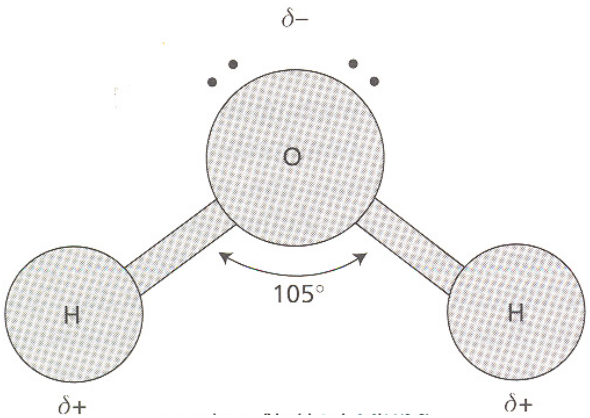
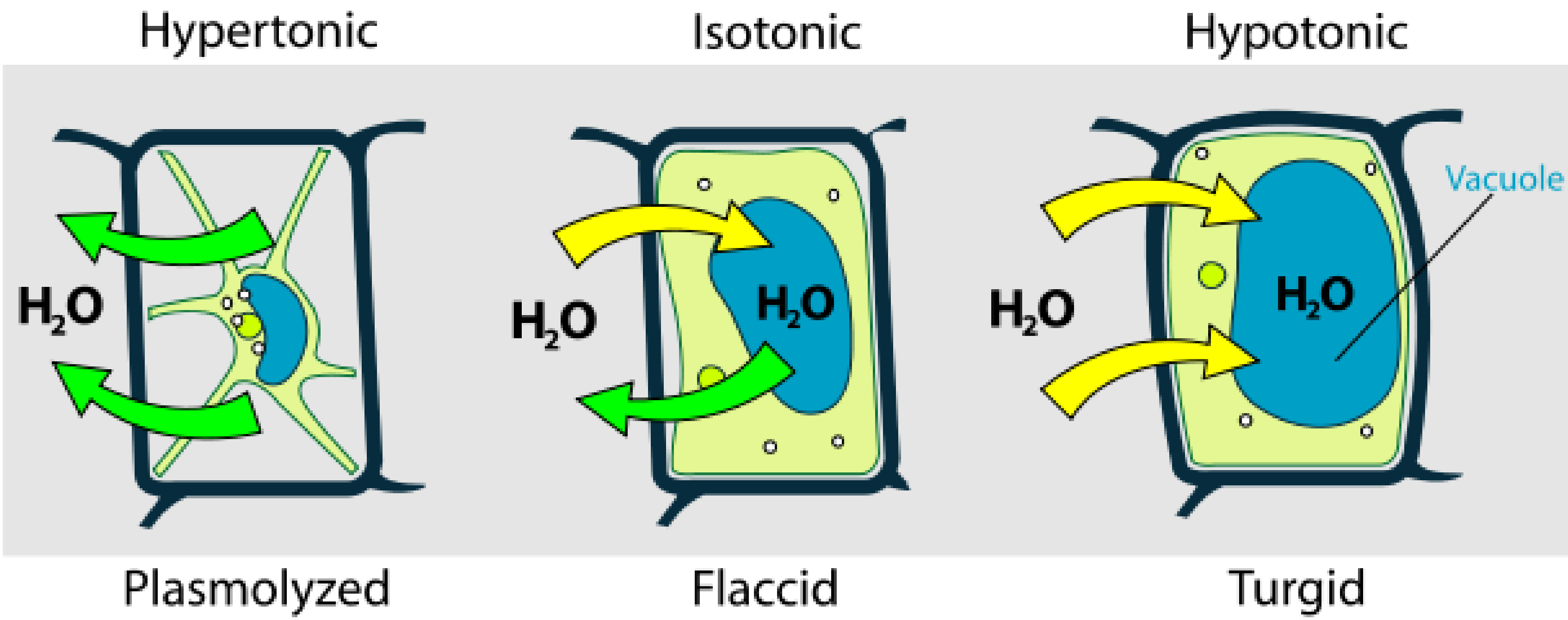
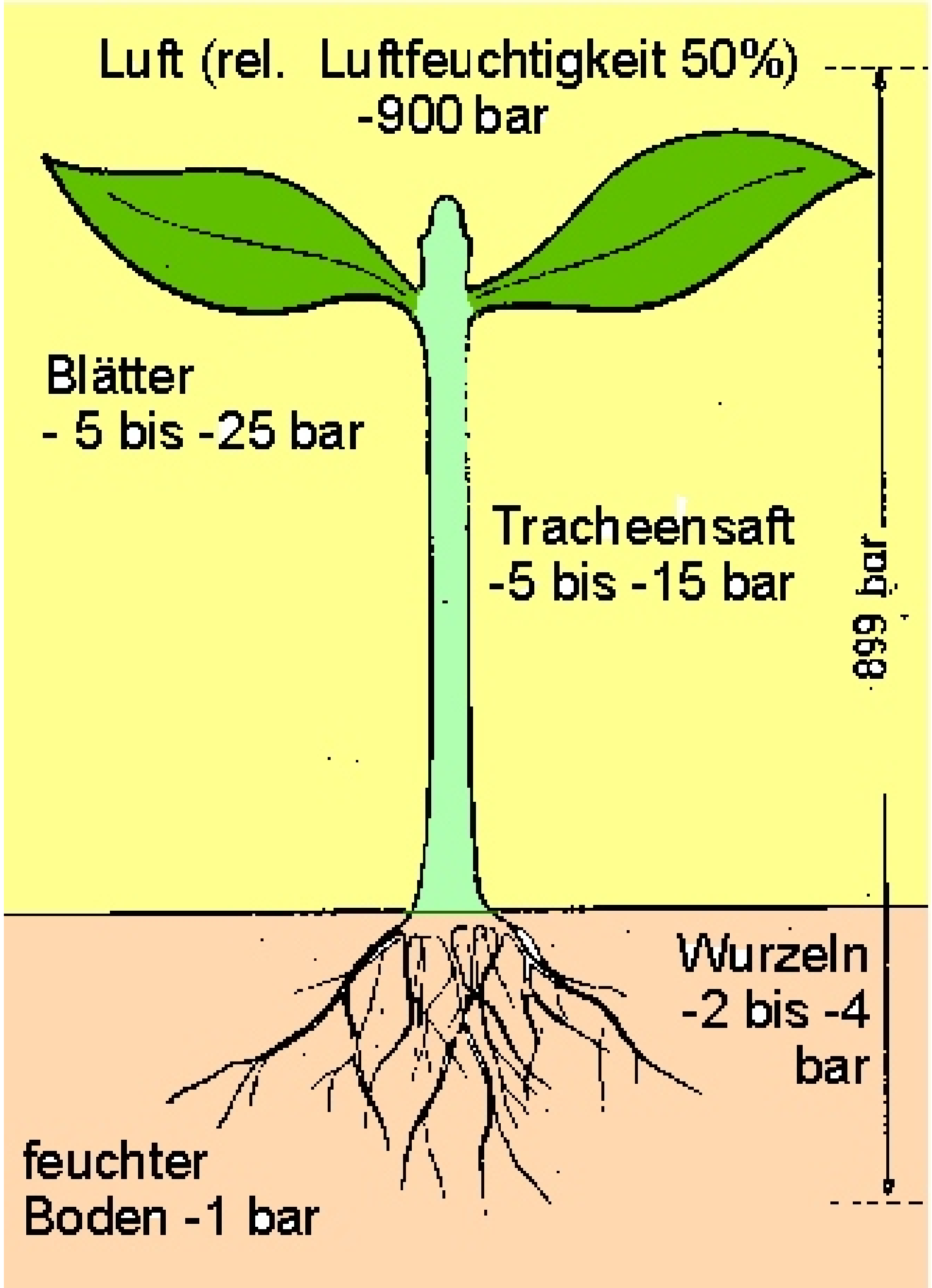
Life on earth depends on water



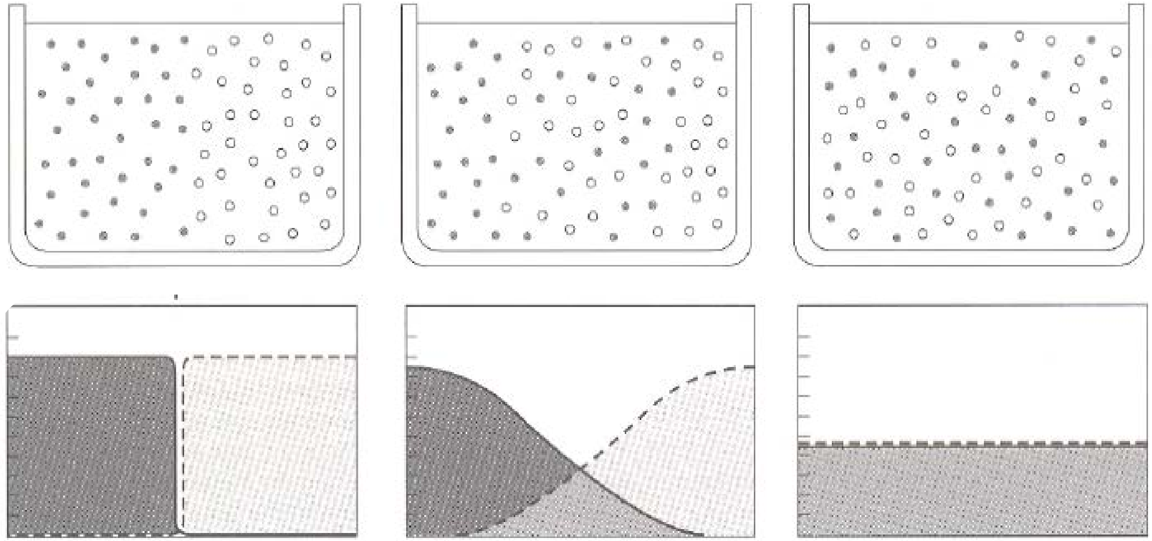
- Water content of plants > 85-95%
- Liquid on earth
- high dipol
- hydration
- cohesion
- adhesion

- proton gradients accross membranes, compartimentation
- pH gradients
- hydrolysis, polymerisation

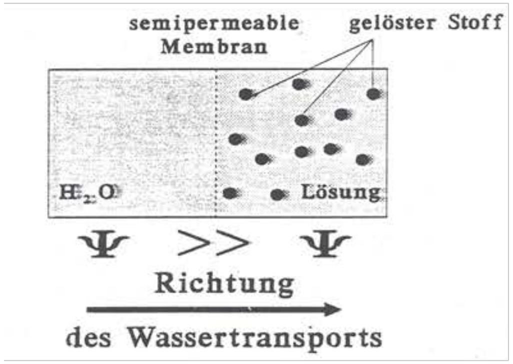

Hypertonic
Isotonic
Hypotonic
H_2O
H_2O
H_2O
H_2O
H_2O
Vacuole
Plasmolyzed
Flaccid
Turgid

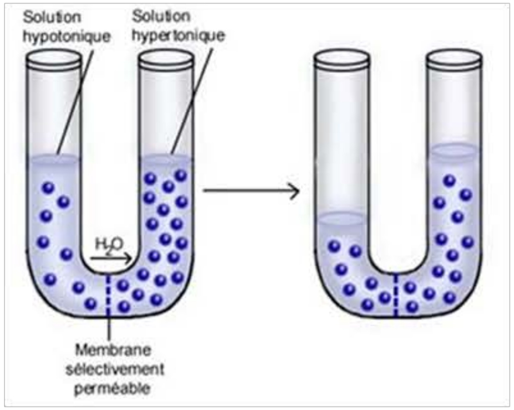

Luft (rel. Luftfeuchtigkeit 50%)
-900 bar
Blätter
- 5 bis -25 bar
Tracheensaft
-5 bis -15 bar
899 bar
Wurzeln
-2 bis -4
bar
feuchter
Boden -1 bar

Diffusion

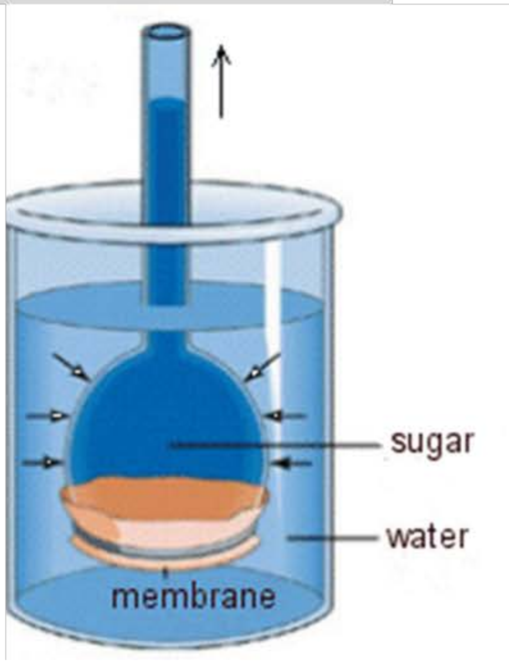


Osmosis – diffusion through semipermeable membrane

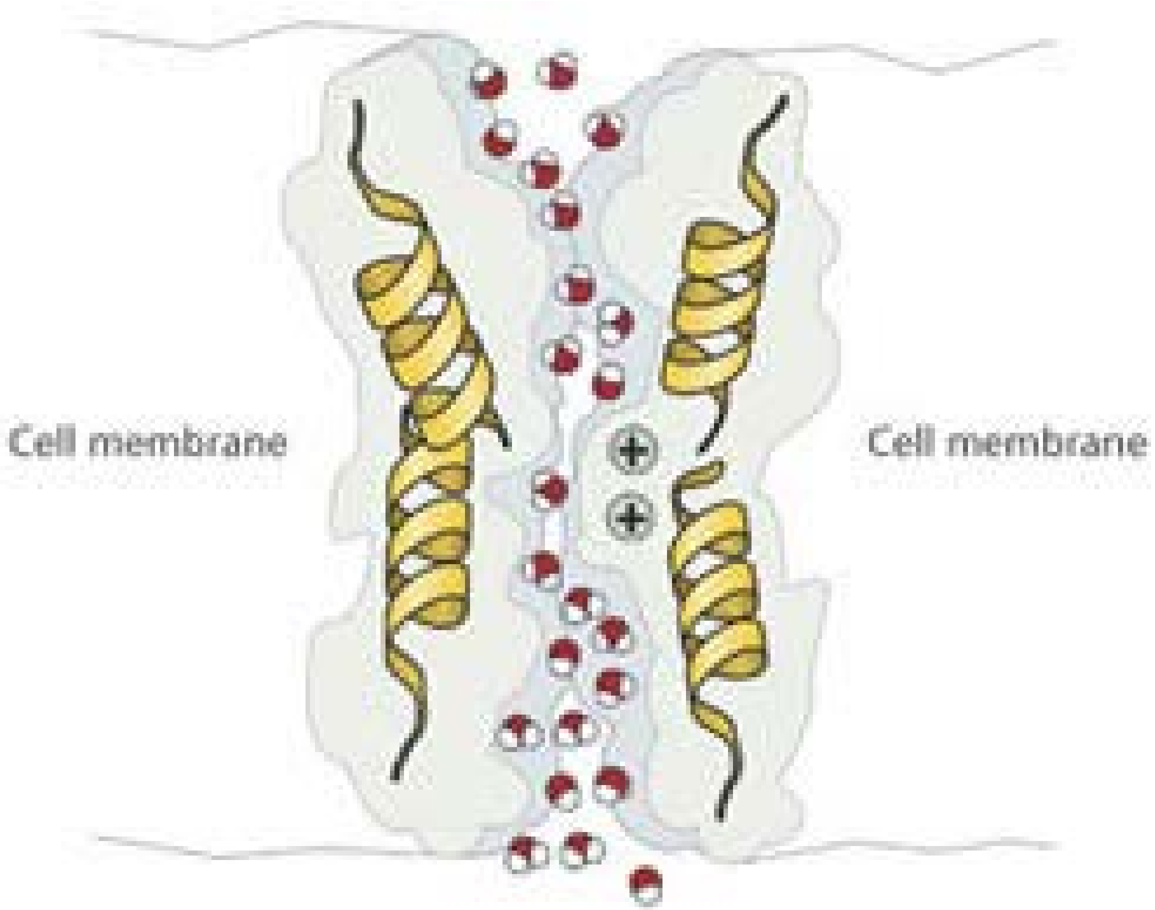




Osmotic pressure / potential



Aquaporins



Water uptake

Capilary Kapilarwasser – Wurzelhaare – Wurzel – Leitgewebe – Blätter

Quellung der Wurzelwand

apoplastischer Transport *versus* symplastischer Transport

Aufnahme ins Cytoplasma der Wurzelhaare

Verteilung in Rhizodermisgewebe

Casparischer Streifen

Endodermis – Zentralzylinder

z. T. aktiver Transport, Aquaporine, Oocytenexperiment

Wurzeldruck (Dekapitierungsexperiment)

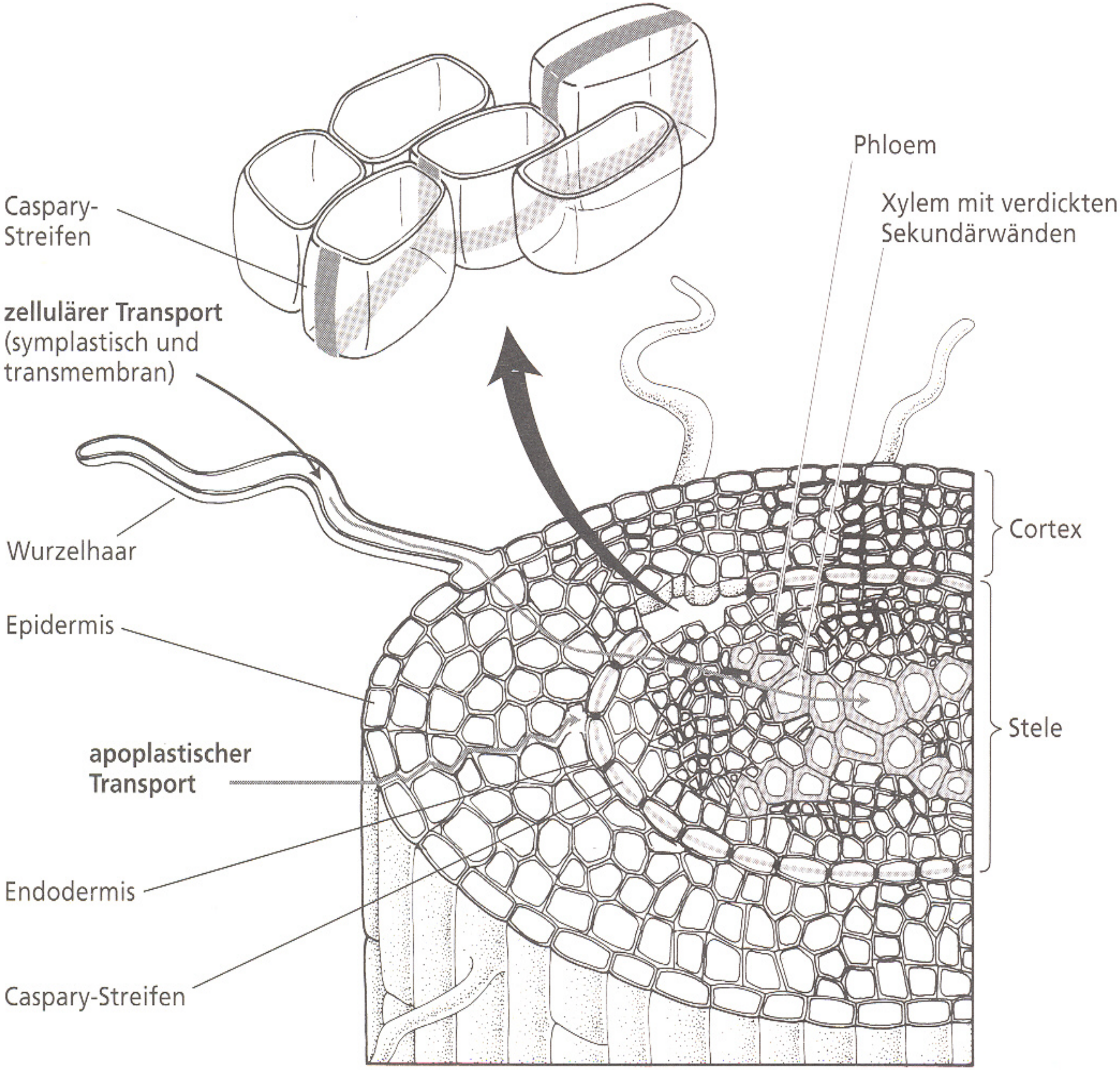
Xylemtransport, Kohäsion, Adhäsion

Max. Baumhöhe 130 m

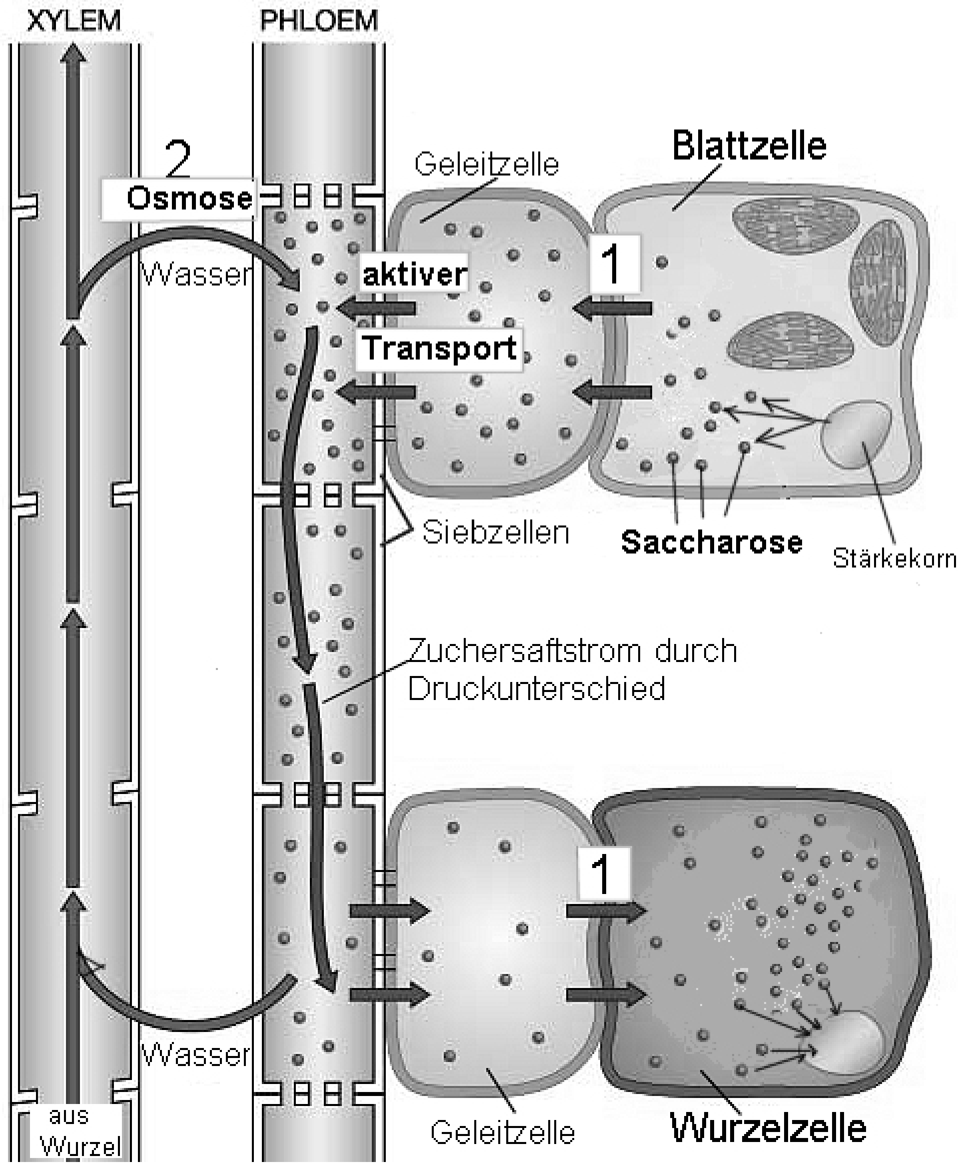
Verletzung des Xylems: Reparatur oder Toxizität

Suberin-Einlagerung im **Casparischen Streifen**

(in der Endodermis)



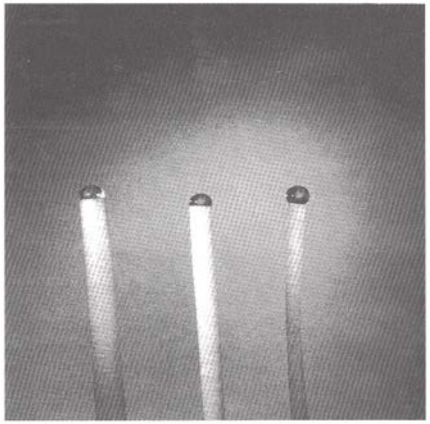
4.4 Wasseraufnahmewege der Wurzel. Durch den Cortex gelangt Wasser sowohl über den apoplastischen als auch über den zellulären Transportweg, welcher den transmembranen und den symplastischen Transportweg umfaßt. Im Symplasten strömt Wasser über die Plasmodesmen von einer Zelle in die nächste, ohne die Plasmamembran zu durchqueren. Beim transmembranen Transport passiert es zunächst die Zellwand und dann die Plasmamembran. An der Endodermis wird der apoplastische Transport vom Caspary-Streifen unterbrochen.


XYLEM
PHLOEM
2
Osmose
Wasser
aktiver
Transport
Geleitzelle
Blattzelle
1
Siebzellen
Saccharose
Stärkekorn
Zuchersaftstrom durch
Druckunterschied
1
Wasser
aus
Wurzel
Geleitzelle
Wurzelzelle

Water transport is based on …

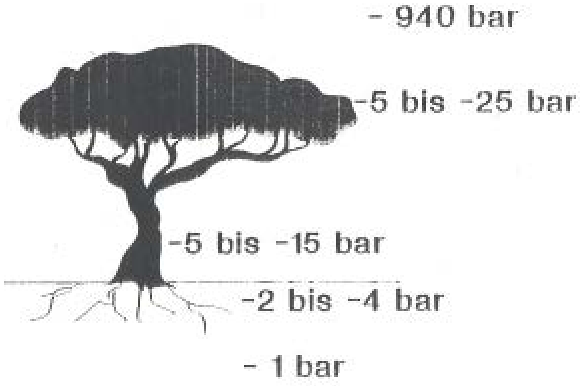
Root Pressure

osmotic pressure within the root cells that causes sap to rise

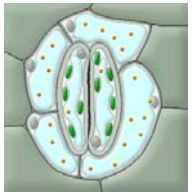


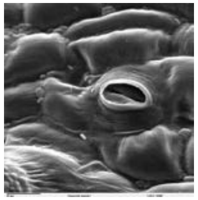
Transpiration

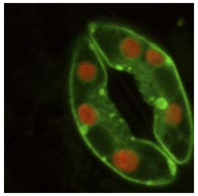
cuticular (10%)
stomata (90%)



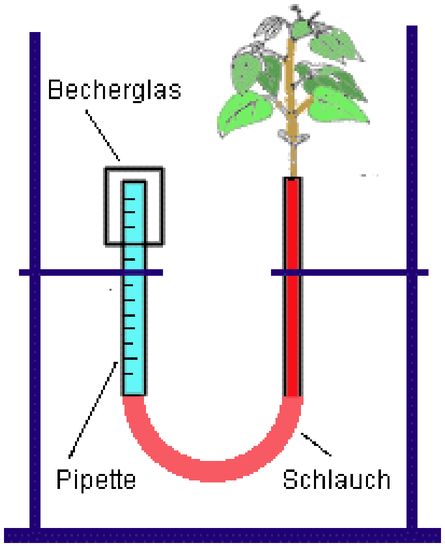
Increase in osmotic pressure: stomata opening

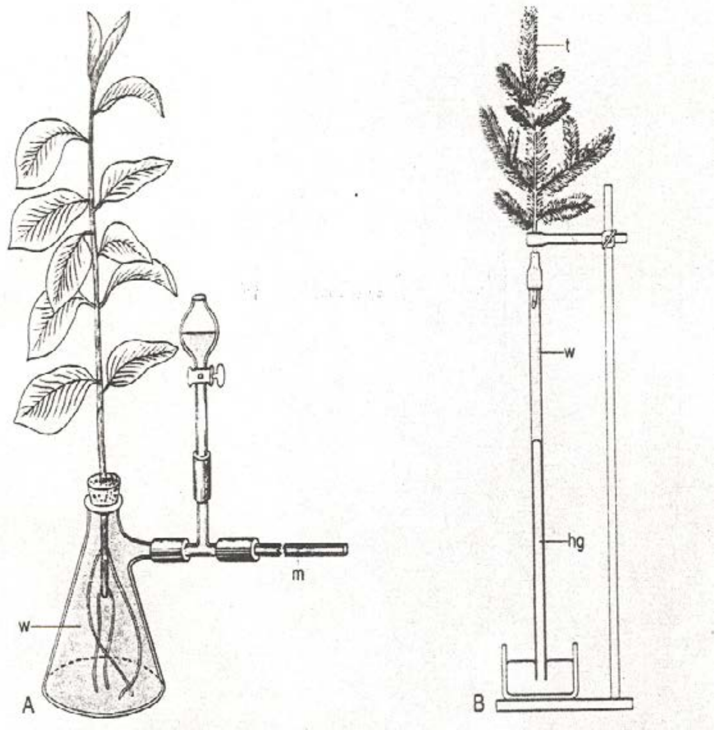






Potometer





Ions

growth, storage (e.g. vacuole), complex formation, secretion (cell wall)

macro-, microelements

active/passive uptake

essentail ions: e.g.

Ca, Na, Fe, Mn, Zn, Cu, NO_3^-, Mg, PO_4^{3-}, SO_4^{2-}, B, Mb

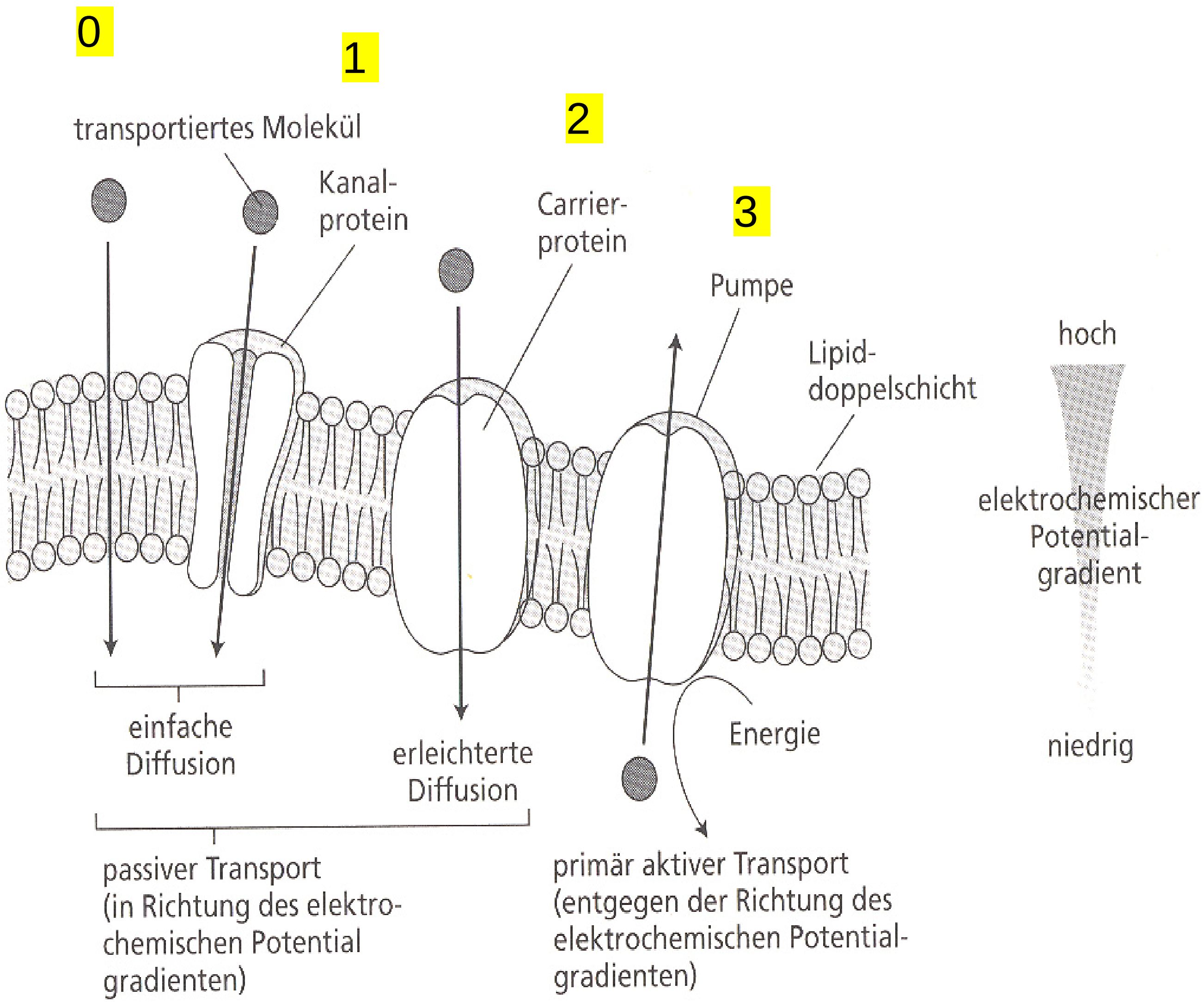
toxic heavy metal ions

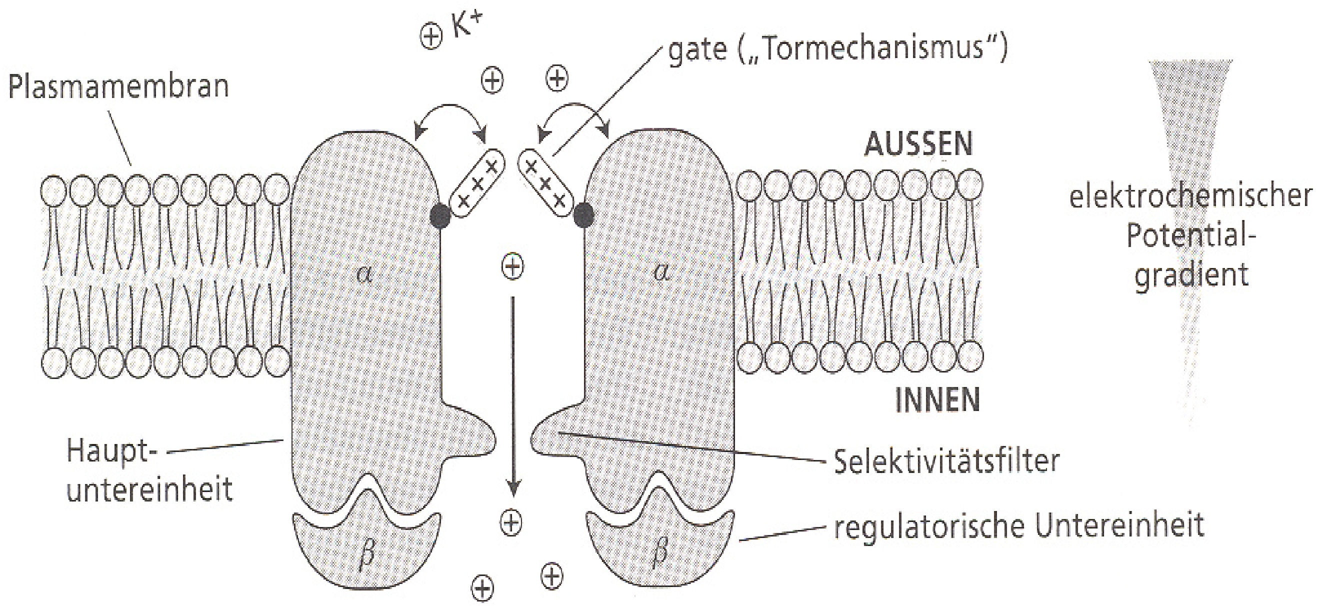
Cd, Hg, *etc.*

control of uptake:

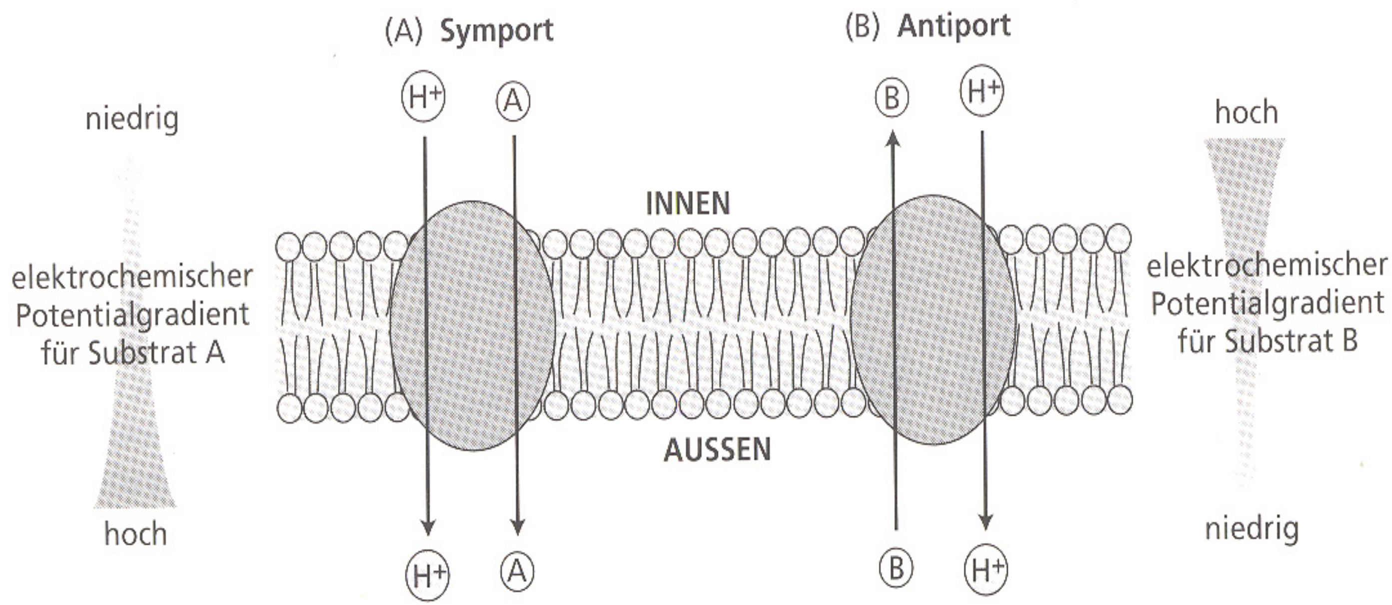
concentration gradients, transporter

Transport mechanisms



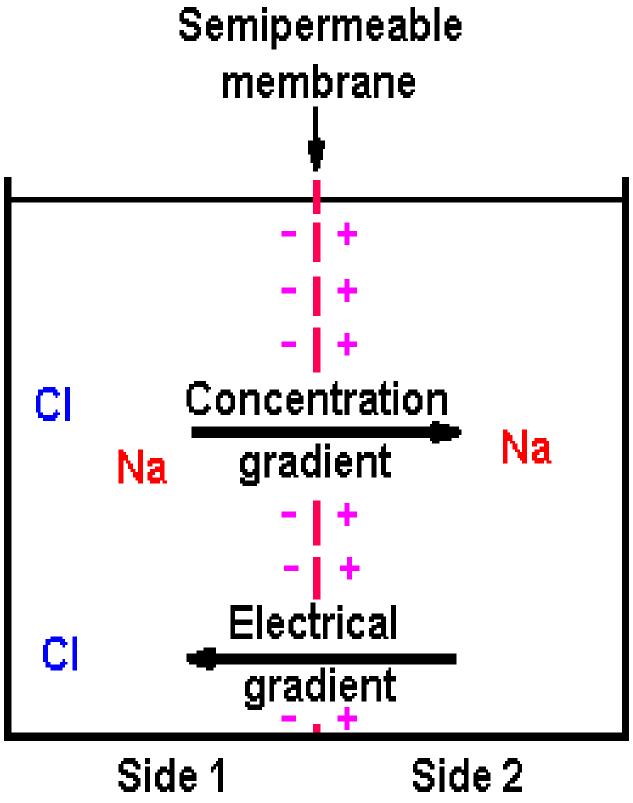


6.8 Modell eines spannungsabhängigen (*voltage-gated*) K^+-Kanals in einer Pflanze. Der Kanal selbst besteht aus einem Tetramer der Hauptuntereinheit (α), die den Selektivitätsfilter und den „Tormechanismus“ (*voltage gate*) enthält. Die Sequenz, die für den Tormechanismus verantwortlich ist, besteht aus einer Gruppe von basischen Aminosäuren, von denen die positive Ladung stammt. Als Reaktion auf Änderungen des Membranpotentials öffnet oder schließt der Tormechanismus den Kanal. Es können auch regulatorische β-Untereinheiten vorkommen.



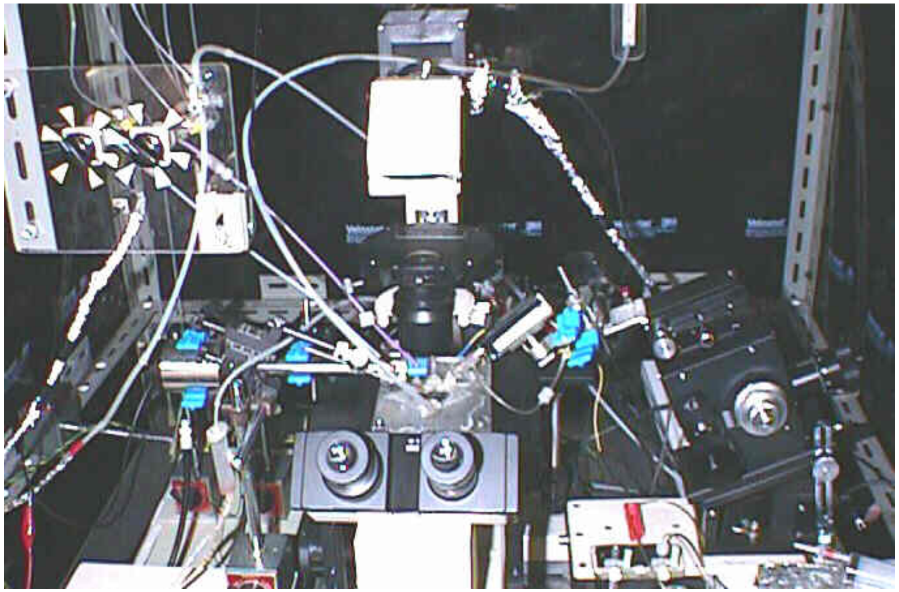
6.10 Zwei Beispiele für einen sekundär aktiven Transport, der an einen Protonengradienten gekoppelt ist. (A) Bei einem Symport wird die Energie, die bei dem Rückfluß des Protons in die Zelle freigesetzt wird, an die Aufnahme eines Substratmoleküls, z. B. eines Zuckers, in die Zelle gekoppelt. (B) Bei einem Antiport wird die Energie, die bei dem Rückfluß des Protons in die Zelle freigesetzt wird, an den aktiven Transport eines Substrats, z. B. eines Natriumions, aus der Zelle gekoppelt. In beiden Fällen bewegt sich das betreffende Substrat entgegen seinem elektrochemischen Potentialgradienten. Sowohl neutrale als auch geladene Substrate können mit Hilfe solcher sekundär aktiven Transportprozesse transportiert werden.

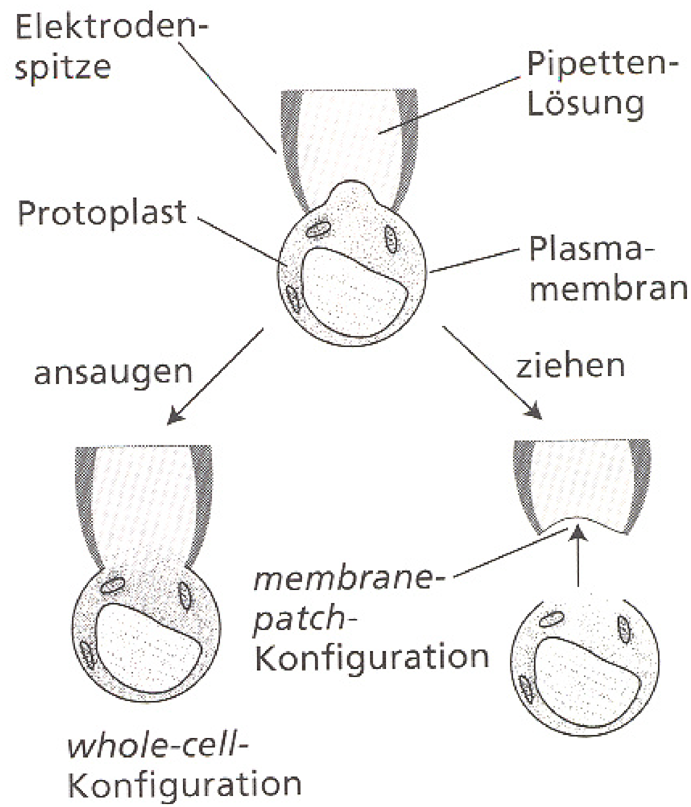
Electrochemical gradients



Electrochemical equilibrium develops in which the Na^+ concentration gradient, indicated by the upper arrow, is just balanced by the elctrical gradient, indicated by the lower arrow. At this point, there is no net flux of Na^+ to either side.

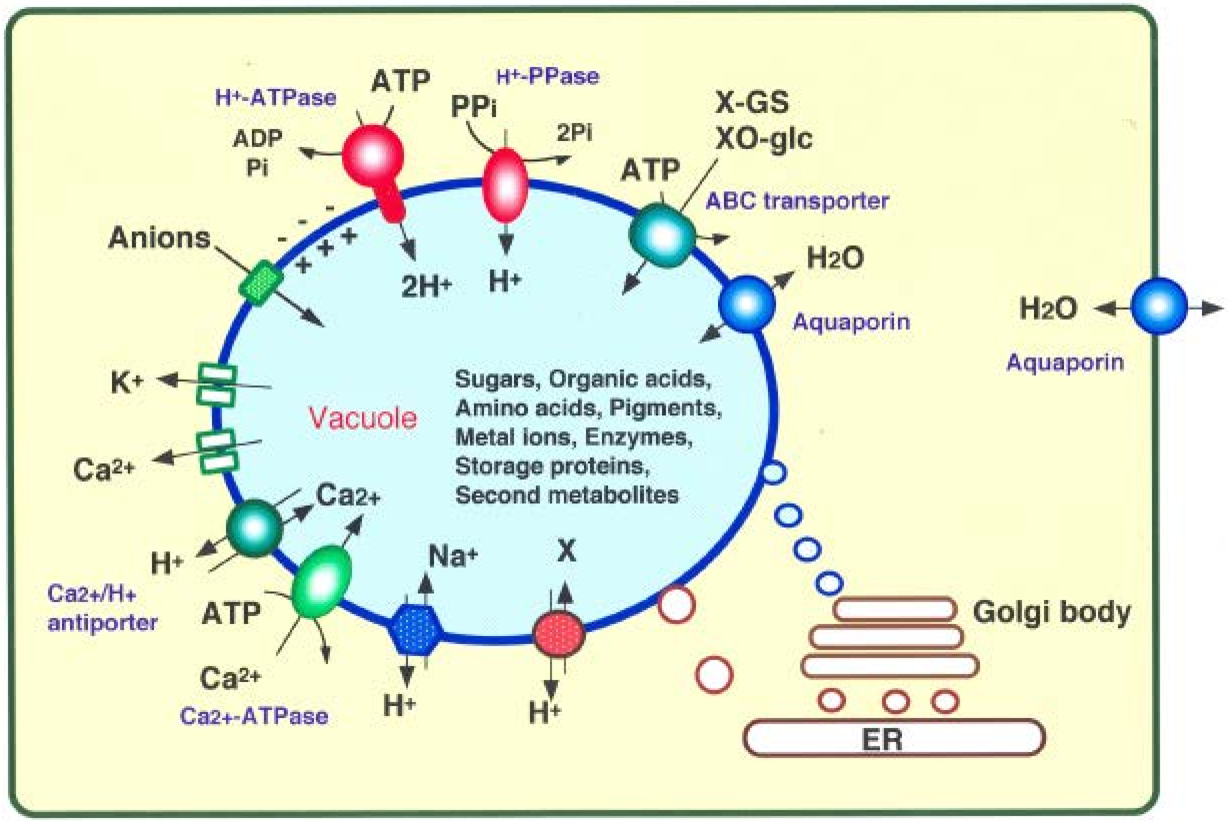
Patch clamp





Elektroden-
spitze
Pipetten-
Lösung
Protoplast
Plasma-
membran
ansaugen
ziehen
membrane-
patch-
Konfiguration
whole-cell-
Konfiguration

Transporters and Channels on Plant Vacuolar Membrane



Identification and characterization of plant transporters by yeast complementation

Yeast transporter mutant
Transformation with plant cDNA library

Test after transformation into plant

Heavy metal uptake and detoxification

Cd stress

40 metals

6 g/cm^3

- Cd, Cr, Cu, Pb, Ni, Tl, Hg, Zn, As, B, Fe, Mo, Mn, Zn
-Fe, Mo, Mn, Zn = essentiel trace elements

- phytoremediation
(e.g. with transgenic plants)

Resistence strategies:

a. No uptake
b. Storage (vacuole)
c. secretion (cell wall)
d. Complex formation
(metallothionein, phytochelatin, organic compounds)

Resistant plants

a. Excluder
b. Indikator
c. Accumulator

Transporters are not always specific

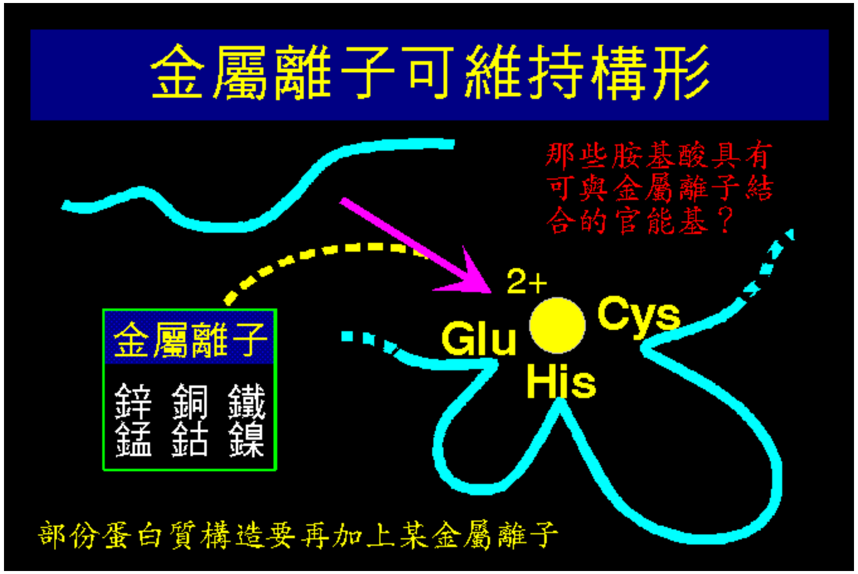
(co-transport of Cd, Zn, Co)

Cu plant from Sambia: Cu-accumulator (+ resistence against As)

Arabidopsis halleri: Cd-accumulator

Metallothionin

- plants and animals
- small proteins with many cyctein residues
- cytoplasma
- complex free metal ions



Phytochelatin

Peptide with 1-6 repetitive gamma-glutamyl-cysteinyl units

- SH groups of cystein bind heavy metals as thiolates

- preference for Cd, Cu, Pb, (Zn)

-

Phytochelatin (PC) synthase

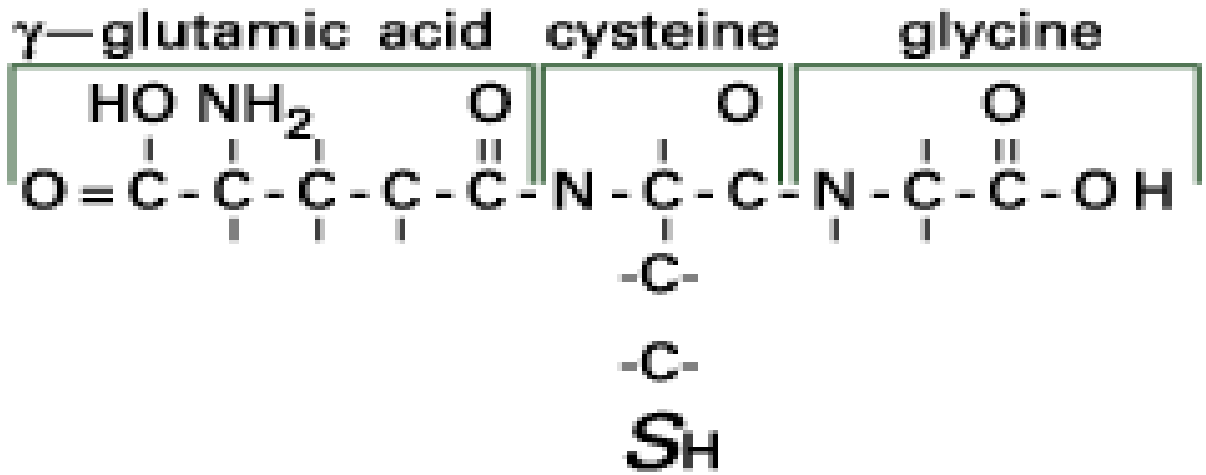
Transfers Glu-Cys-rest onto the tripeptid glutathione

Interesting: posttranslational regulation of PC synthese enzyme

Heavy metals activate PC-synthase activity

Arabidopsis PC-synthase ovrexpressor: heavy metal resistance

Glutathione



Phytochelatin Synthesis

glutathione (n=2-11) *phytochelatin*

n(γ-Glu-Cys-Gly) → $(\gamma\text{-Glu-Cys})_n$ - Gly + m-1Gly

phytochelatin synthase

γ-glutamylcysteine dipeptidyl transpeptidase
(heavy metal activated catalyzing enzyme)

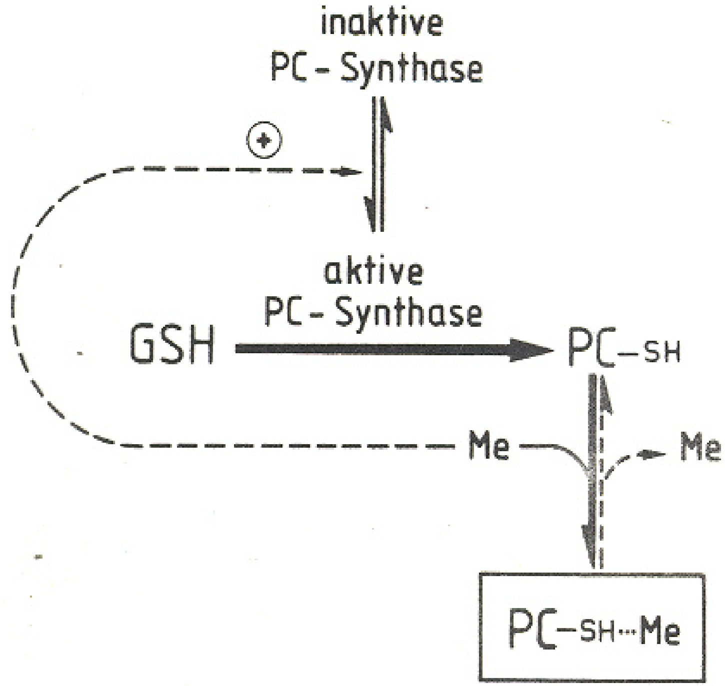
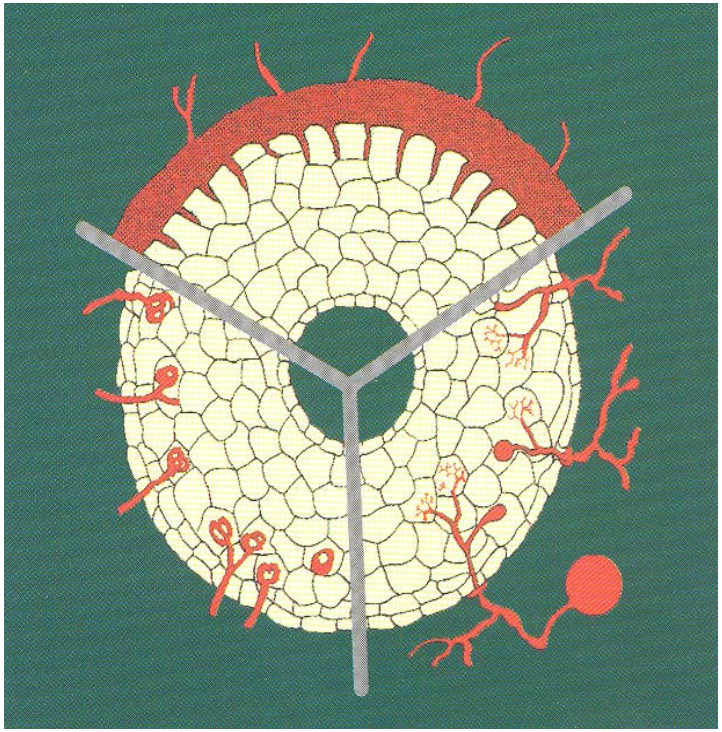


Abb. 15.12. Metabolischer Regelkreis zur Sequestrierung (Ablagerung) von toxischen Schwermetallen durch Komplexierung mit Phytochelatinen (*PC*). Diese cysteinreichen Peptide werden durch Übertragung eines oder mehrerer γ-Glutamylcysteinylreste auf Glutathion (*GSH*) durch eine Transpeptidase (**Phytochelatinsynthase**) gebildet. In Abwesenheit von Schwermetallionen (Me) ist das Enzym inaktiv, wird jedoch durch Cd, Pb, Hg, Cu, Ni, Zn und einige andere Metallionen in einen aktiven Zustand versetzt. Beim Abfall des Pegels an freien Schwermetallionen sinkt die Aktivität des Enzyms wieder ab. Diese Reaktionen spielen sich im Cytoplasma ab. (Nach Grill u. Zenk 1989)

Roots are associated with beneficial microbes

Mycorrhizal fungi

beneficial endphytic fungi and bacteria



Beneficial interaction between plants and microbes

mycorrhiza

“

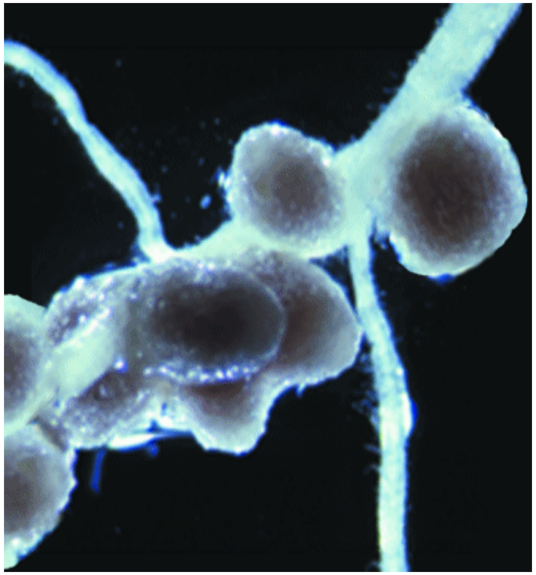
endomycorrhiza
ectomycorrhiza

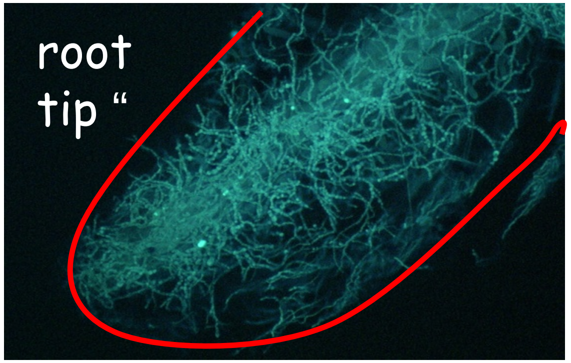
N_2fixing bacteria/ legumes

endophytes

“

bacteria
fungi

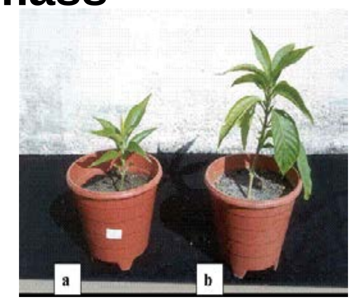




Common feature:
Promotion of plant performance

1. Colonisation of roots

2. Promotion of growth & biomass



3. Resistanz aginst abiotic & biotic stress

drought

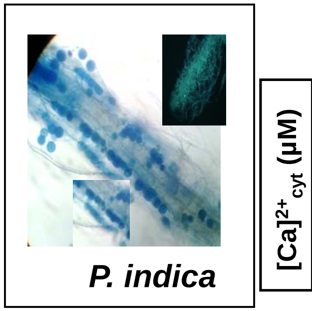
heavy metal

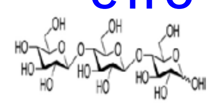
pathogen infection

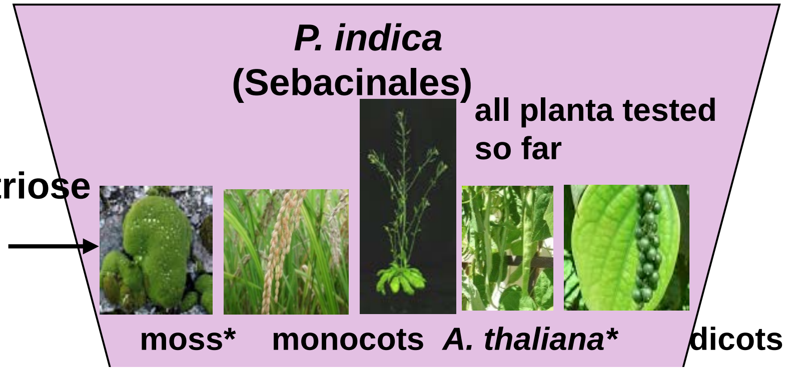
mycorrhial fungi and rhizobacteria
few host plants

endophytes
often colonizes many hosts
important for agriculture
easier recognition mechanisms

microbe	biomolecules	host range







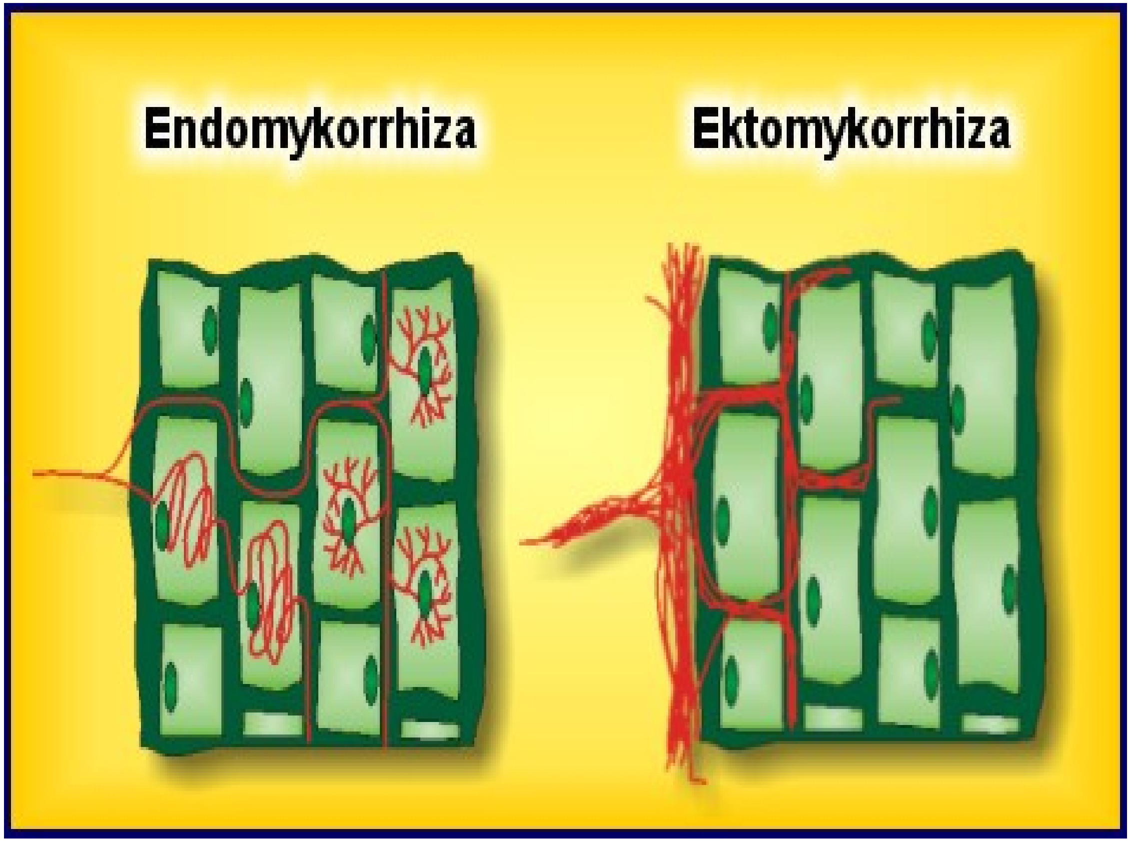
#LCO: lipochitooligosaccharide

Both partners MUST profit from the symbiosis.

Photosynthesis
“
sucrose

water, soil
nutrients,
phosphate,
nitrogen

Two types of mycorrhiza



Beneficial interaction between plants and microbes

mycorrhiza

“

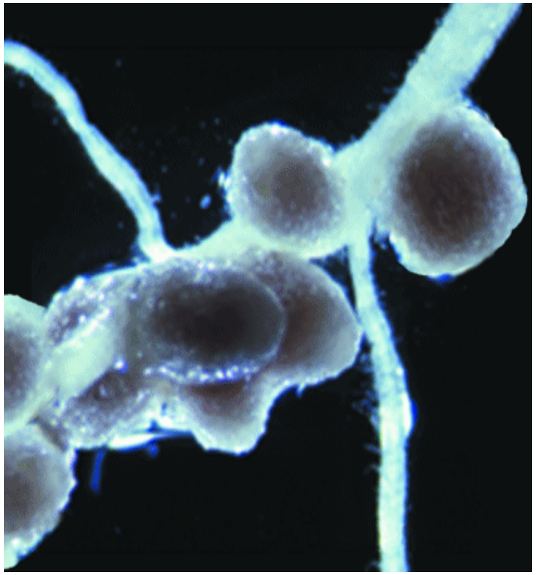
endomycorrhiza
ectomycorrhiza

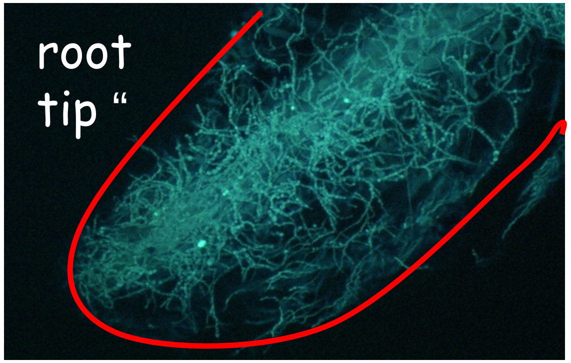
N_2 fixing bacteria/ legumes

endophytes

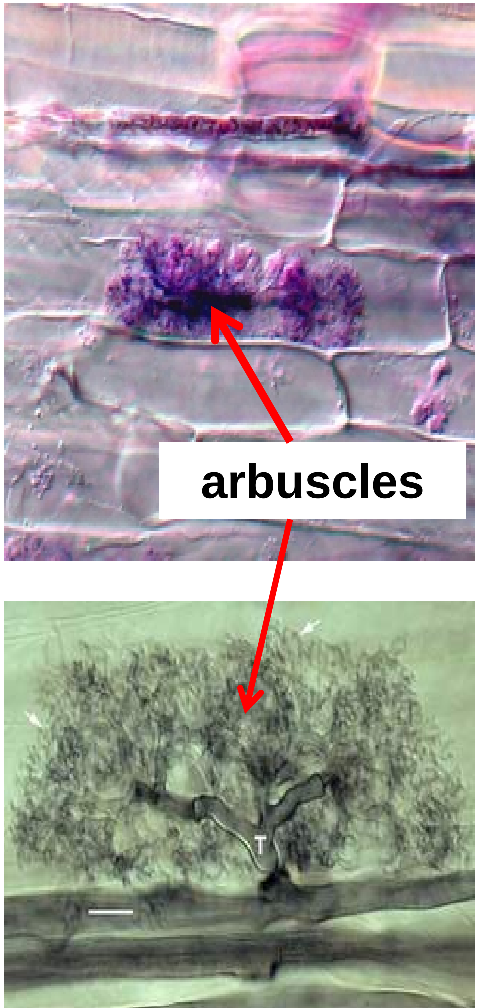
“

bacteria
fungi

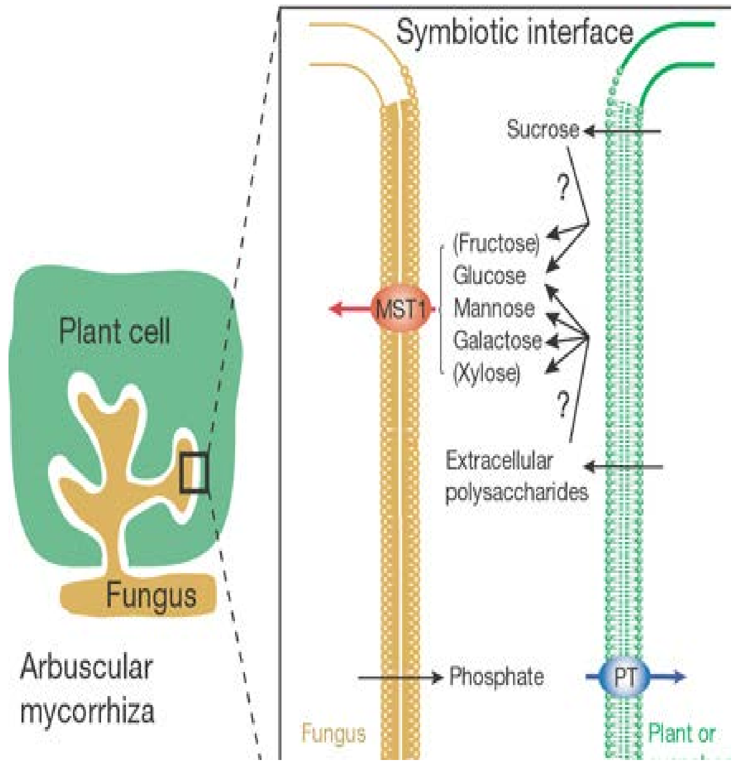




Endomycorrhiza



Fungal and plant cells are COMPLETELY separated.

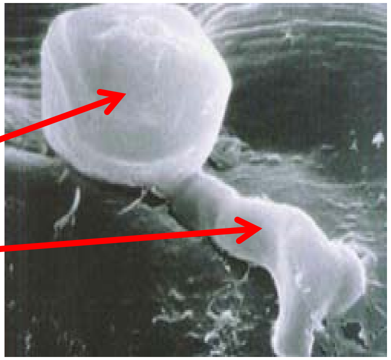


Endomycorrhiza

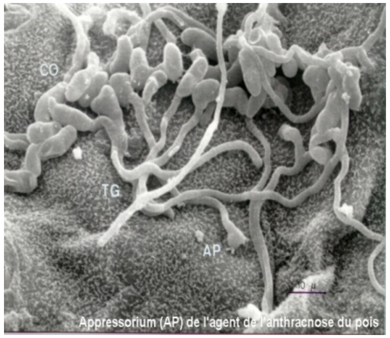
- 80% of endomycorrhizal fungi are arbuscular mycorrhiza (VAM)
- only 6 fungal species [*Glomales,* Zygomycetes] form VAM

Initiation:

- germination of spores
- Hyphae form **appressorium**
  (attachment sites)

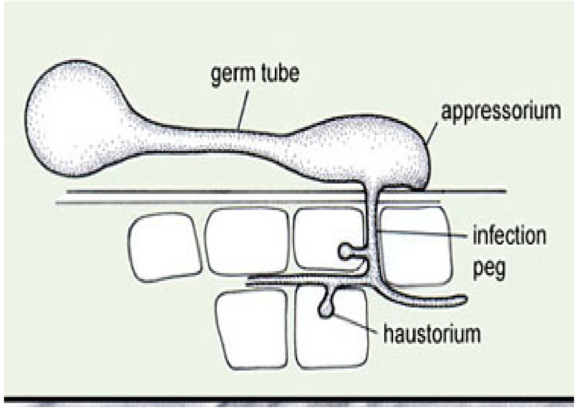


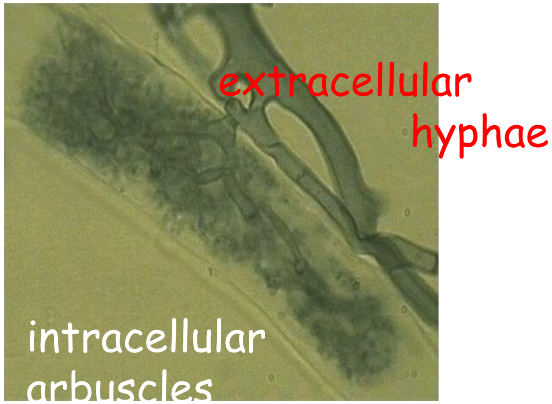
- Formation of an **extracellular** hyphal system in the apoplast



Penetration:

- formation of **haustorium**: penetration into the plant cell



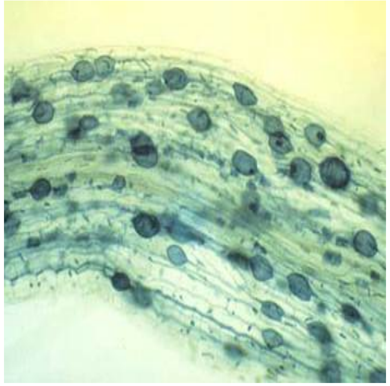


- Extracellular hyphae:
    - collection of nutrients from rhizosphere
- Intracellular hyphae:
    - enlargement of interaction surface
    - nutrient/metabolite exchange with plant cell

Life time of arbuscle: a few days

Ektomycorrhiza

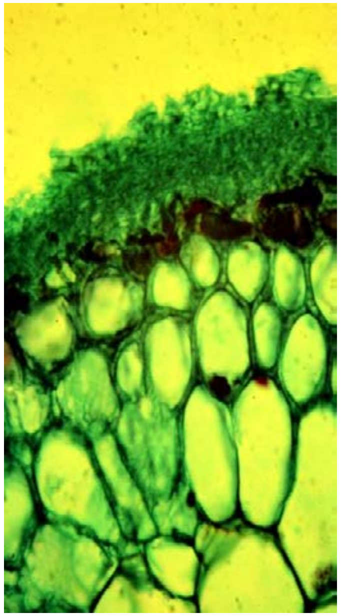
hyphae: rhizosphere, on root surface, between root cells
do not enter vascular tissue

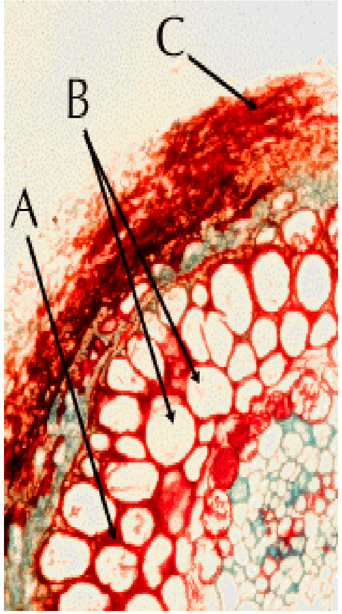


fruit bodies

Hartig Net

- many **trees** form ectomycorrhizas
- **Hartig Net:**
  - a net around the root (hairs) to extent access to soil nutrients





Function of Hartig Net

- Optimization of nutrient exchanges

- Protection against soil pathogens

- **Connection of organisms in biophere**
  - 60 km network
  - Support for young trees in forests
  - Connections between different plant species

Beneficial interaction between plants and microbes

mycorrhiza

"

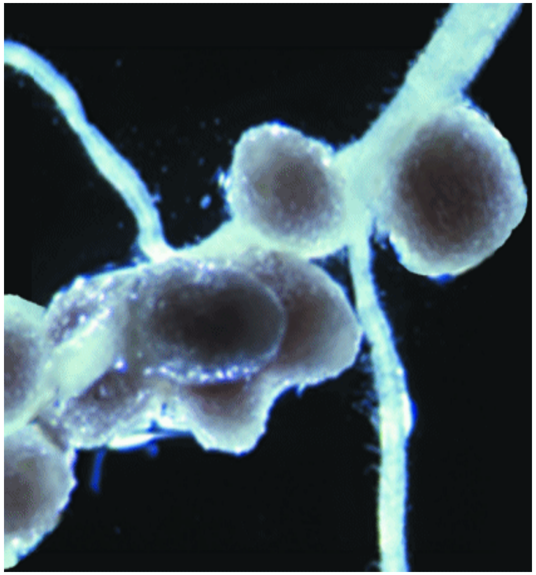
endomycorrhiza
ectomycorrhiza

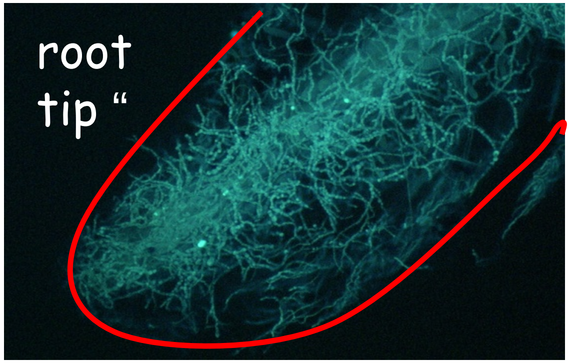
N_2 fixing bacteria/ legumes

endophytes

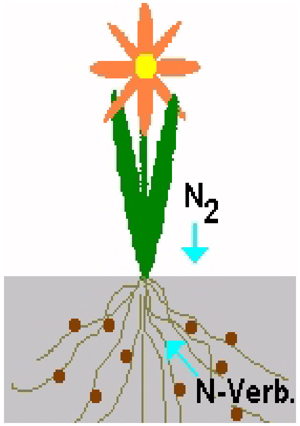
"

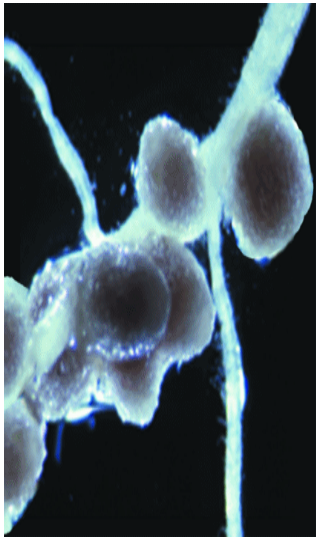
bacteria
fungi





Nodules



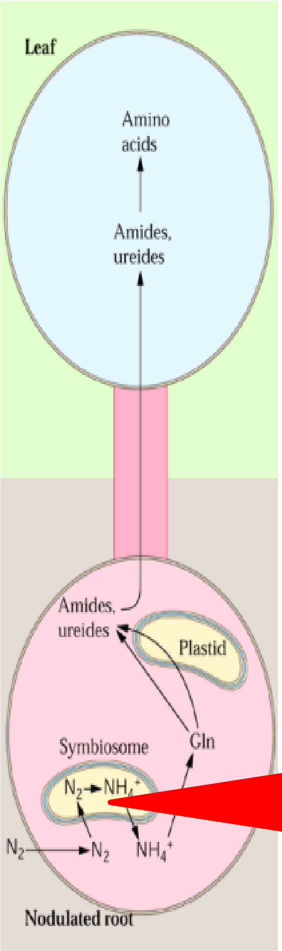


N_2 fixation

- **Haber-Bosch: N-fertilizer**

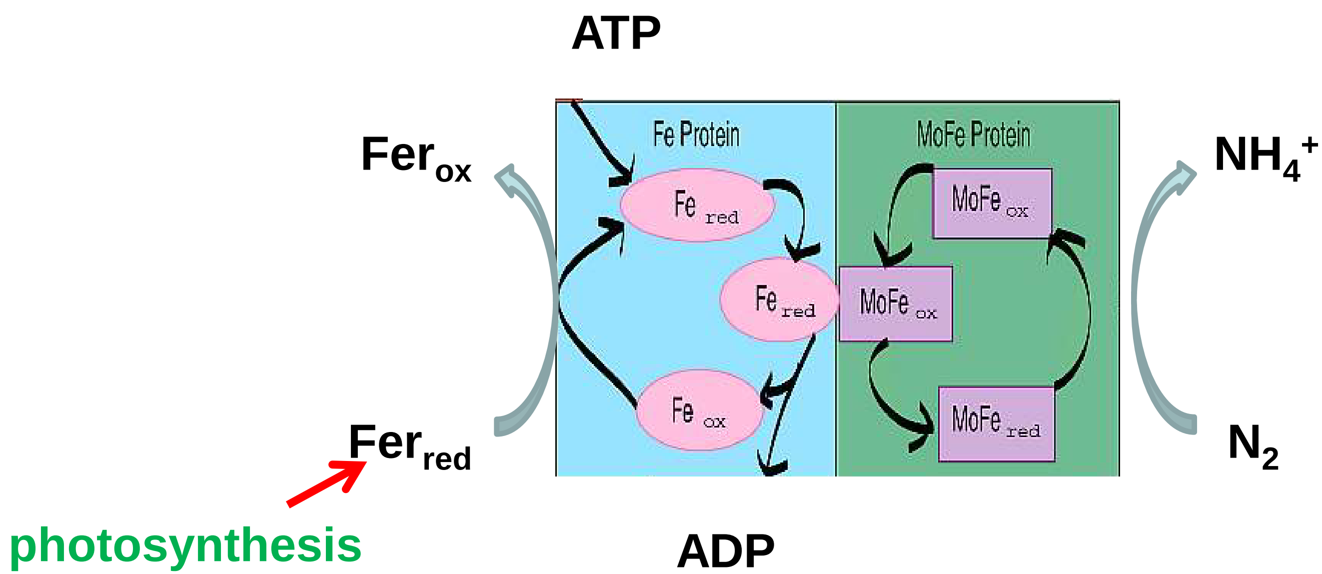
N_2 + 8H+ + 8e- + 16 ATP = 2NH_3 + H_2 + 16ADP + 16 Pi

- **N_2 fixation**
  - **rhizobacteria**
  - **cyanobacteria**



rhizobia with nitrogenase

bacterial nitrogenase



- **nitrogenase O_2-sensitive**

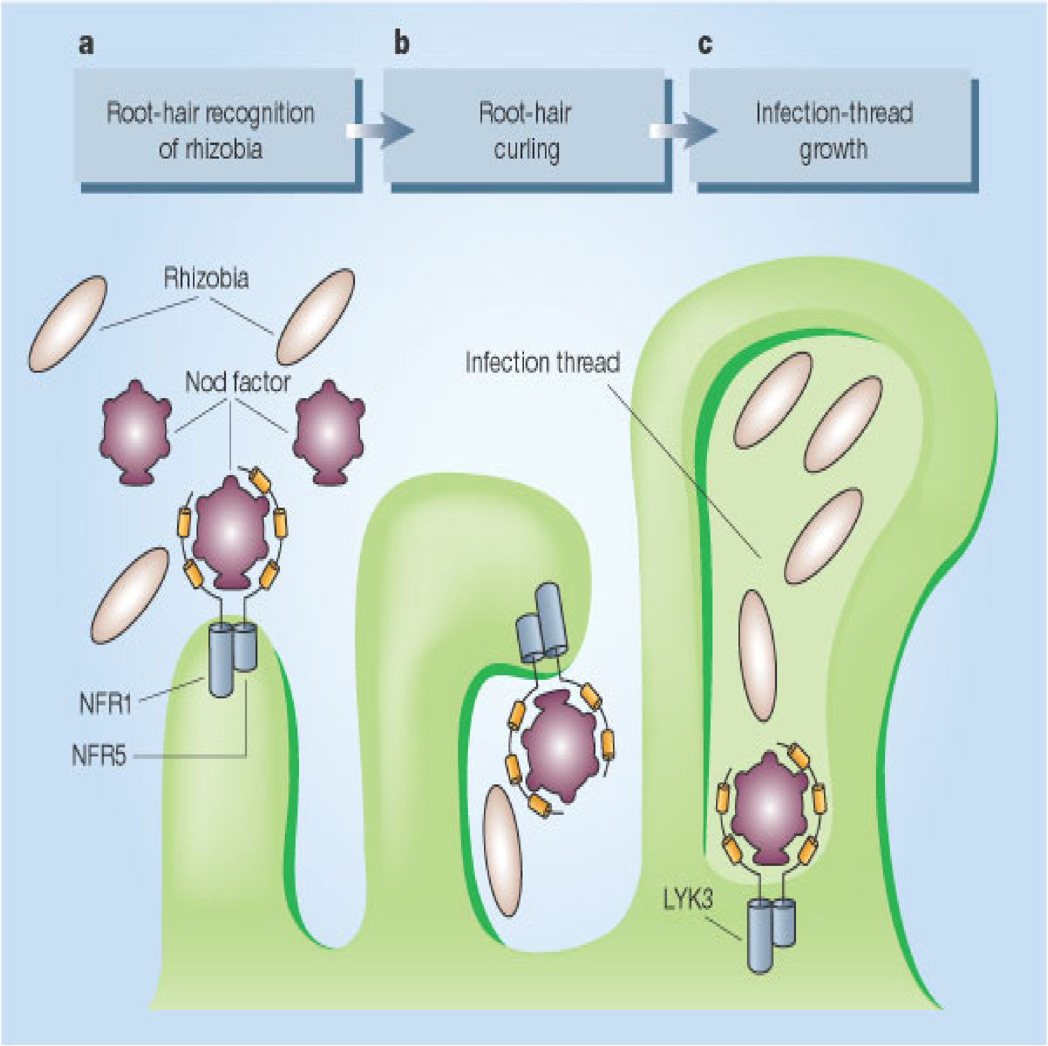
- **leghaemoglobin (plant- and bacteria-encoded)**

Rhizobia under N limitation

alfalfa

soybean

recognition

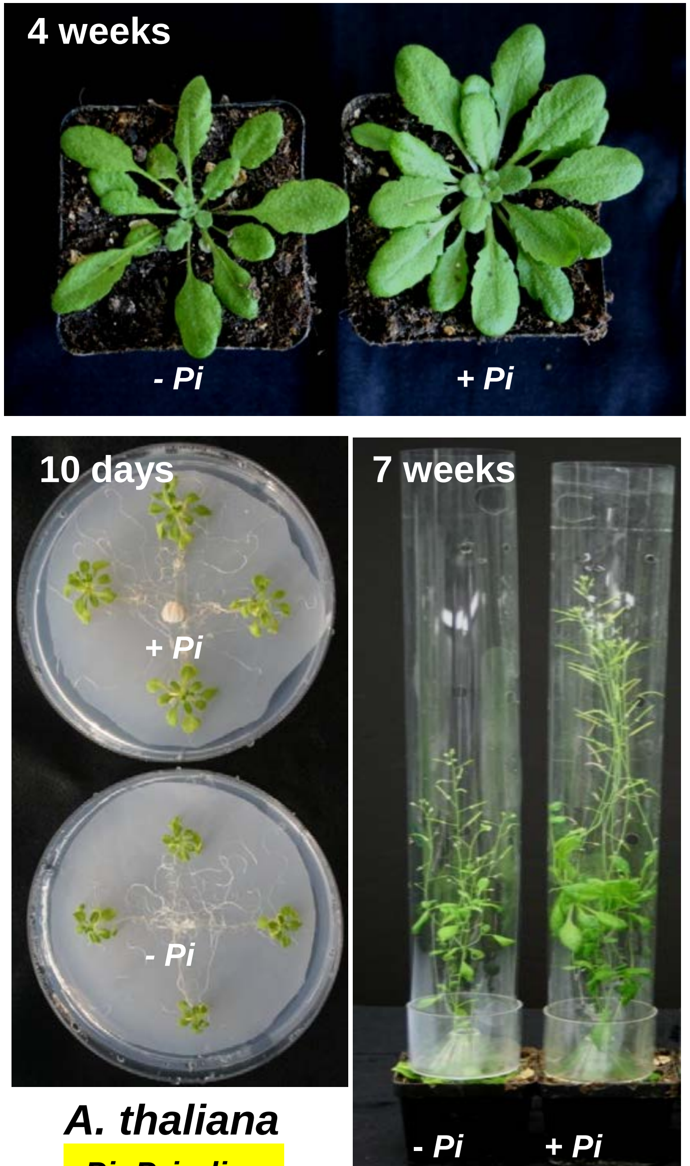


Endophytes

GOALS:

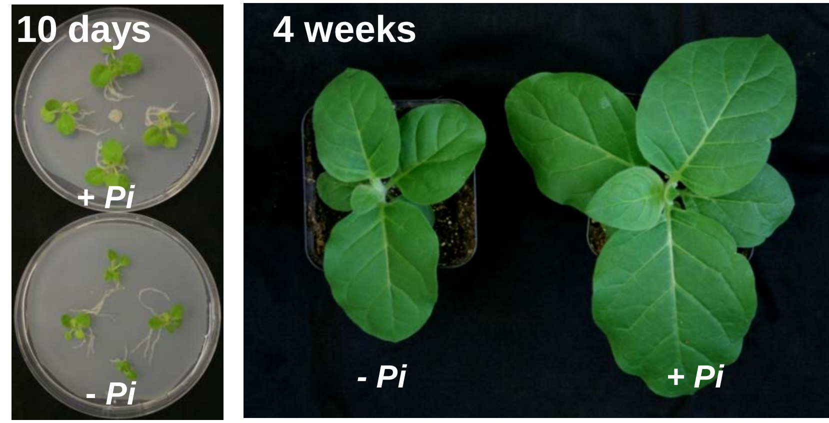
- Isolation of endophytic fungi from roots of plants growing under extreme conditions
  (deserts, salt lakes, high mountains, flooded areas)
- Cultivation of fungi, identification
- Test with model plant *Arabidopsis thaliana* under extreme conditions
- Molecular mechanisms of resistance

Piriformospora indica - plant growth promoting fungus



A. thaliana

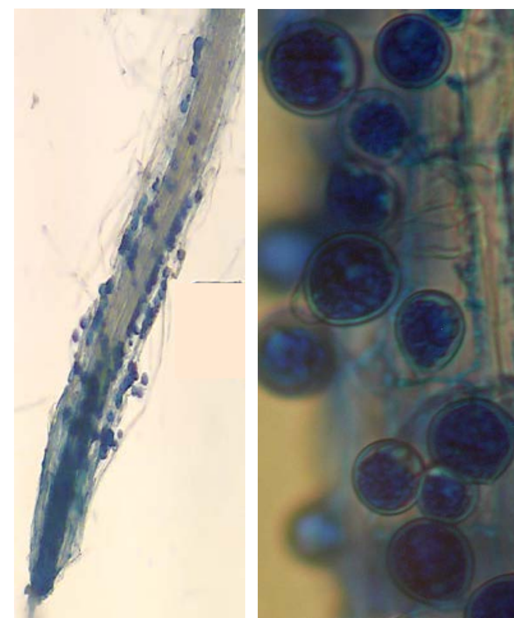
Pi: P. indica



N. tabaccum

Kaefer medium

KM broth

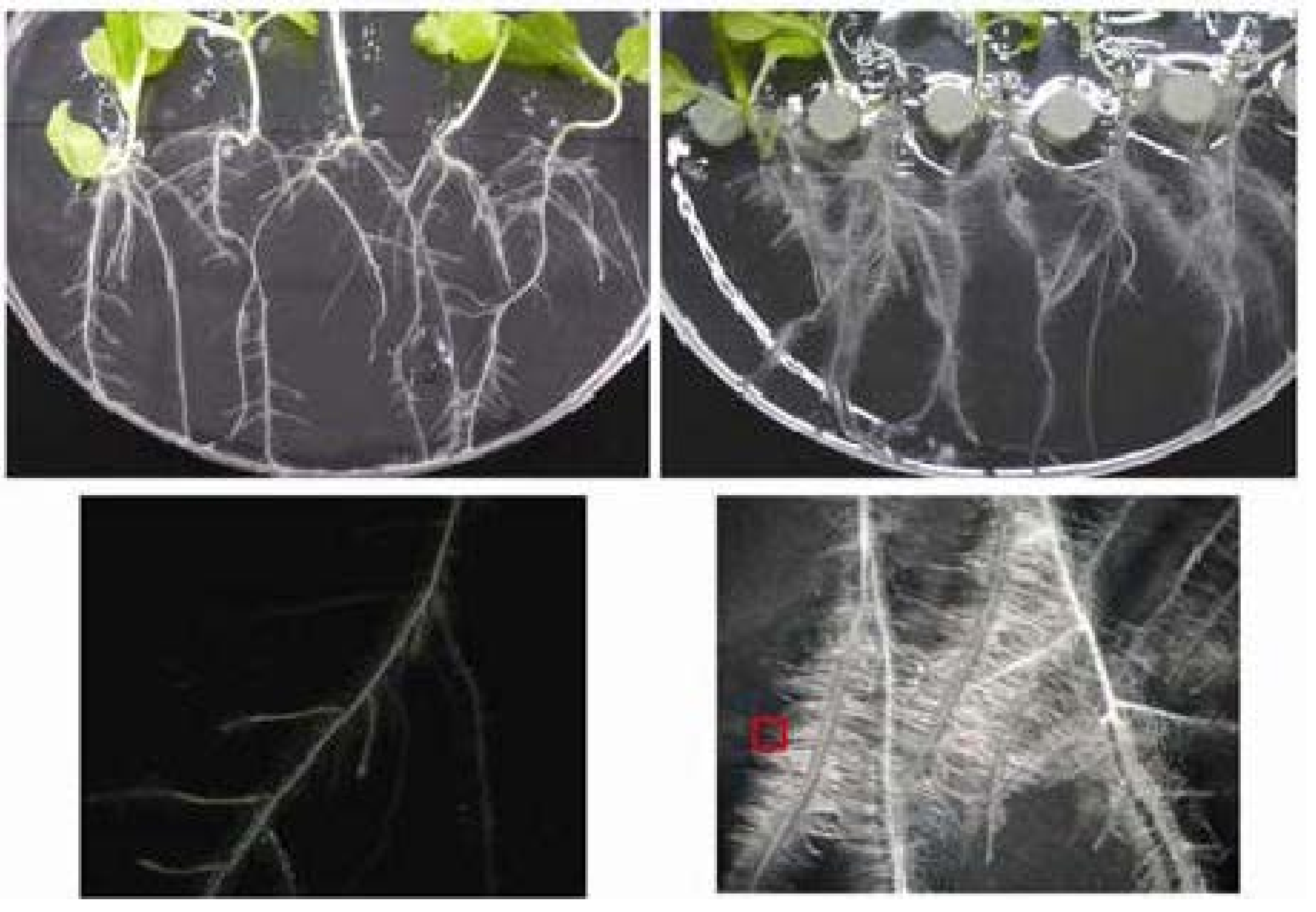


***Pi* colonized Arabidopsis root**

Johnson et al. (2011) *Endocyt Cell Res*, 21, 101-113.

Oelmüller et al. (2009) *Symbiosis*, 49, 1-17; Varma et al. (2012) *Agric Res*, 1, 117-131.

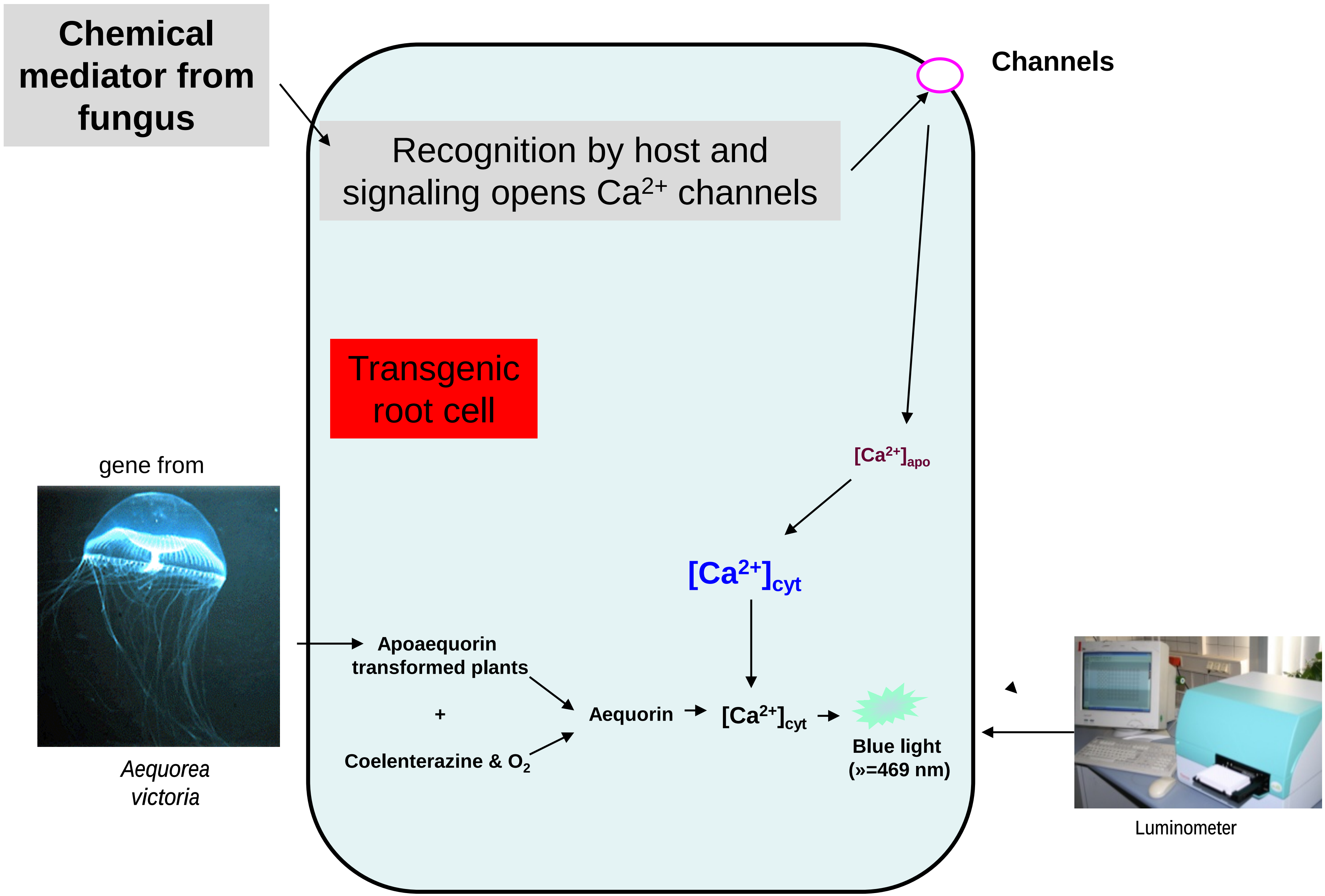
Piriformospora indica – lateral root development

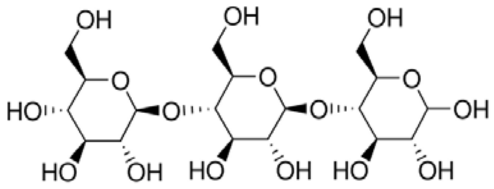


- fungus

+ fungus

Recognition by $[Ca^{2+}]_{cyt}$ –inducing chemical mediators





e.g. cellotriose