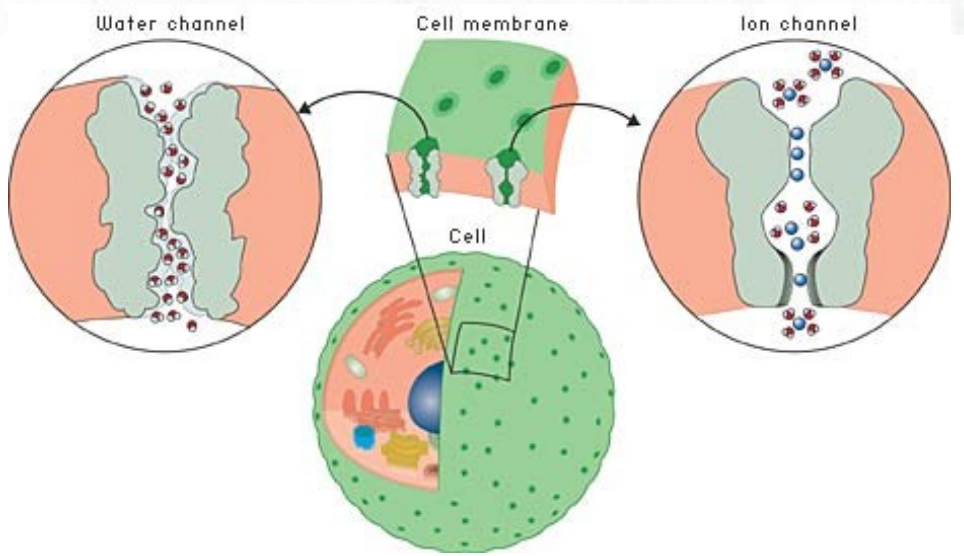
Figure 4.13 Chloride Absorption by Barley Roots as a Function of Chloride Concentration The inset shows the data at low concentrations. (After Elzam, Rains, and Epstein 1964.)

Ion and Water Uptake

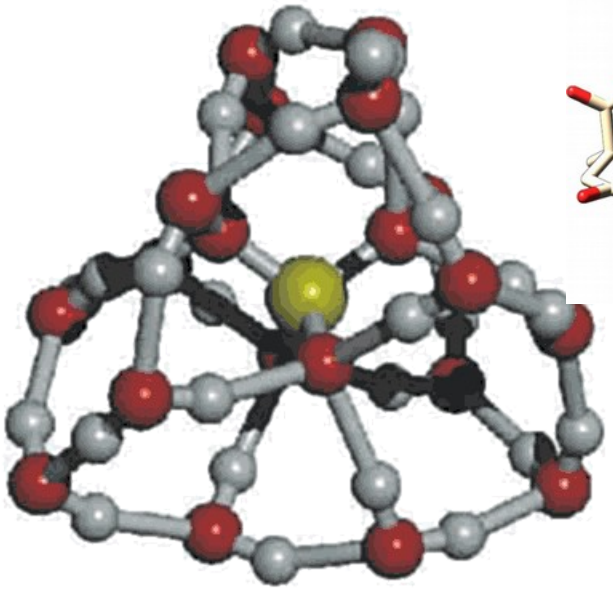
Channel proteins provide the openings through which small, dissolved particles, especially ions, diffuse by passive transport.



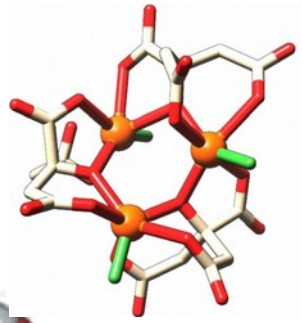


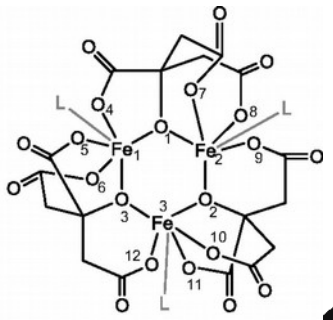


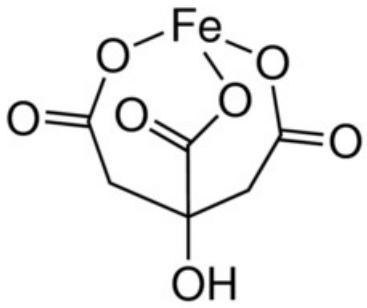
Ion and Water Uptake

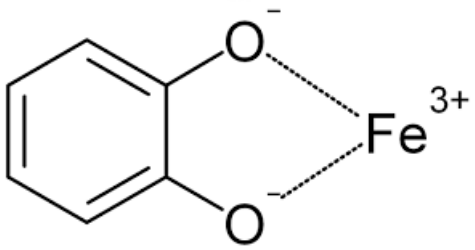


Hydratisation

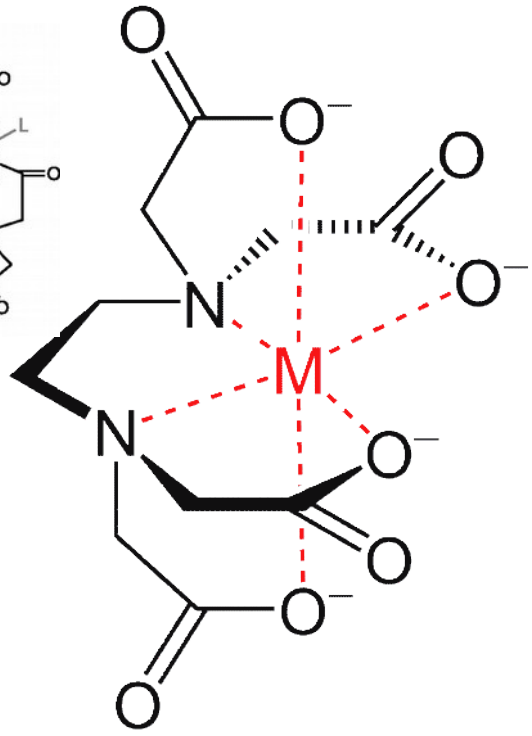








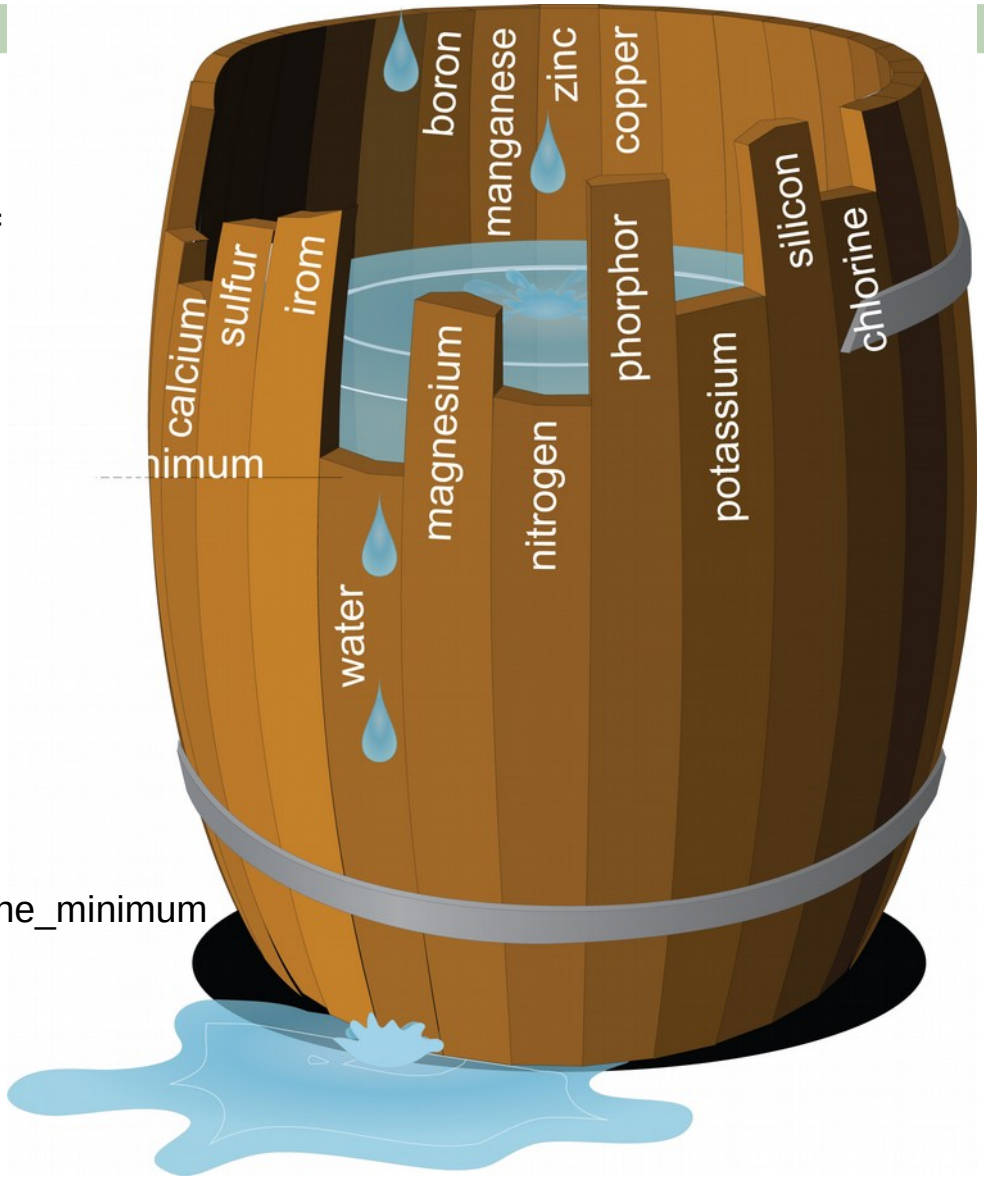
Siderophores



Chelatisation

Law of the Minimum

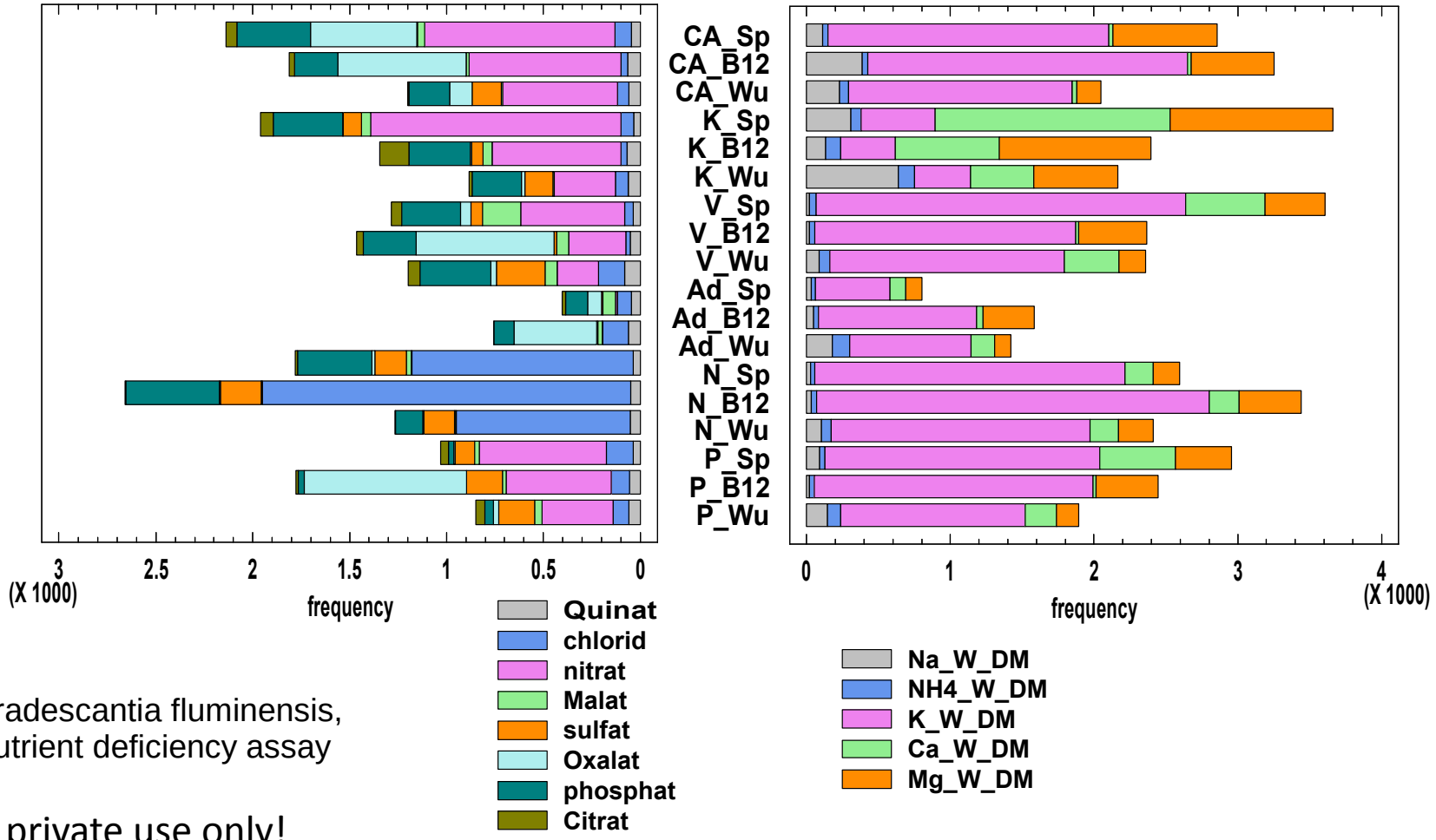
Liebig's law of the minimum, often simply called Liebig's law or the law of the minimum, is a principle developed in agricultural science by Carl Sprengel (1828) and later popularized by Justus von Liebig. It states that growth is controlled not by the total amount of resources available, but by the scarcest resource (limiting factor).



https://en.wikipedia.org/wiki/Liebig%27s_law_of_the_minimum

Ion Concentrations of Plants

Ions in the plant organs (µE g DM $^{-1}$)



Tradescantia fluminensis,
nutrient deficiency assay

Ion Concentrations of Plants

Table 2. Amount of common anions in aqueous extracts of some vegetable tissues[a]

Sample analysed	Chloride		Nitrate		Phosphate		Sulphate		Malate		Oxalate	
	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]
Zucchini cotyledons	30.3 ± 1.1	2.7 ± 0.1	184 ± 6	9.3 ± 0.3	80.6 ± 1.4	2.7 ± 0.1	52.1 ± 5.0	1.7 ± 0.2	4.2 ± 1.0	0.1 ± 0.02	2.7 ± 0.7	0.10 ± 0.03
Watermelon cotyledons	99.8 ± 12.6	8.8 ± 1.1	76.7 ± 10.7	3.9 ± 0.5	39.6 ± 6.5	1.3 ± 0.2	57.5 ± 3.6	1.9 ± 0.1	28.0 ± 3.4	0.7 ± 0.08	2.6 ± 0.1	0.11 ± 0.01
Cucumber leaves	10.7 ± 0.7	0.95 ± 0.06	2.1 ± 0.1	0.1 ± 0.004	31.0 ± 0.3	1.02 ± 0.01	28.9 ± 0.3	0.94 ± 0.01	7.6 ± 0.2	0.18 ± 0.01	2.1 ± 0.2	0.07 ± 0.01
Watermelon leaves	33.1 ± 1.8	2.9 ± 0.2	52.2 ± 6.8	2.6 ± 0.3	58.4 ± 7.1	1.9 ± 0.2	42.5 ± 1.7	1.38 ± 0.06	27.9 ± 2.1	0.65 ± 0.05	2.3 ± 0.3	0.080 ± 0.01
Olive roots	15.9 ± 0.3	1.4 ± 0.03	6.5 ± 0.2	0.33 ± 0.01	7.8 ± 0.4	0.26 ± 0.01	29.3 ± 1.9	0.95 ± 0.06	8.9 ± 0.1	0.21 ± 0.003	37 ± 1	1.31 ± 0.03
Olive leaves	3.7 ± 0.1	0.33 ± 0.01	nd[c]	nd	8.3 ± 1.0	0.27 ± 0.03	23.4 ± 3.8	0.76 ± 0.1	3.2 ± 0.4	0.08 ± 0.01	4.6 ± 0.7	0.16 ± 0.03

[a] The corresponding chromatograms are shown in Fig. 2.
[b] Mean values ($n = 3$) ± standard deviation: values expressed in terms of dry weight plant tissue; concentrations were calculated using 12.5 mg of freeze-dried vegetable material extracted with 4.0 mL of pure water.
[c] nd, not detected.

Table 3. Amount of common cations in aqueous extracts of some vegetable tissues

Sample analysed	Sodium		Potassium		Ammonium		Magnesium[a]		Calcium[a]	
	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]	mg/g[b]	mM[b]
Zucchini cotyledons	1.47 ± 0.04	0.20 ± 0.01	54.6 ± 5.5	4.4 ± 0.4	0.46 ± 0.02	0.08 ± 0.01	5.2 ± 0.1	0.667 ± 0.008	19.7 ± 0.2	1.53 ± 0.02
Watermelon cotyledons	2.00 ± 0.04	0.27 ± 0.01	41.2 ± 2.1	3.3 ± 0.2	—	—	7.0 ± 0.5	0.9 ± 0.06	13 ± 1	1.00 ± 0.08
Cucumber leaves	0.5 ± 0.3	0.10 ± 0.03	23.1 ± 0.4	1.85 ± 0.03	1.4 ± 0.1	0.25 ± 0.01	3.1 ± 0.2	0.40 ± 0.03	15.6 ± 0.8	1.2 ± 0.1
Watermelon leaves	0.9 ± 0.2	0.11 ± 0.02	48.9 ± 9.2	3.4 ± 0.2	0.8 ± 0.1	0.14 ± 0.02				
Olive leaves	0.6 ± 0.1	0.08 ± 0.01	16.2 ± 0.6	1.27 ± 0.01	—	—	1.3 ± 0.2	0.16 ± 0.03	4.5 ± 0.1	0.35 ± 0.02
Olive roots	11.4 ± 0.2	1.55 ± 0.03	20.7 ± 0.4	1.65 ± 0.04	—	—	3.3 ± 0.1	0.43 ± 0.02	4.8 ± 0.1	0.37 ± 0.02

[a] The extraction of Group II cations was carried out using a solution containing 5 mM hydrochloric acid.
[b] Mean values ($n = 3$) ± standard deviation: values expressed in terms of dry weight plant tissue; concentrations were calculated using 12.5 mg of freeze-dried vegetable material extracted with 4.0 mL of pure water.
[c] Amount expressed as mg of nutrient per g of dry weight; the concentration was calculated using 12.5 mg of freeze-dried vegetable material extracted with 4.0 mL of pure water.

PHYTOCHEMICAL ANALYSIS
Phytochem. Anal. **14**, 176–183 (2003)
Published online in Wiley InterScience (www.interscience.wiley.com). **DOI**: 10.1002/pca.700

Ionic Content in Plant Extracts Determined by Ion Chromatography with Conductivity Detection

Tommaso R. I. Cataldi,[1]* Giovanna Margiotta,[2] Antonella Del Fiore[2] and Sabino A. Bufo[2]
[1]Dipartimento di Chimica, Università degli Studi della Basilicata, Via N. Sauro, 85-85100 Potenza, Italy
[2]Dipartimento di Produzione Vegetale, Università degli Studi della Basilicata, Via N. Sauro, 85-85100 Potenza, Italy

Potassium – Calcium

K+ is Phloem mobile, Ca++ is not!

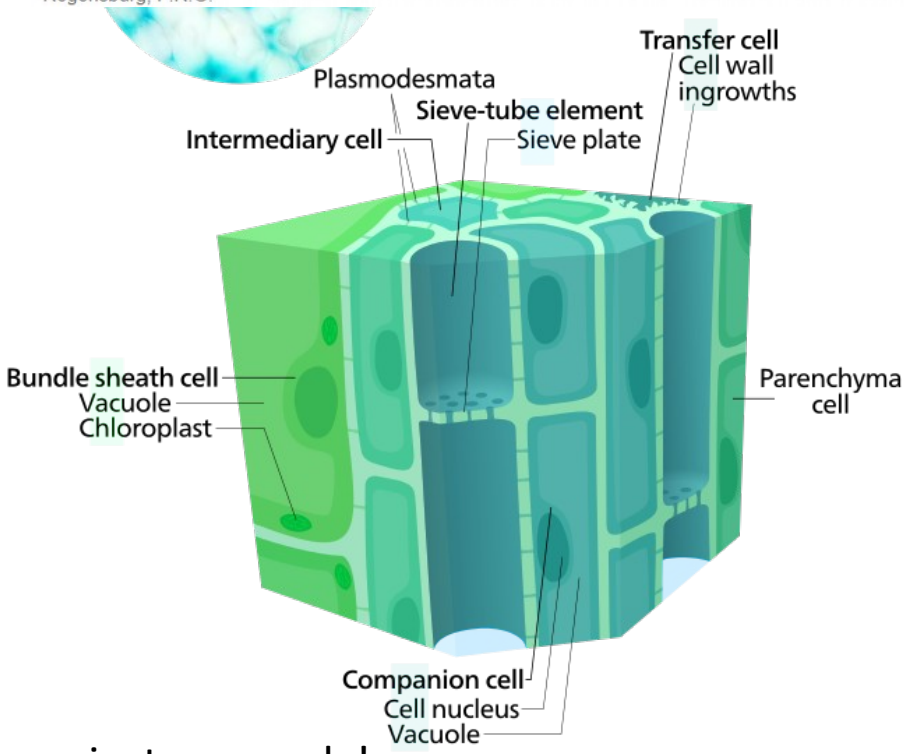
Phloem Loading, H^+,K^+-Sucrose Cotransport

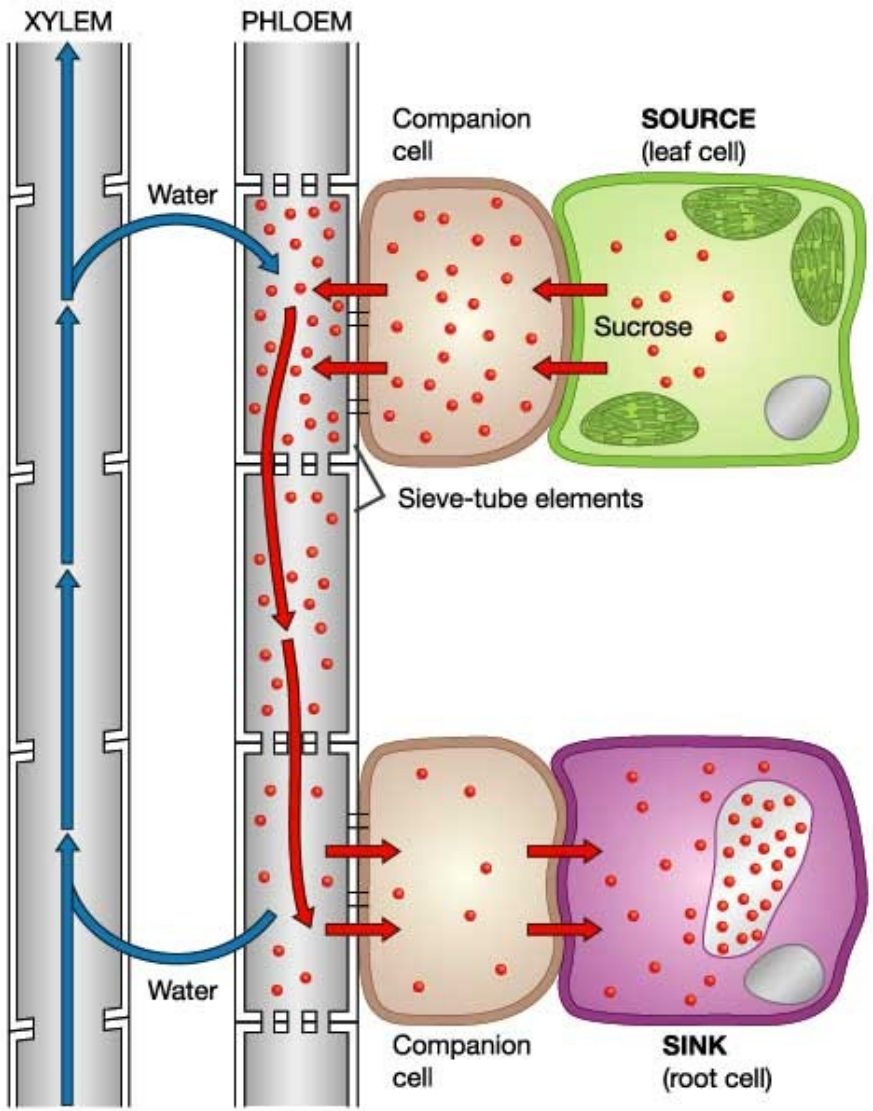
Plant Science Letters
Volume 17, Issue 4, March 1980, Pages 425–435

The role of potassium in charge compensation for sucrose-proton-symport by cotyledons of *Ricinus communis*

Bong-Heuy Cho, Ewald Komor

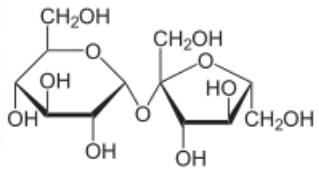
Universität Regensburg, Fachbereich Biologie und Vorklinische Medizin, Universitätsstrasse 31, 8400 Regensburg, F.R.G.





Standard Potentials - Series of Elements

	Reduction Half-Reaction		E° (V)	
Stronger oxidizing agent	$F_2(g) + 2e^-$	$\longrightarrow 2F^-(aq)$	2.87	Weaker reducing agent
	$H_2O_2(aq) + 2H^+(aq) + 2e^-$	$\longrightarrow 2H_2O(l)$	1.78	
	$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\longrightarrow Mn^{2+}(aq) + 4H_2O(l)$	1.51	
	$Cl_2(g) + 2e^-$	$\longrightarrow 2Cl^-(aq)$	1.36	
	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$	$\longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	1.33	
	$O_2(g) + 4H^+(aq) + 4e^-$	$\longrightarrow 2H_2O(l)$	1.23	
	$Br_2(aq) + 2e^-$	$\longrightarrow 2Br^-(aq)$	1.09	
	$Ag^+(aq) + e^-$	$\longrightarrow Ag(s)$	0.80	
	$Fe^{3+}(aq) + e^-$	$\longrightarrow Fe^{2+}(aq)$	0.77	
	$O_2(g) + 2H^+(aq) + 2e^-$	$\longrightarrow H_2O_2(aq)$	0.70	
	$I_2(s) + 2e^-$	$\longrightarrow 2I^-(aq)$	0.54	
	$O_2(g) + 2H_2O(l) + 4e^-$	$\longrightarrow 4OH^-(aq)$	0.40	
	$Cu^{2+}(aq) + 2e^-$	$\longrightarrow Cu(s)$	0.34	
	$Sn^{4+}(aq) + 2e^-$	$\longrightarrow Sn^{2+}(aq)$	0.15	
	$2H^+(aq) + 2e^-$	$\longrightarrow H_2(g)$	0	
	$Pb^{2+}(aq) + 2e^-$	$\longrightarrow Pb(s)$	- 0.13	
	$Ni^{2+}(aq) + 2e^-$	$\longrightarrow Ni(s)$	- 0.26	
	$Cd^{2+}(aq) + 2e^-$	$\longrightarrow Cd(s)$	- 0.40	
	$Fe^{2+}(aq) + 2e^-$	$\longrightarrow Fe(s)$	- 0.45	
	$Zn^{2+}(aq) + 2e^-$	$\longrightarrow Zn(s)$	- 0.76	
	$2H_2O(l) + 2e^-$	$\longrightarrow H_2(g) + 2OH^-(aq)$	- 0.83	
	$Al^{3+}(aq) + 3e^-$	$\longrightarrow Al(s)$	- 1.66	
	$Mg^{2+}(aq) + 2e^-$	$\longrightarrow Mg(s)$	- 2.37	Stronger reducing agent
Weaker oxidizing agent	$Na^+(aq) + e^-$	$\longrightarrow Na(s)$	- 2.71	
	$Li^+(aq) + e^-$	$\longrightarrow Li(s)$	- 3.04	



Sucrose +1.25

OH^-

K^+ -2.99

Table 17-1 Chemistry, 5/e

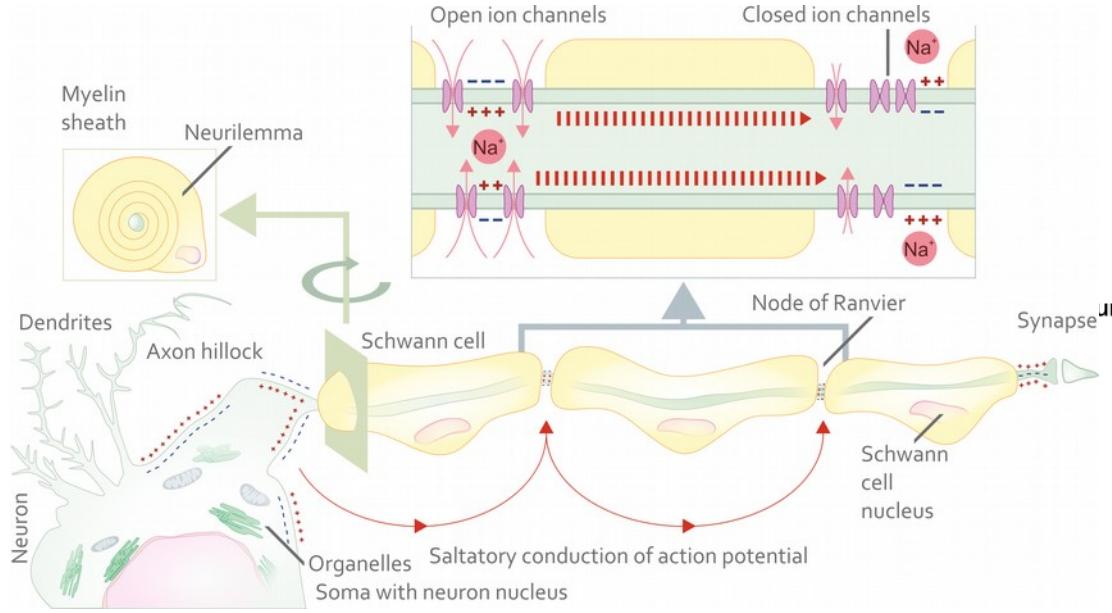
Sucrose Transport – Neuron Analogy

Plant Science Letters
Volume 17, Issue 4, March 1980, Pages 425–435

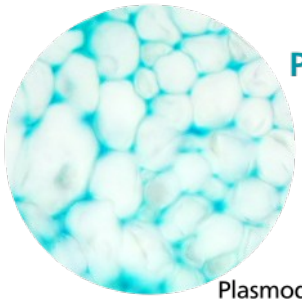
The role of potassium in charge compensation for sucrose-proton-symport by cotyledons of *Ricinus communis*

Bong-Heuy Cho, Ewald Komor

Universität Regensburg, Fachbereich Biologie und Vorklinische Medizin, Universitätsstrasse 31, 8400 Regensburg, F.R.G.

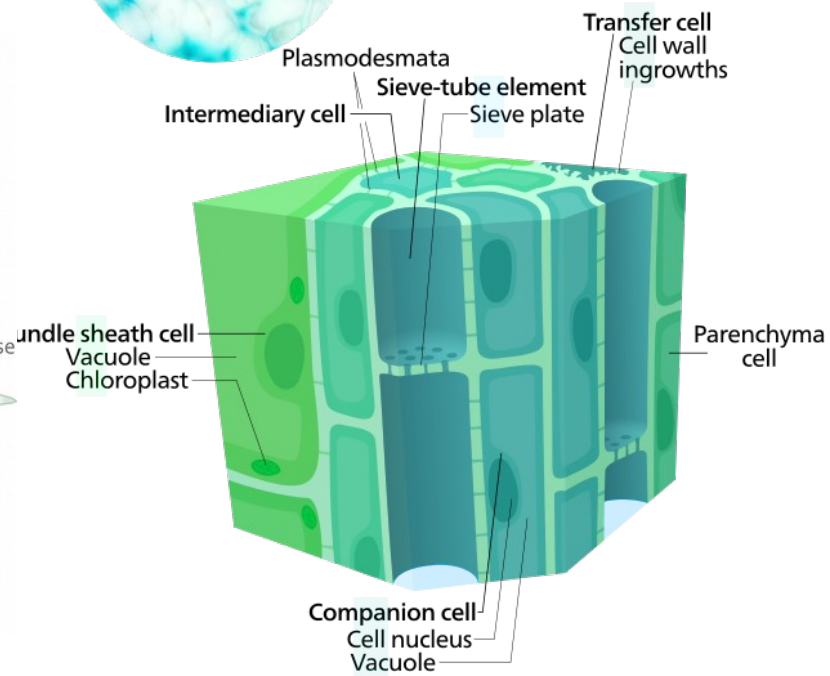


Saltatory conduction

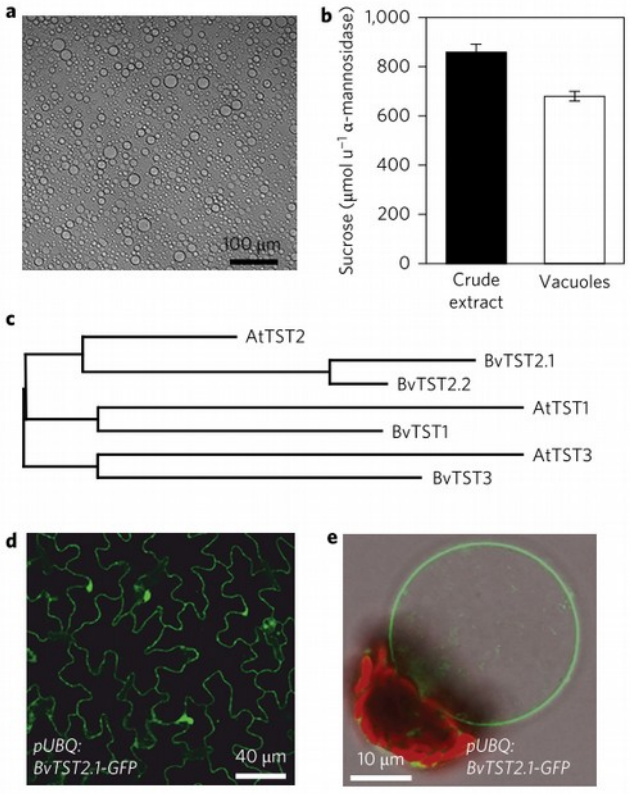


Phloem

Phloem transports sugars and other items. In angiosperms, **sieve-tube elements** contain the sugar solution. Sieve-tube cells are surrounded by various support cells .



Sucrose Storage



Sucrose storage in storage parenchyma

nature plants

ARTICLES

PUBLISHED: 8 JANUARY 2015 | ARTICLE NUMBER: 14001 | DOI: 10.1038/NPLANTS.2014.1

Identification of the transporter responsible for sucrose accumulation in sugar beet taproots

Benjamin Jung[1†], Frank Ludewig[2†], Alexander Schulz[3†], Garvin Meißner[1], Nicole Wöstefeld[2], Ulf-Ingo Flügge[2], Benjamin Pommerrenig[4], Petra Wirsching[4], Norbert Sauer[4], Wolfgang Koch[5], Frederik Sommer[6], Timo Mühlhaus[6], Michael Schroda[6], Tracey Ann Cuin[3], Dorothea Graus[3], Irene Marten[3], Rainer Hedrich[3*] and H. Ekkehard Neuhaus[1*]

Sugar beet provides around one third of the sugar consumed worldwide and serves as a significant source of bioenergy in the form of ethanol. Sucrose accounts for up to 18% of plant fresh weight in sugar beet. Most of the sucrose is concentrated in the taproot, where it accumulates in the vacuoles. Despite 30 years of intensive research, the transporter that facilitates taproot sucrose accumulation has escaped identification. Here, we combine proteomic analyses of the taproot vacuolar membrane, the tonoplast, with electrophysiological analyses to show that the transporter BvTST2.1 is responsible for vacuolar sucrose uptake in sugar beet taproots. We show that BvTST2.1 is a sucrose-specific transporter, and present evidence to suggest that it operates as a proton antiporter, coupling the import of sucrose into the vacuole to the export of protons. BvTST2.1 exhibits a high amino acid sequence similarity to members of the tonoplast monosaccharide transporter family in *Arabidopsis*, prompting us to rename this group of proteins 'tonoplast sugar transporters'. The identification of BvTST2.1 could help to increase sugar yields from sugar beet and other sugar-storing plants in future breeding programs.

Figure 1 | Vacuole preparations and identification of BvTST proteins in *B. vulgaris*. a, Light microscopic picture of a vacuole preparation after den: gradient centrifugation. **b**, Sucrose content in taproot crude extract and isolated vacuoles per unit (u) α-mannosidase, a vacuolar marker enzyme (mean ± s.e.m.). **c**, Unrooted phylogentic tree of TST-proteins from *Arabidopsis* and sugar beet, generated using the 'One-click' mode of http://www.phylogeny.fr. **d**, Expression of *pUBQ:BvTST2.1-GFP* fusion construct (under control of the ubiquitin 10 promoter, *pUBQ10*), in the *Attst1-2* double-knockout mutant. Depicted is a confocal picture of green-fluorescing epidermal cells. **e**, Released vacuole of *pUBQ:BvTST2.1-G* stably transformed *Attst1-2* double-knockout mutant. The bright-light, green (GFP) and the red (chlorophyll autofluorescence) channels are merged.

Electric signaling

Plant, Cell and Environment (2007) **30**, 249–257 doi: 10.1111/j.1365-3040.2006.01614.x

Electrical signals and their physiological significance in plants

JÖRG FROMM & SILKE LAUTNER

Fachgebiet Holzbiologie, TU München, Winzererstrasse 45, 80797 München, Germany

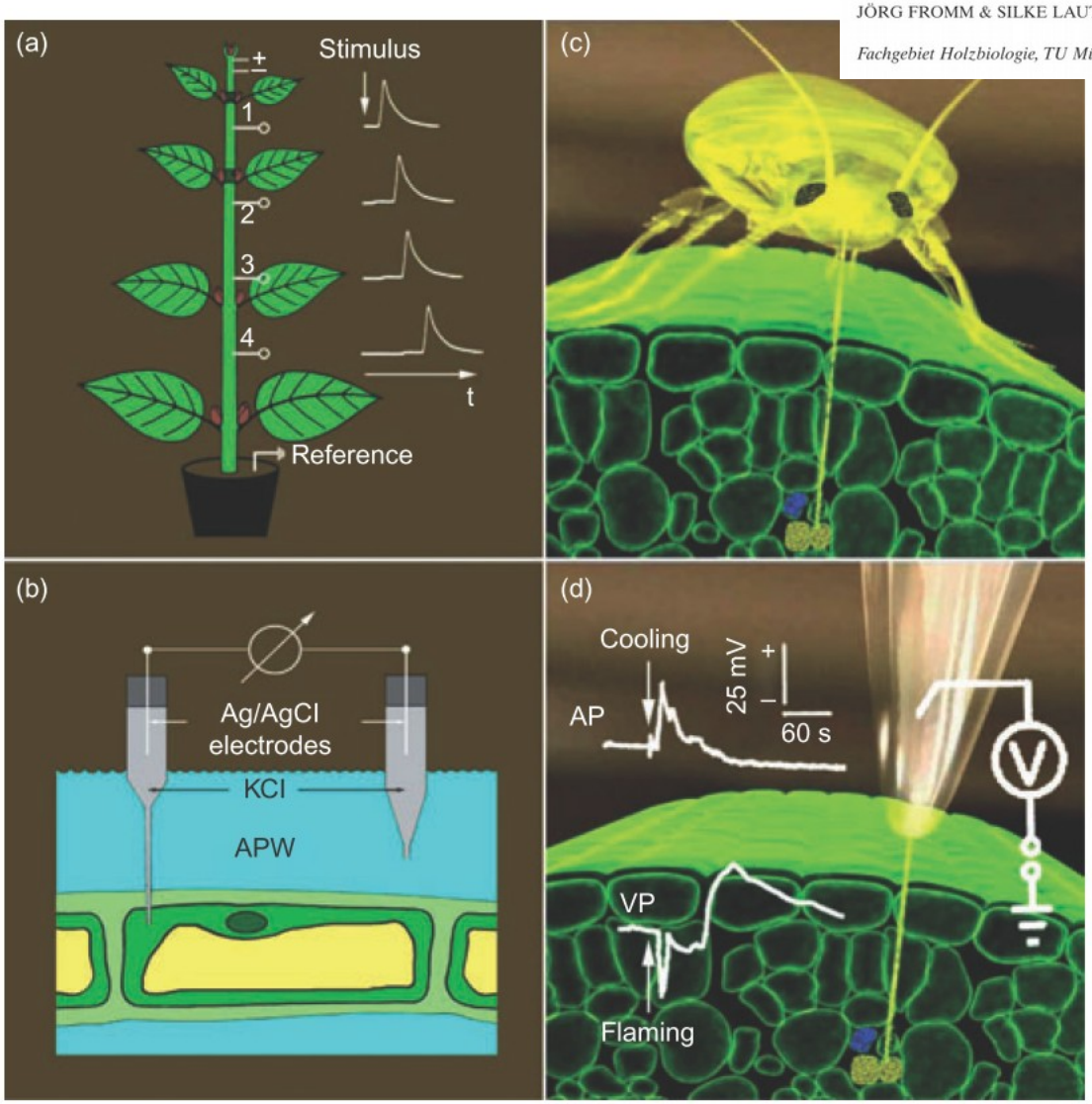
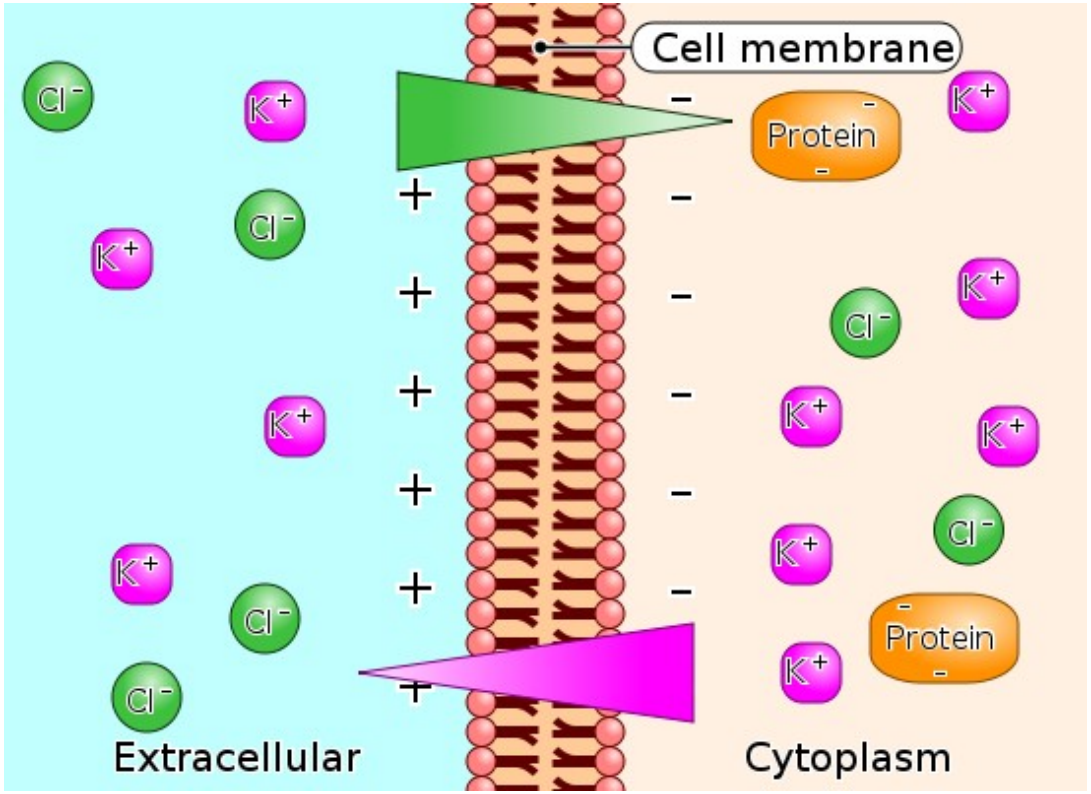


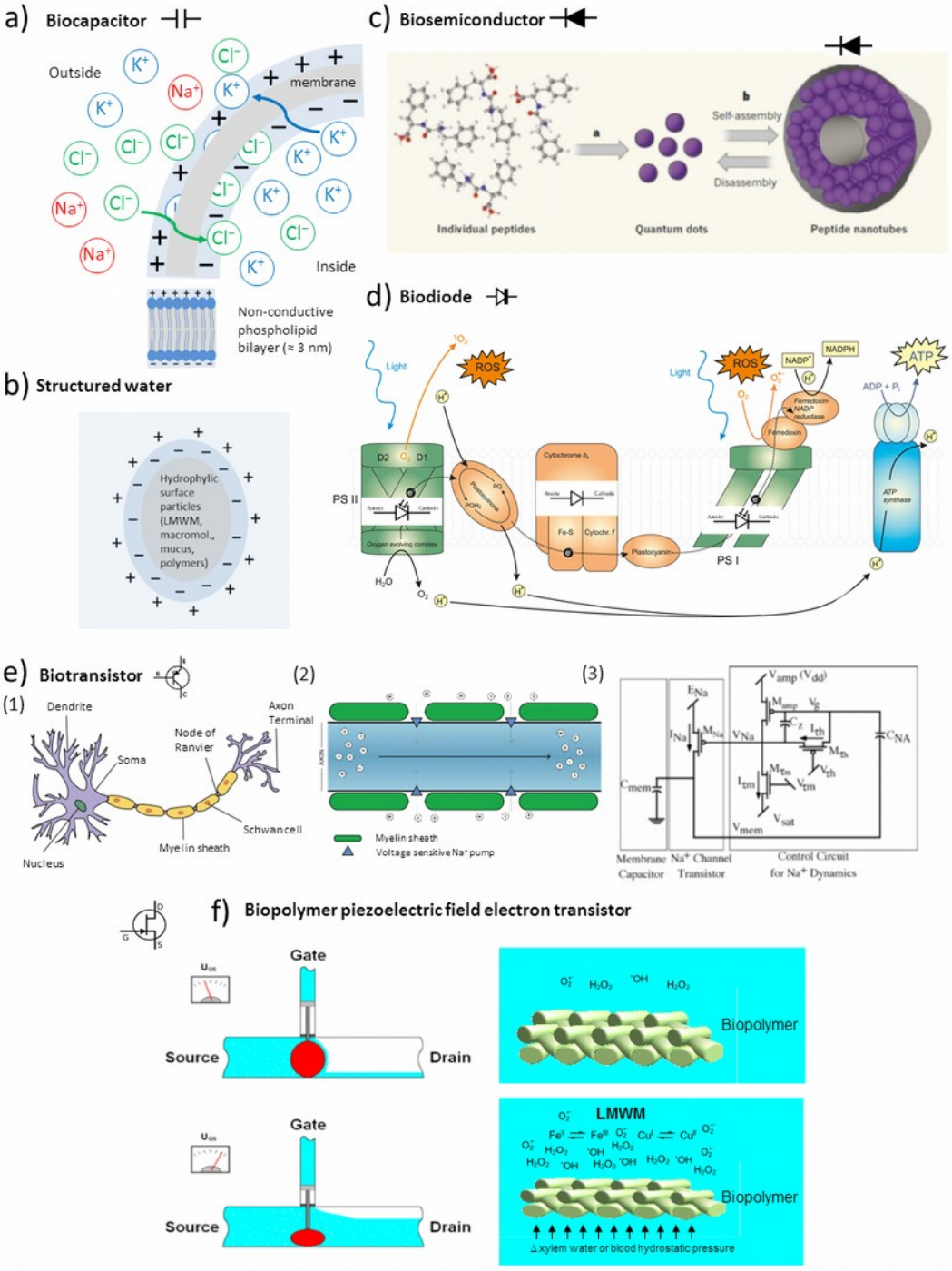
Figure 1. Techniques for measuring electrical signals in plants. (a) Extracellular recording with four channels and a reference electrode inserted in the soil. ±, electrical stimulation. An AP (right) generated by electrical stimulation appeared successively at electrodes 1, 2, 3 and 4. (b) Intracellular measurement of the membrane potential with a microelectrode inserted into the cytoplasm of an algal cell while the reference electrode is in contact with the artificial pond water (APW) outside the cell. Both electrodes are filled with KCl, clamped in Ag/AgCl pellet holders and connected to an electrometer. (c) Phloem potential measurements; an aphid in feeding position with its stylet inserted into a sieve element on the upper side of a leaf. (d) After the aphid is separated from its stylet by a laser pulse, the stylet stump exuded sieve tube sap to which the tip of a microelectrode was attached. Cooling the shoot evoked an AP transmitted acropetally within the phloem, while flaming of a leaf generated a VP with different form and of long duration. t, time.

Donnan Potential

Some ionic species can pass through the barrier while others cannot. The solutions may be gels or colloids as well as solutions of electrolytes, and as such the phase boundary between gels, or a gel and a liquid, can also act as a selective barrier. The electric potential arising between two such solutions is called the Donnan potential.



Bioelectronics



REVIEW ARTICLE

Front. Environ. Sci., 04 March 2015 | http://dx.doi.org/10.3389/fenvs.2015.00012

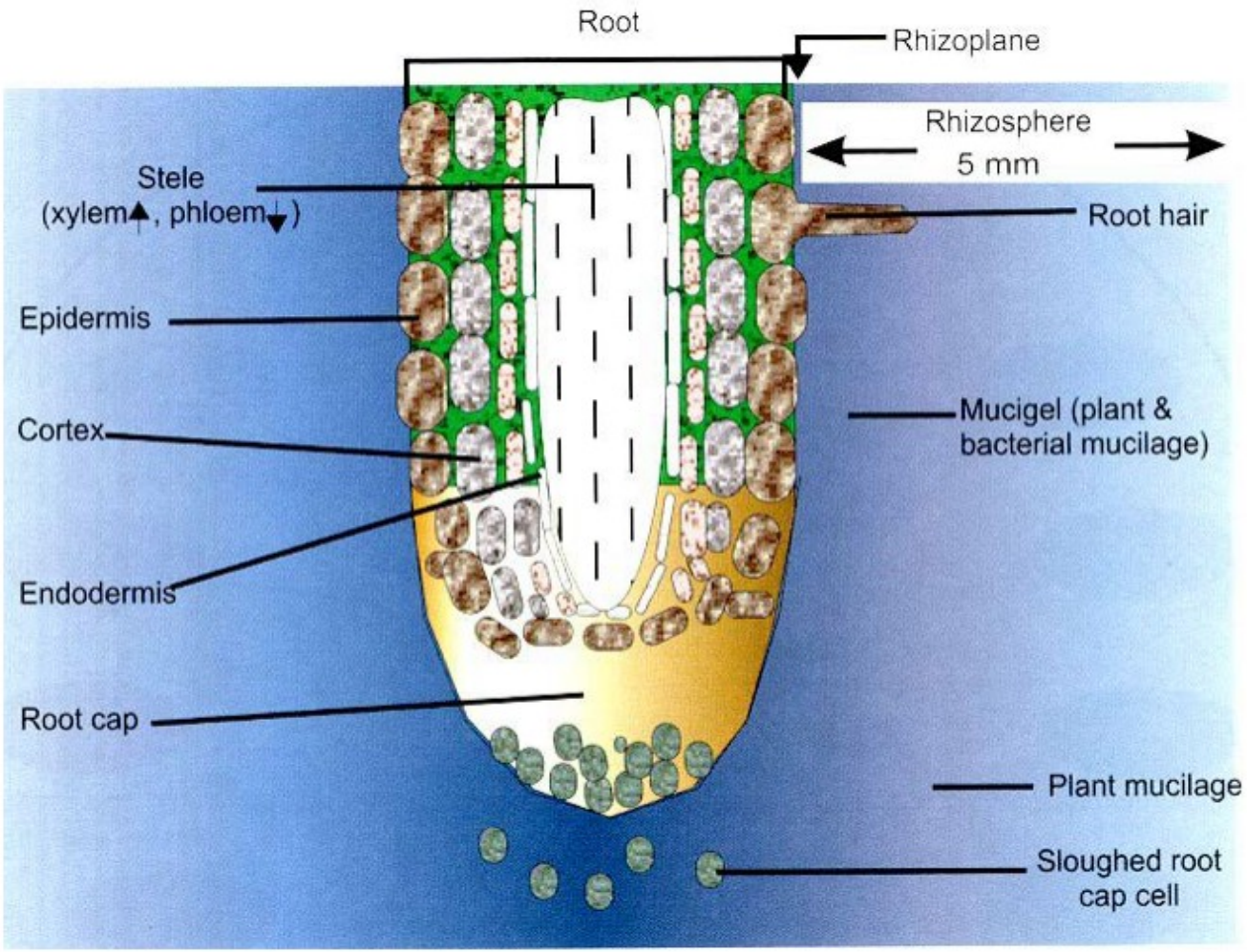
Low-molecular-weight metabolite systems chemistry

 **Franz Hadacek**[1*] and  **Gert Bachmann**[2]

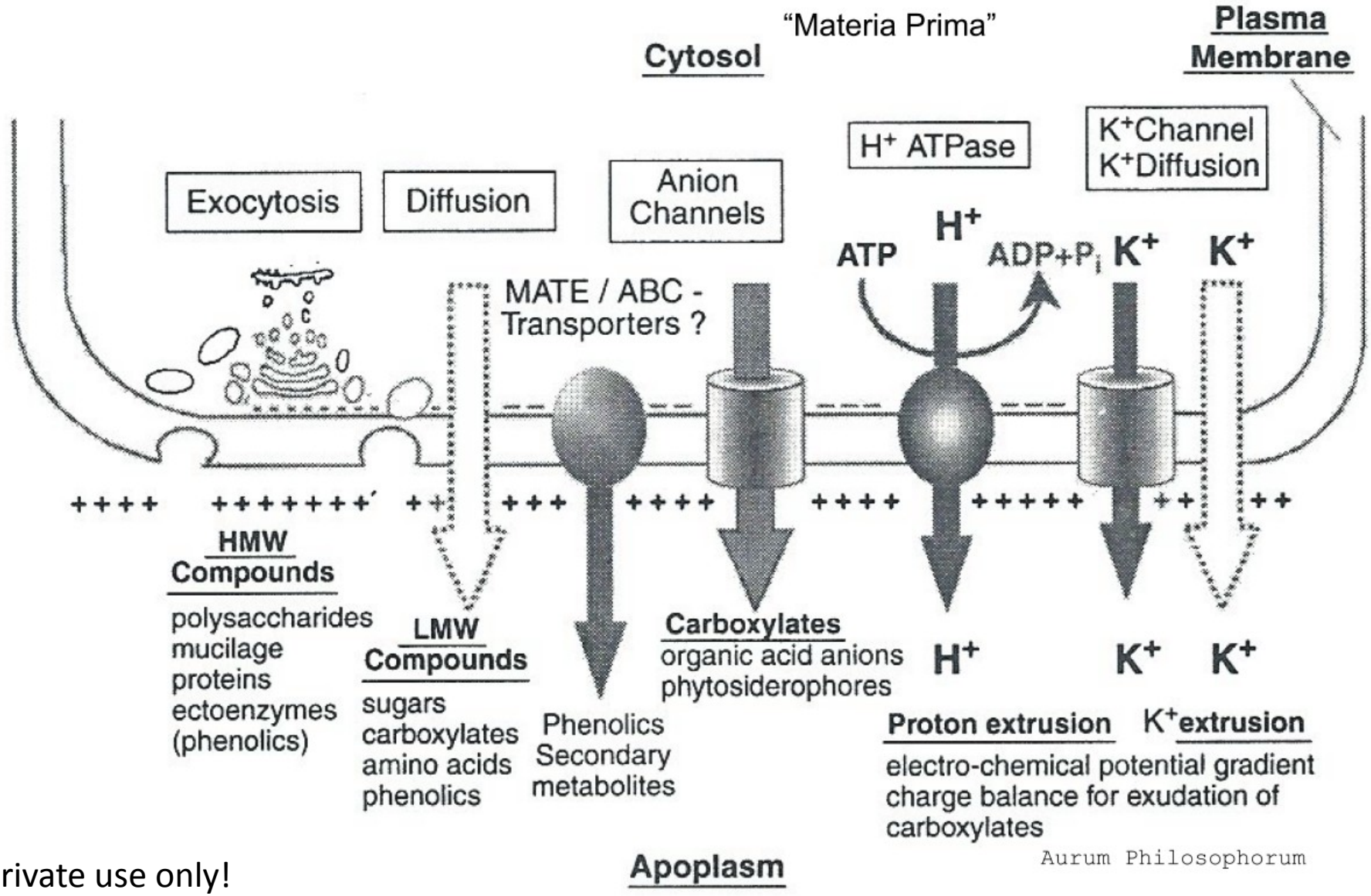
[1]Plant Biochemistry, Faculty of Biology and Psychology, Albrecht-von-Haller Institut, Georg-August Universität, Göttingen, Germany

[2]Molecular Systems Biology, Ecogenomics and Systems Biology, Faculty of Life Sciences, Universität Wien, Vienna, Austria

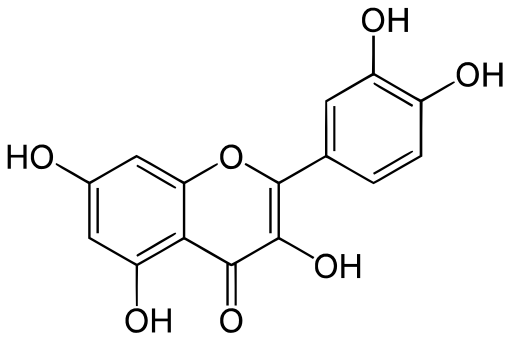
Root Exudation



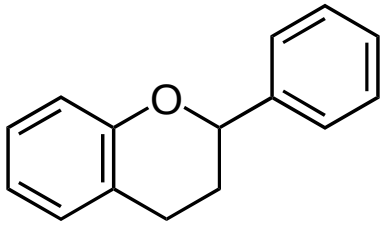
Root Exudates



Root Exudates: Flavonoides

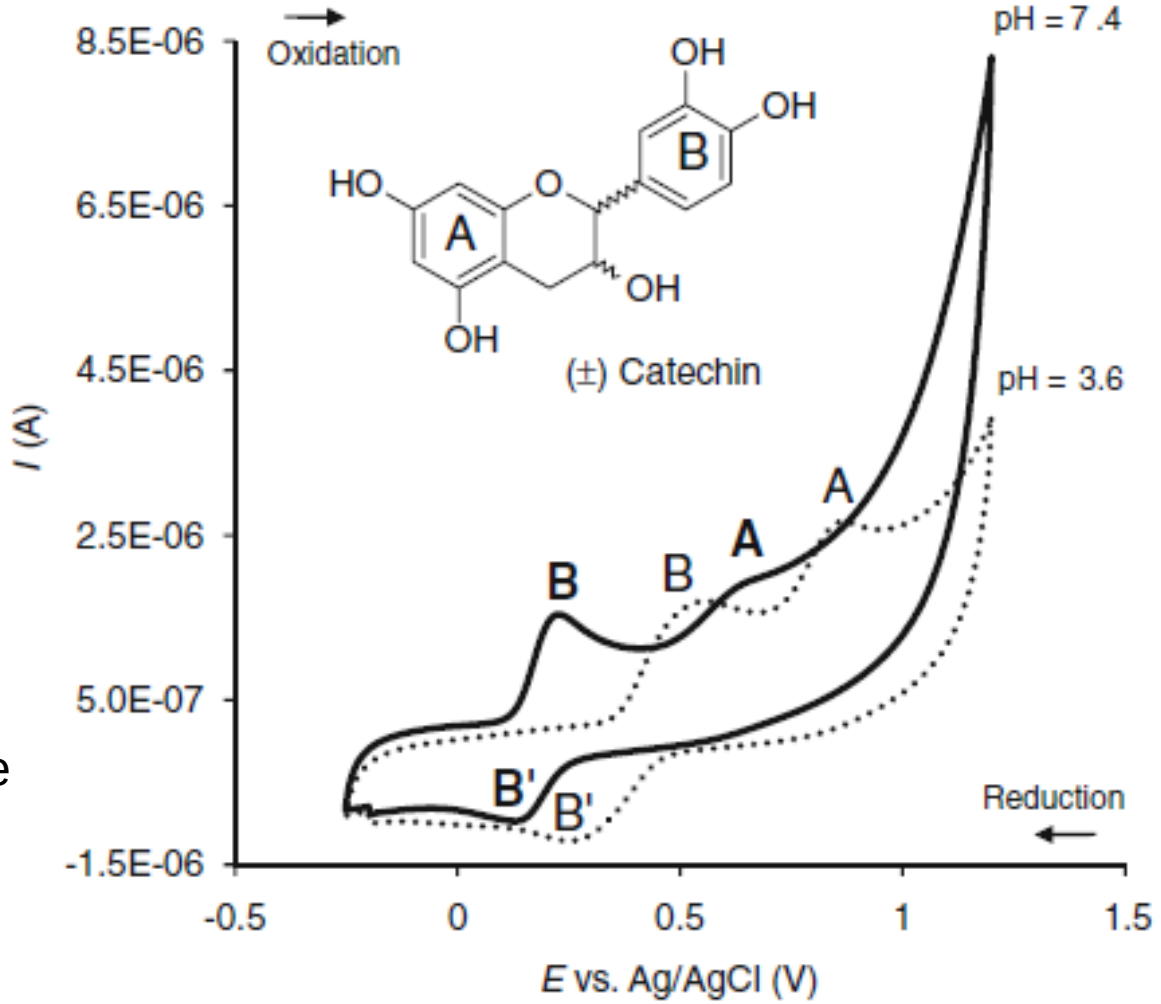


Quercitin



Flavonoid basic structure

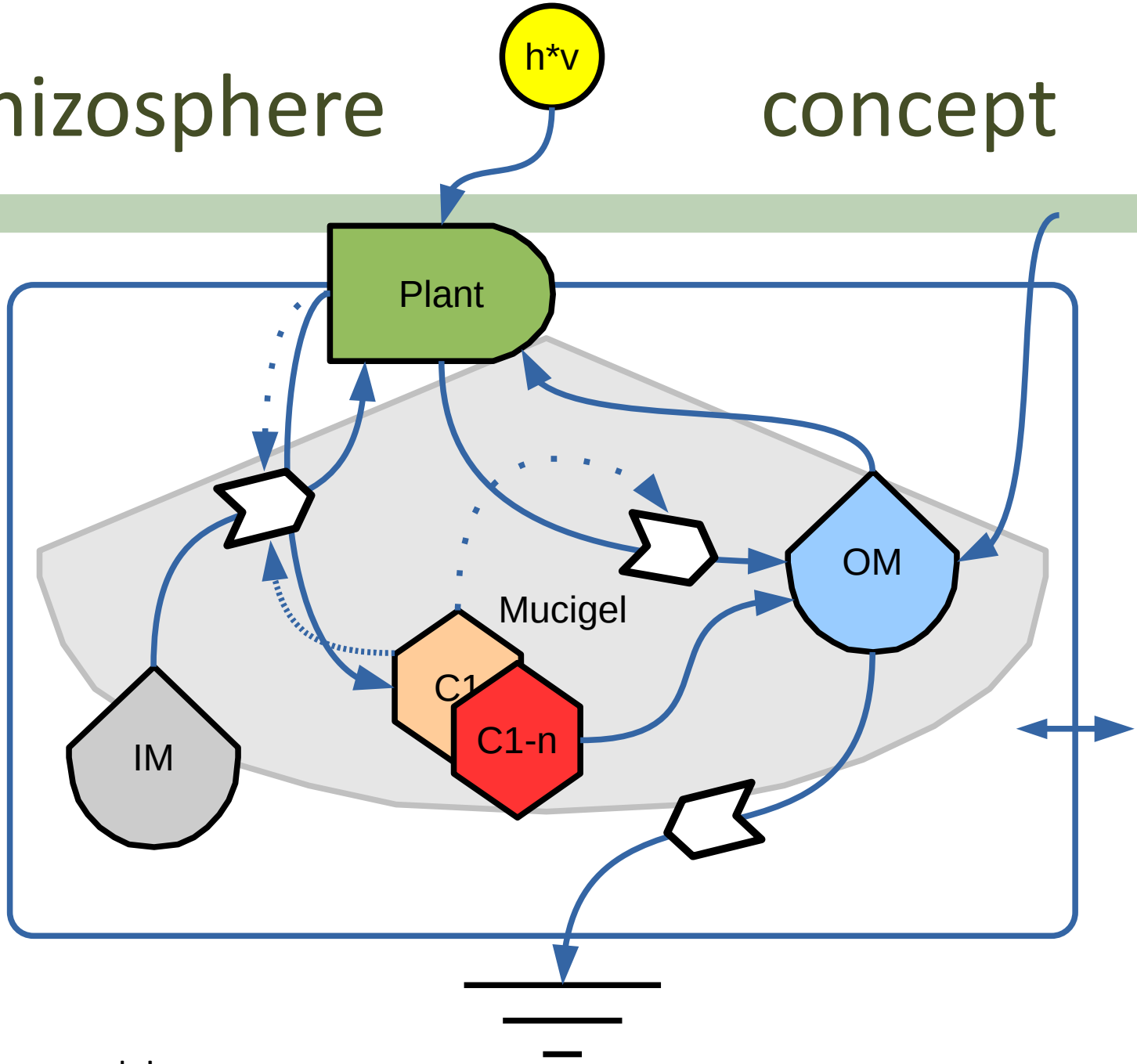
Chobot et al. 2009



Proteoid Clusters

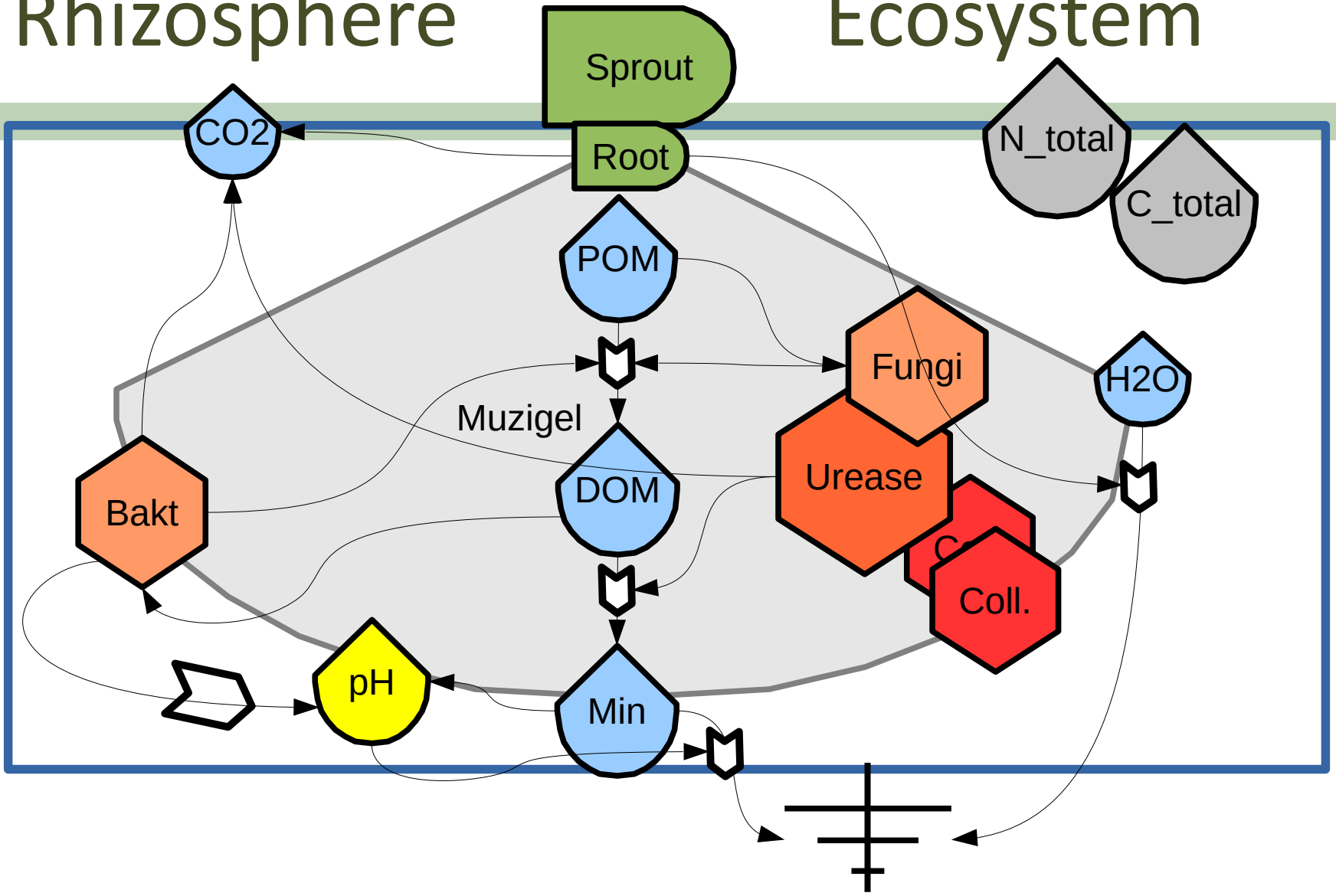
Proteoid roots, also known as cluster roots, are plant roots that form clusters of closely spaced short lateral rootlets.
They may form a two- to five-centimetre-thick mat just beneath the leaf litter.
They enhance nutrient uptake by chemically modifying the soil environment to improve nutrient solubilisation (citrate, flavonoids...)
As a result, plants with proteoid roots can grow in soil that is very low in nutrients.

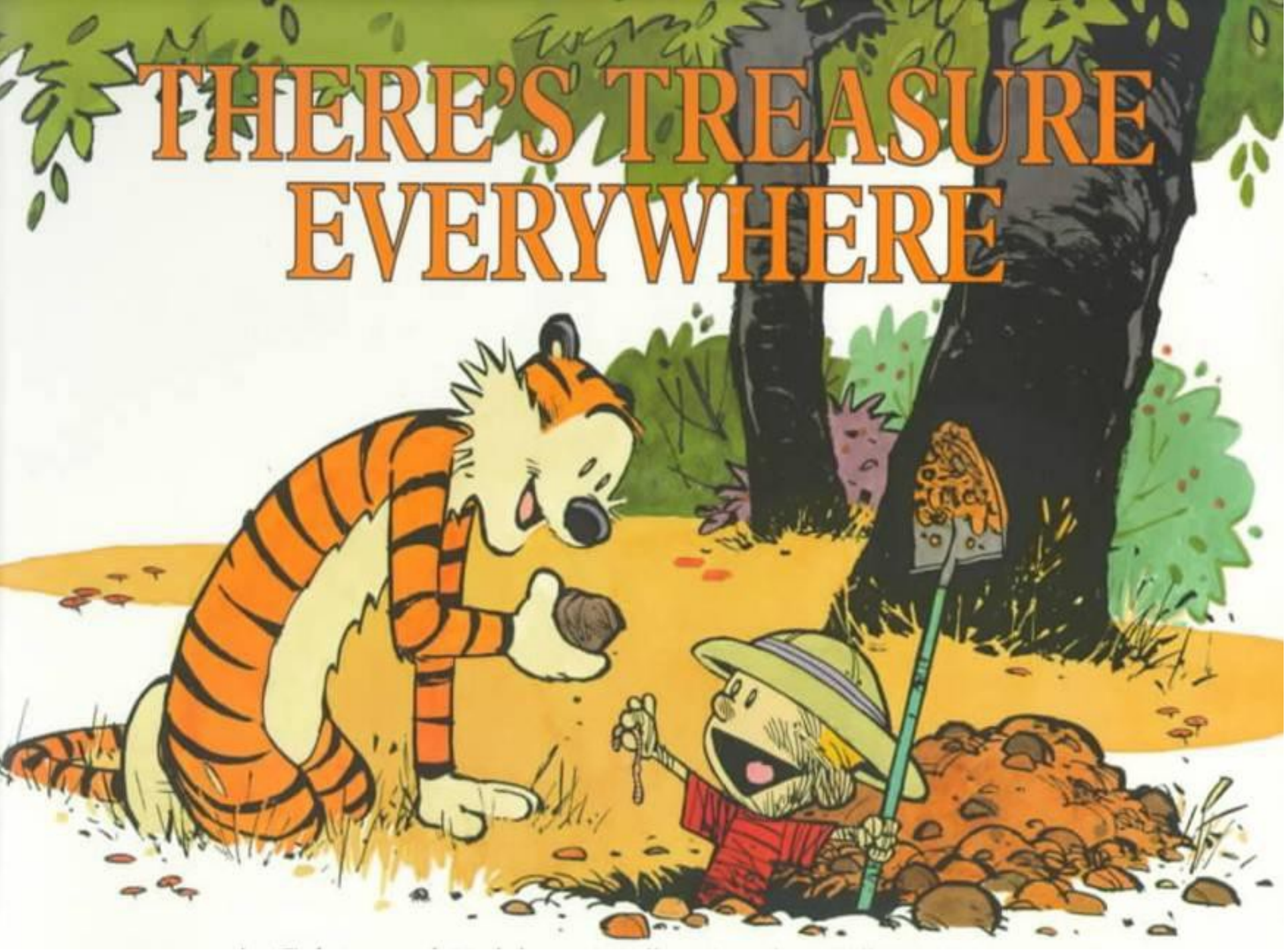
Rhizosphere concept



Rhizosphere

Ecosystem




THERE'S TREASURE
EVERYWHERE

Bioelectricity in Photosynthesis