Fisiologia Vegetal
Nutrição

Quinta aula teórica de nutrição vegetal
2023-2024

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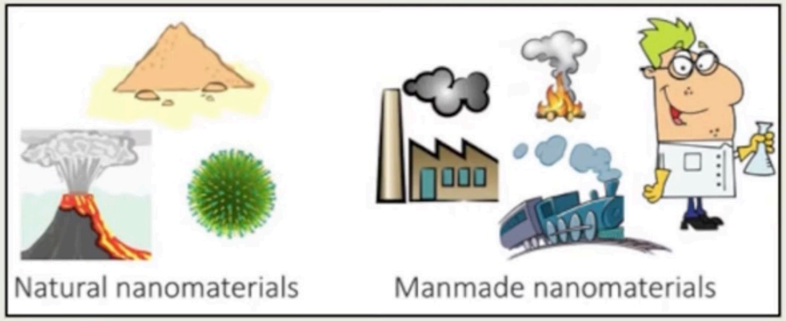
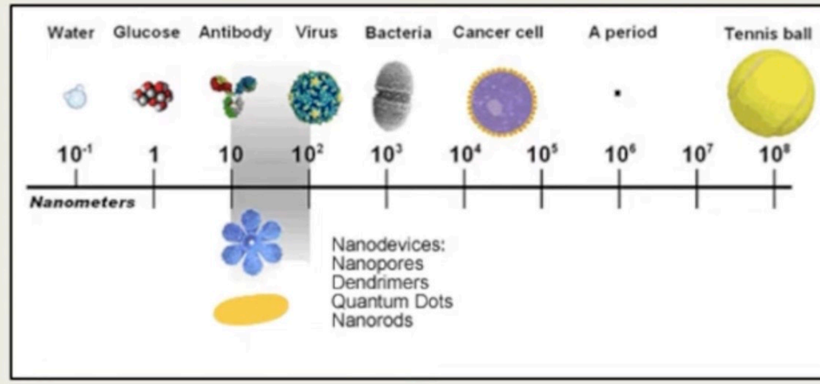
NANOPARTICLE'S INTERACTION WITH PLANT SPECIES



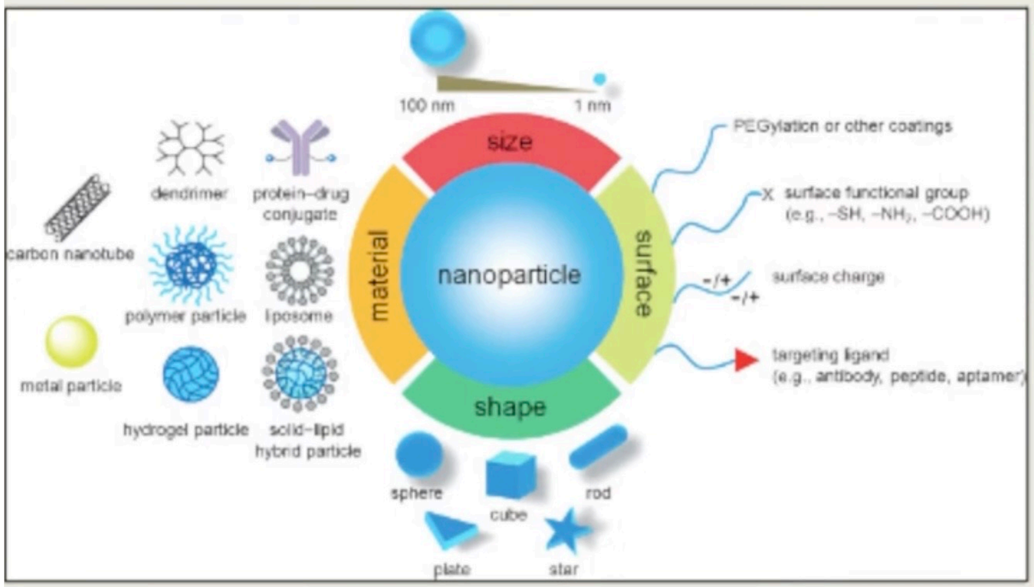


What are Nanoparticles?

- "Nano" = very small or at microscopic level
- Nanoparticles or NPs are defined as particles with sizes between 1 and 100nm
  - *Example of size: a thousand nanoparticles lined up can go across the tip of your hair*
- There are naturally occurring NPs and engineered or man-made NPs

(Maurer-Jones et. al., 2013; Chakraborty et. al., 2016)

How are NPs size influence reactivity and living things?



- Engineered NPs have different sizes, shapes which can change their physiochemical properties.
- Due to their small size, NPs will have more surface area. With more surface area, creates more activity.
  - *HIGHER SURFACE AREA LEADS TO HIGHER REACTIVITY*
- Many nanoparticles make its way into the environment which may cause a variety of problems.

(Husen, 2020)

Interactions between Ions in the Rhizosphere

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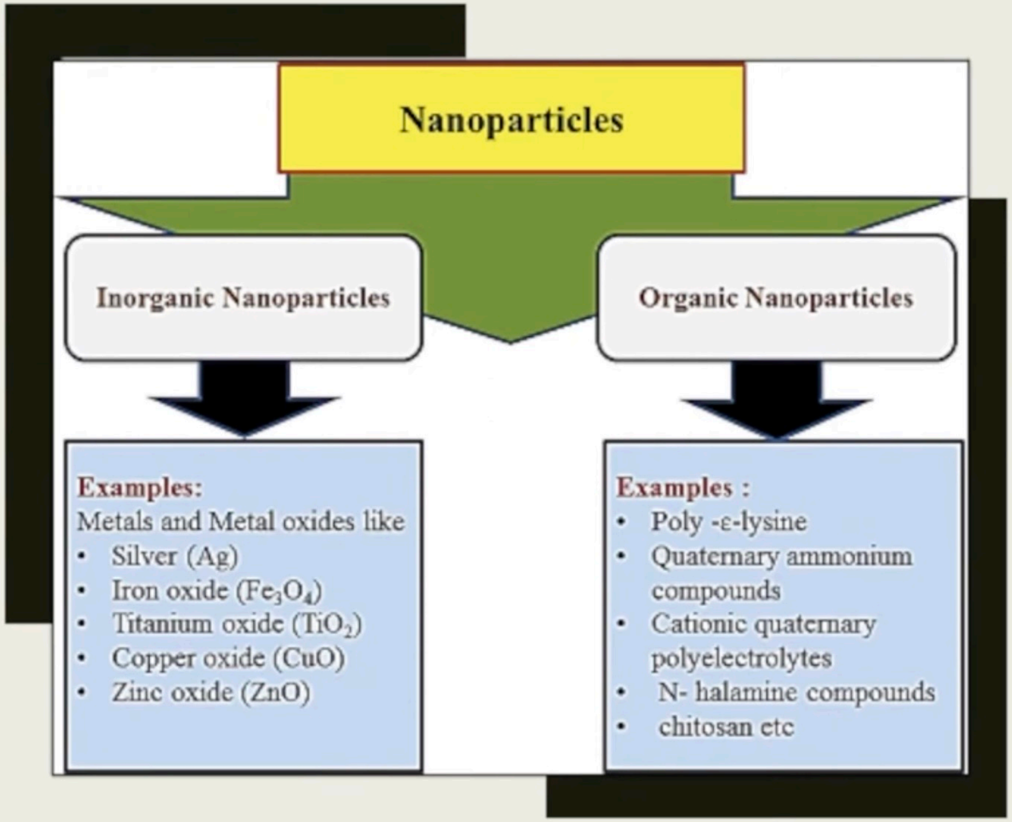

TYPES OF NANOPARTICLES

(LewisOscar et. al., 2016)

Interactions between Ions in the Rhizosphere

Figure represents uses of NPs in different industries and its leakage to the environment

(Rastogi et. al., 2017)

Where can we find Nanoparticles?

- NPs are used in various household and industrial products
  - *Solar cells*
  - *Pharmaceuticals*
  - *Cosmetics*
  - *Textiles*

Interactions between Ions in the Rhizosphere

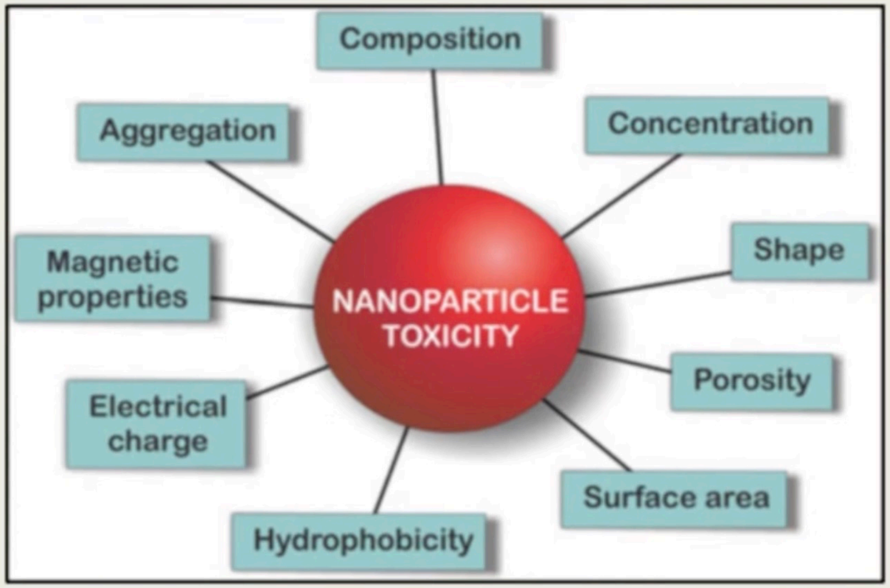

Figure represents Nanoparticle toxicity is determined by its physicochemical and morphological characteristics

Plants vs Nanoparticles

- There are both positive and negative effects of nanoparticles or nanomaterials on plant function and development.
- Crop toxicity depends on the concentration, exposure time, growth media, shape and size of NPs/NMs.

Pacheco & Buzea, 2018; Bose, 2020; Husen, 2020)

Interactions between Ions in the Rhizosphere

The effects of silver nanoparticles on Wheat (*Triticum aestivum* L.)

- Study: To evaluate the phytotoxicity of silver NP to wheat yields and food quality
- Methods: different concentrations of Silver NP amended soils (20, 200, and 2000 mg kg^{-1}) for 4 months
- We will be observing the physiological parameters of silver and micronutrients (Fe, Cu, and Zn) contents and amino acid and total protein in the edible portions of wheat which will provide useful information for crop safety.

(Yang et. al, 2018)

Interactions between Ions in the Rhizosphere

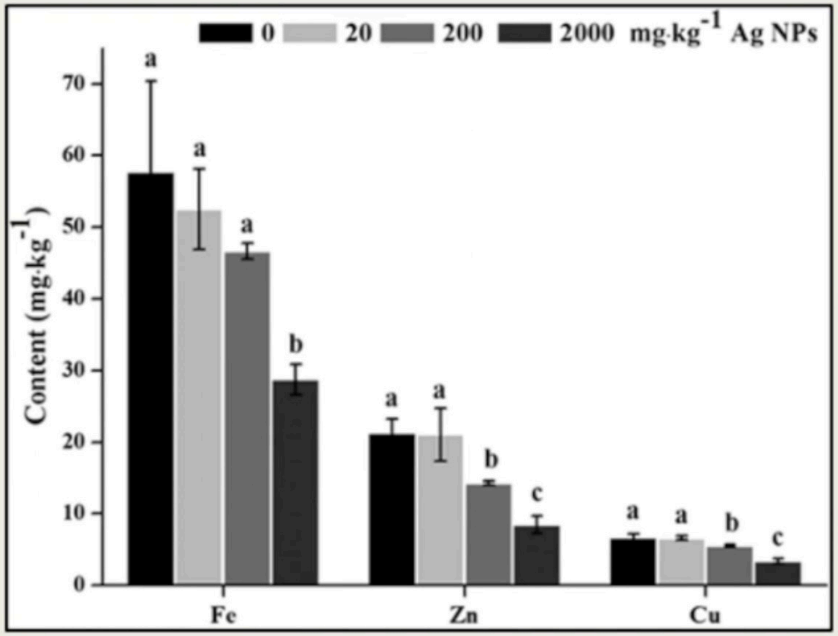

Figure represents micronutrient contents in different exposure doses of Ag- NP-treated wheat grains

Contents of Micronutrients in Wheat Grains

- Iron – helps in chlorophyll synthesis and is directly involved in plant photosynthesis
- Zinc – an important component in auxin synthesis and in the enzymes of the metal activators
- Copper – participates in electron transfer in the chloroplasts and mitochondria as well as the oxidative stress of plants

(Yang et. al, 2018)

Interactions between Ions in the Rhizosphere

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Effects of Silver NP on Plant Height and Biomass

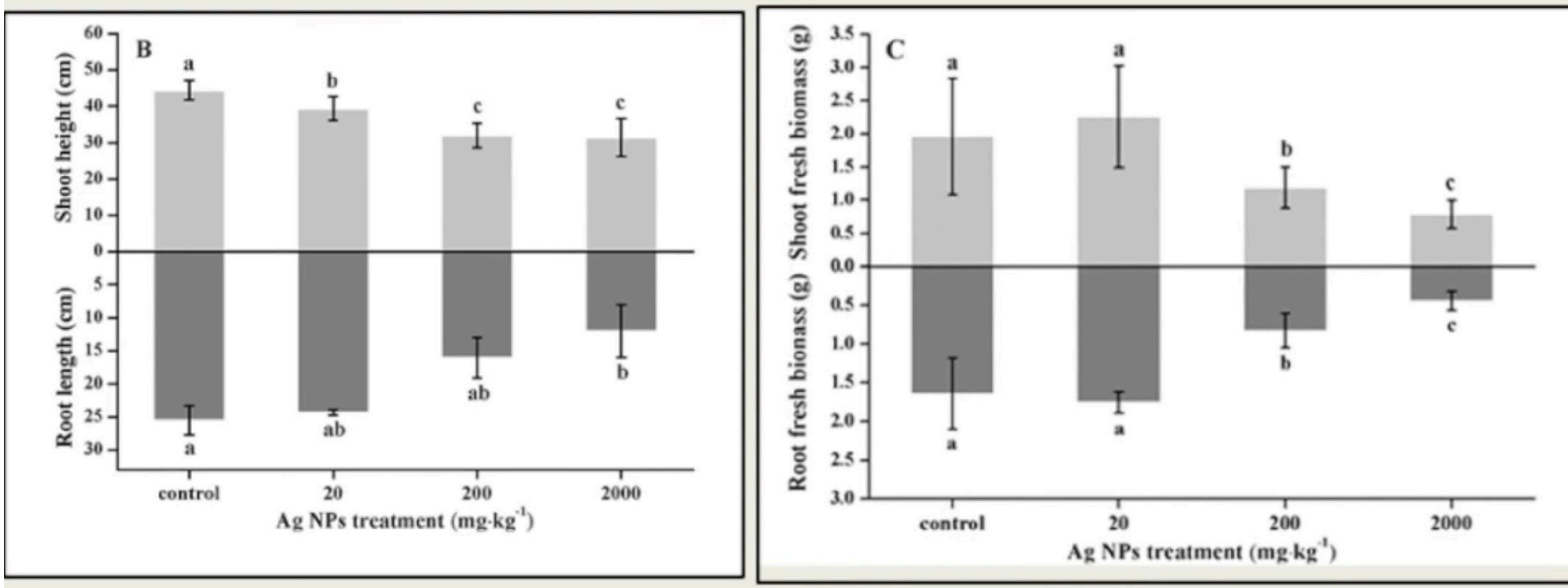
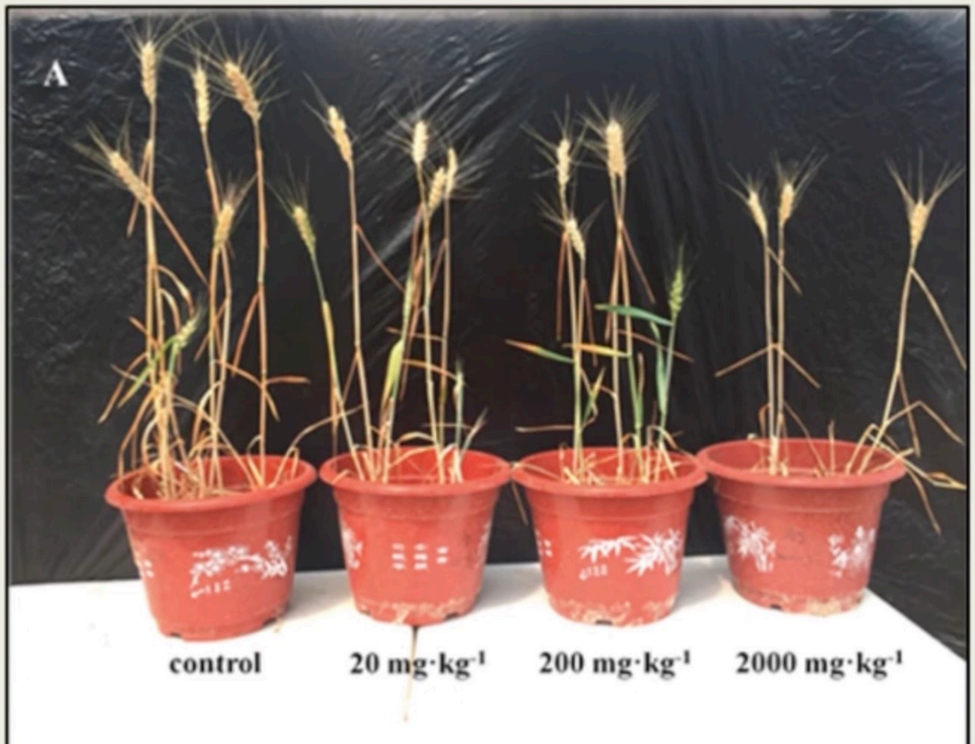


Figure B and C represent plant height and fresh biomass

Effects of Silver NP on Plant Height and Biomass



Interactions between Ions in the Rhizosphere

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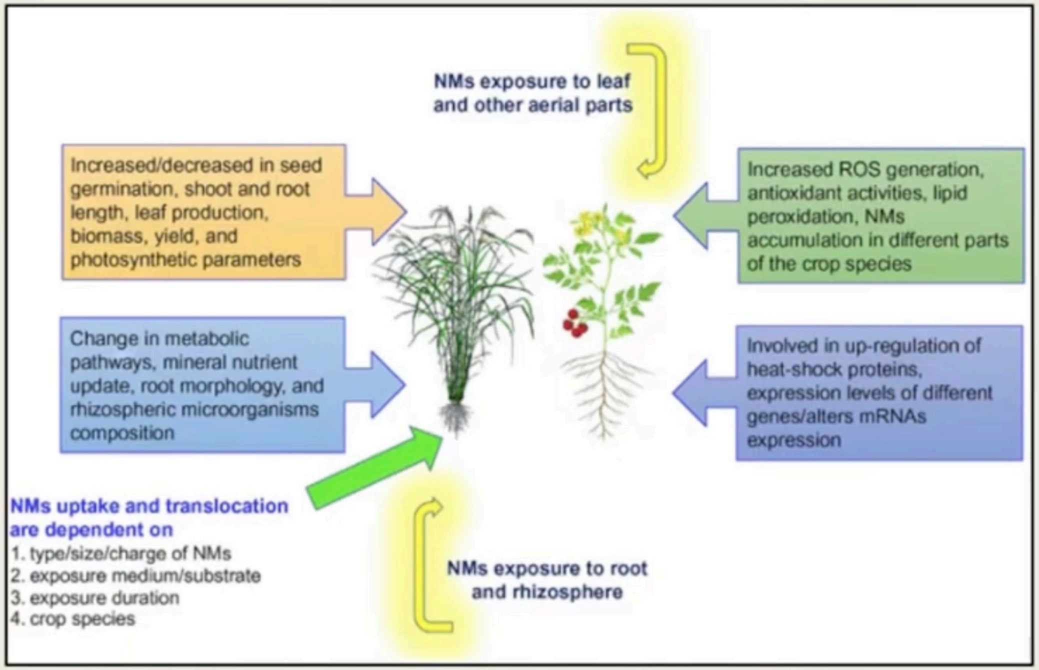

Figure represents possible interactions of metal and metal-oxide nanomaterials (NMs) with agricultural crops.

Plants vs Nanoparticles

- There are both positive and negative effects of nanoparticles or nanomaterials on plant function and development.
- Crop toxicity depends on the concentration, exposure time, growth media, shape and size of NPs/NMs.

(Bose, 2020; Husen, 2020)

O desenvolvimento radicular

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O desenvolvimento radicular

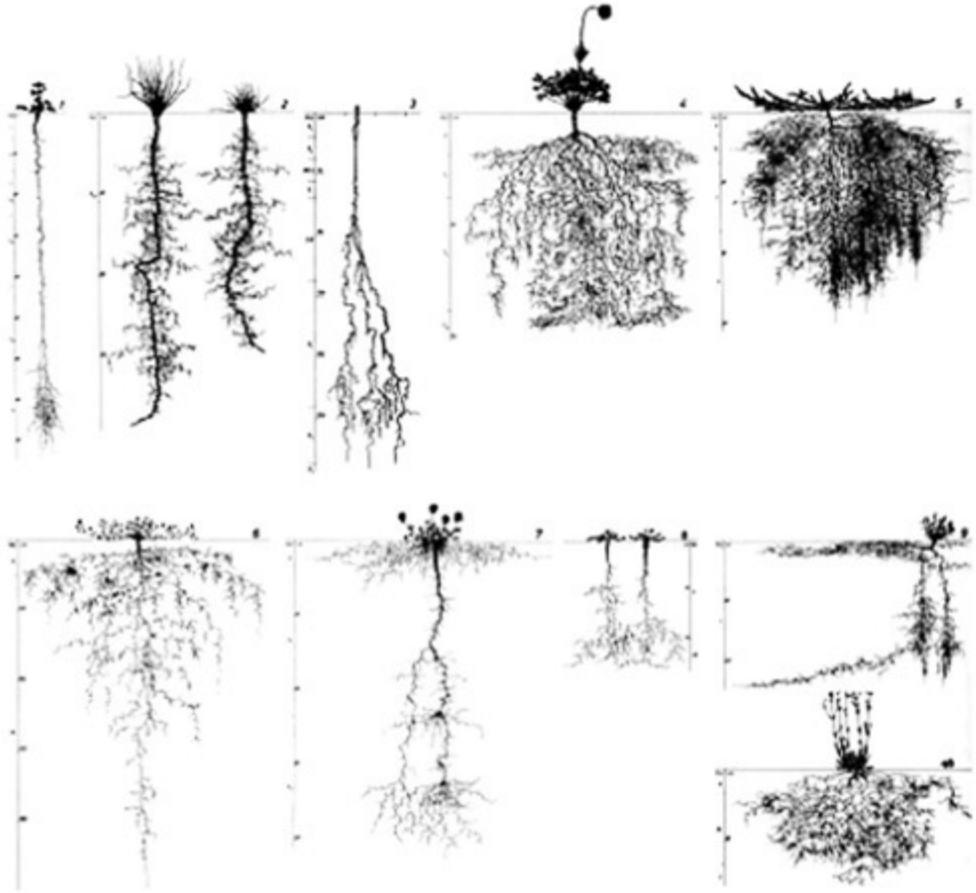

FIGURE 13.4 Root architecture of several dicotyledonous species observed in the field. *From Kutschera and Lichtenegger (1992). With permission from Gustav Fischer Verlag.*

O desenvolvimento radicular

O desenvolvimento radicular

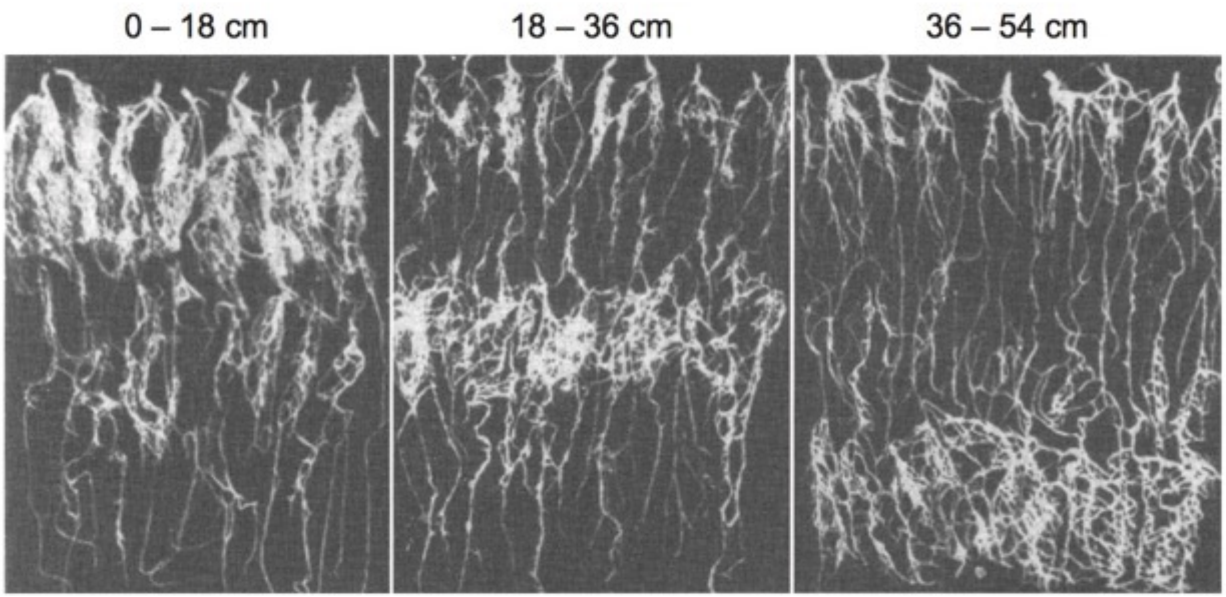

FIGURE 13.6 Root distribution of barley growing in sandy soil with N fertilizer placement at different depth. *From Gliemeroth (1953). With permission from Wiley & Sons.*

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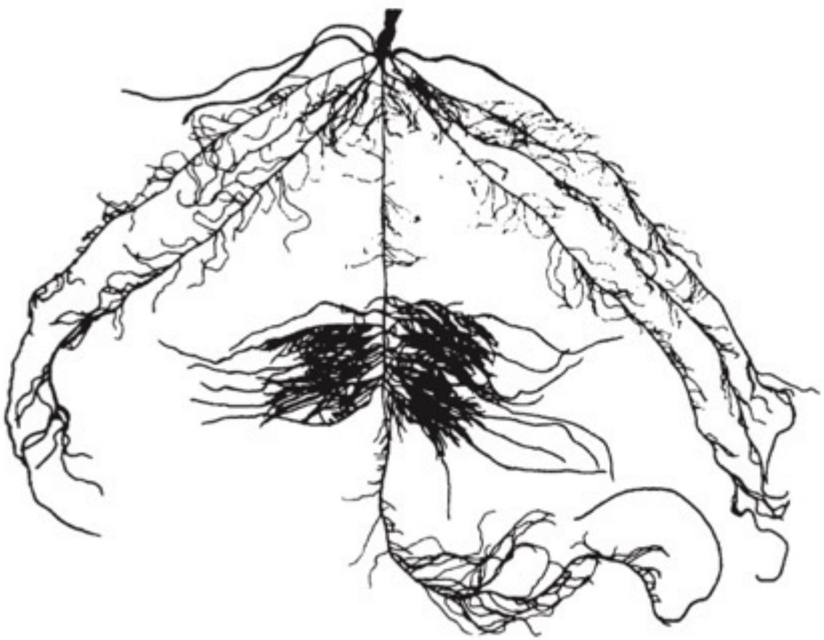

FIGURE 13.7 Modification of the root system of barley by providing 1 mM nitrate to the middle part of one root axis for 15 days, the remainder of the root systems received 0.01 mM nitrate. *From Drew and Saker (1975) by permission of Oxford University Press.*

TABLE 13.3 Lateral root length and dry weight of barley (21 days) with uniform or localized P supply (to middle section only)

	Uniform supply		Localized supply	
	Lateral roots			
Root zone	Length (m)	Dry weight (mg)	Length (m)	Dry weight (mg)
A (basal)	40	9	14	4
B (middle)	27	4	332	38
C (apical)	18	10	11	5

Based on Drew and Saker (1978).
P was applied to the 4 cm section in zone B (middle) to a single seminal root axis.

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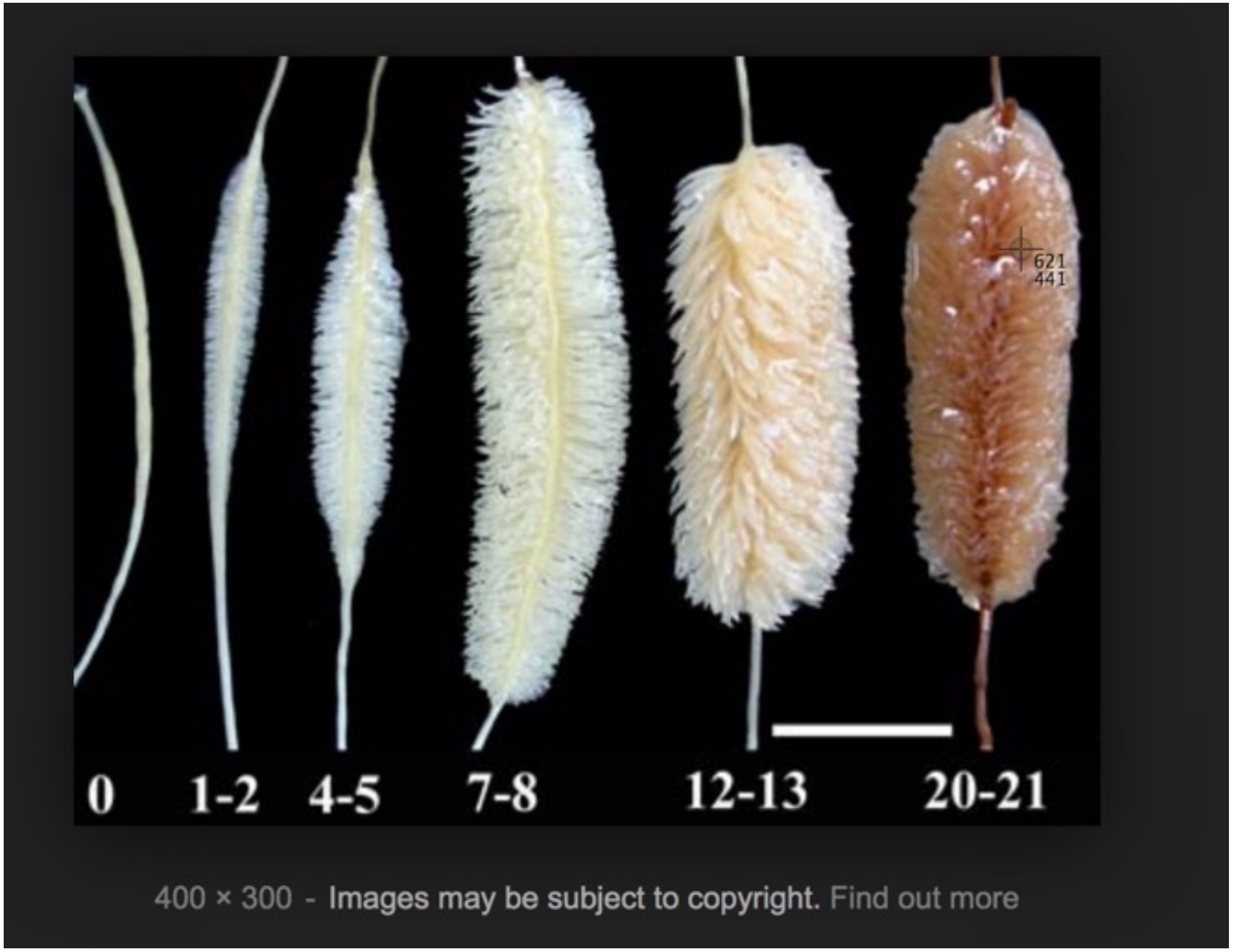

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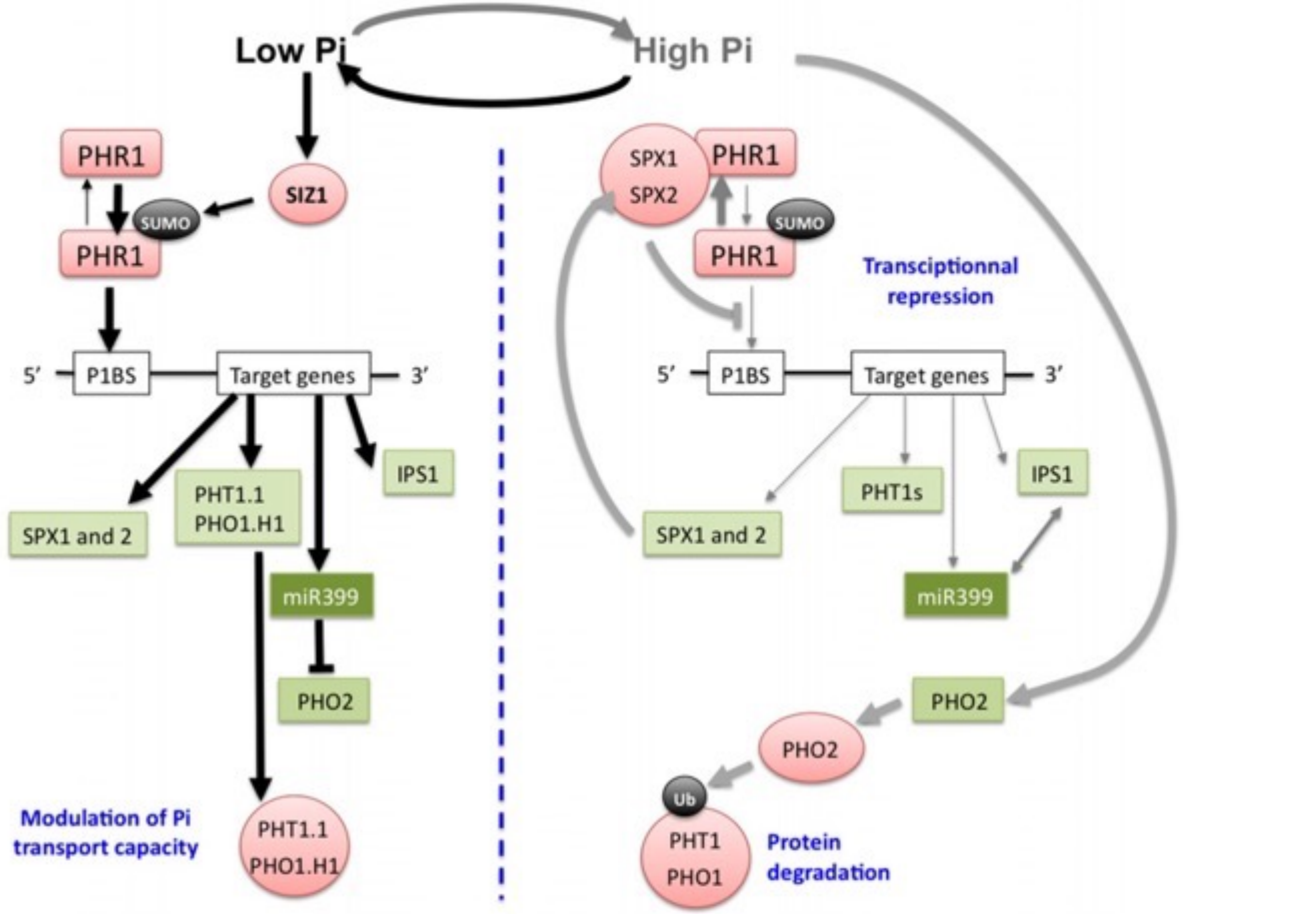


FIGURE 2 | Schematic representation of the regulatory pathways required for plant adaptation to Pi deficiency. Under low Pi nutrition conditions **(left)** the transcriptional activation of a set of genes necessary for Pi uptake by the roots (*PHT1*, *PHO1*), occurs through binding of the transcription factor (TF) PHOSPHATE STARVATION RESPONSE 1(PHR1) to its *cis*-target present in the promoter region of these genes. Under low Pi conditions, PHR1 is sumoylated by SIZ1, and this post-translational modification is likely important for PHR1 activity because Pi-deficient regulated genes are no more induced in *siz1* mutant under this condition (Miura et al., 2005), although the mechanism of this regulation is unknown. Post-transcriptional regulators of Pi transporter proteins (PHT1.1, PHO1.H1) are also transcriptionally up-regulated through PHR1 activity under Pi-deficiency. Among them the miRNA miR399 negatively regulates the ubiquitin E2 conjugase PHO2 responsible of the ubiquitination of PHT1 and PHO1 proteins in order to target them for proteasome degradation. miR399-dependent inhibition of PHO2 can be titrated under high Pi through RNA mimicry *via* its appariement to *IPS1*, a non-coding RNA positively regulated by PHR1 under Pi deficiency. Under high Pi nutrition conditions **(right)** PHR1 target genes are transcriptionally repressed and PHO2 expression is activated promoting Pi transporters degradation. This transcriptional repression under these conditions is mediated through Pi sensing of nuclear SPX proteins which interact with PHR1 via their SPX domain in Pi-dependent manner in order to inhibit PHR1 binding to its P1BS *cis*-acting sequence found in the promoter region of Pi responsive genes. Green: transcripts, red: proteins, black: post-translational modifications, arrows thickness is proportional to the strength of the considered flux.

O desenvolvimento radicular

TABLE 13.4 Shoot and root growth of maize seedlings grown for 1–6 days without P supply

	Shoot		Root		
Days without P	Dry weight ($g pot^{-1}$)	P concentration ($mg kg^{-1}$)	Dry weight ($g pot^{-1}$)	Length ($m pot^{-1}$)	Radius (mm)
1	2.10	9.5	0.27	46	2.3
2	2.34	6.5	0.31	58	2.2
4	1.93	3.2	0.40	76	2.0
6	1.65	2.7	0.43	91	1.8

Based on Anghinoni and Barber (1980).

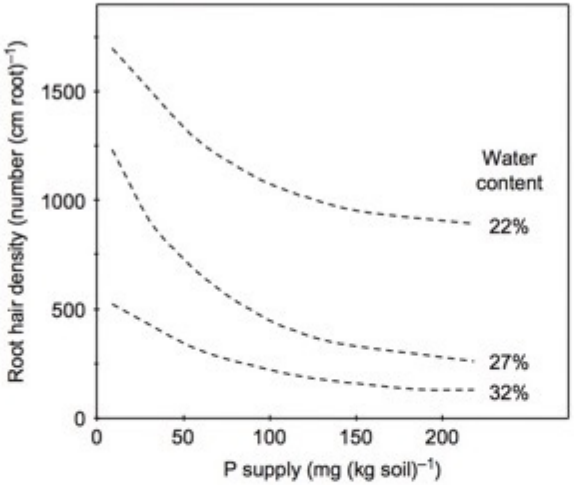


FIGURE 13.8 Root hair density in 21-day-old maize plants grown in soils with different P supply and water content. *From Mackay and Barber (1985). With kind permission from Springer Science & Business Media.*

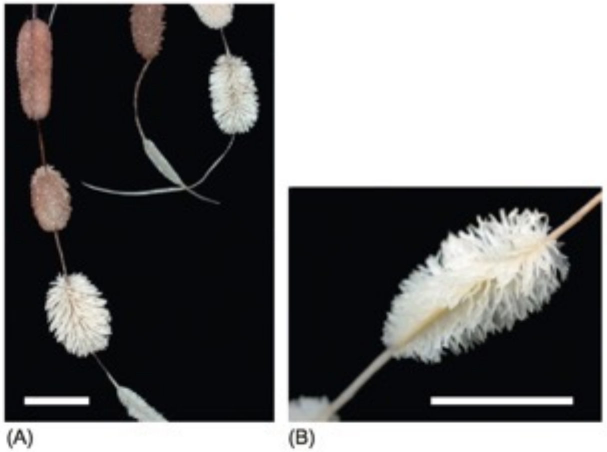
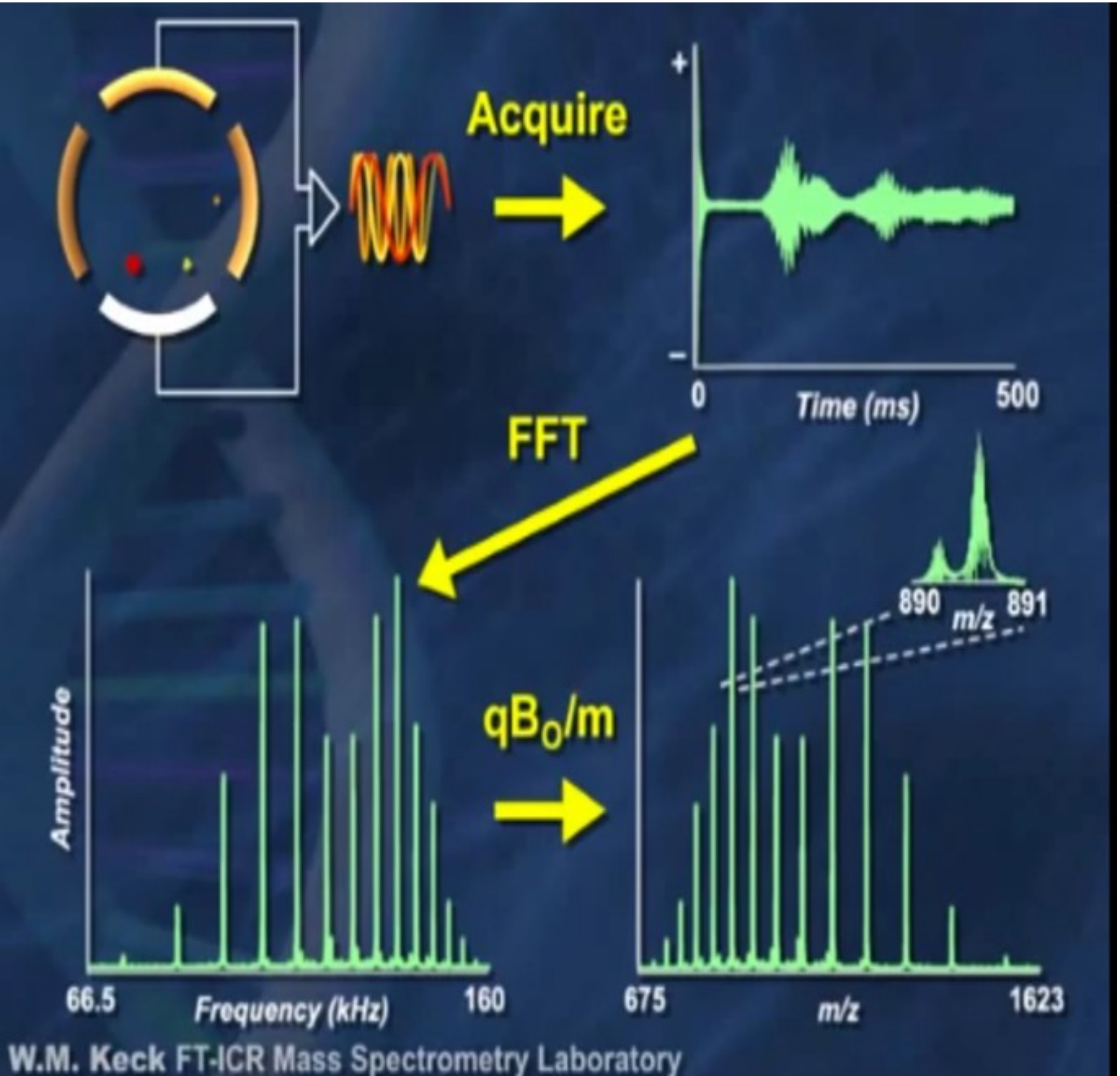


FIGURE 13.9 Proteoid root morphology (simple type) induced in species of hydroponically grown Proteaceae by a low (≤1 μM) P supply in nutrient solution. (A) *Hakea petiolaris* and (B) *Hakea prostrata*. Both species are well adapted to soils of extremely low P concentrations and endemic to the South West Botanical Province of Western Australia. White bar represents 20 mm. *Courtesy of Michael Shane.*

Exsudados radiculares



FTICR-MS –
Fourier Transform
Ion Cyclotron
Resonance Mass
Spectrometry

Metabolic analysis by Mass Spectrometry

FTICR-MS – Fourier Transform Ion Cyclotron Resonance Mass Spectrometry

Mass spectra and m/z values determination (Compass Data Analysis software v. 4.1)

Metabolite identification based on KEGG, HMDB and LipidMaps databases (MassTrix 3 server)

Manual curation for putative metabolites with biological role

Metabolic pathways analysis

Metabolic analysis by Mass Spectrometry

O desenvolvimento radicular

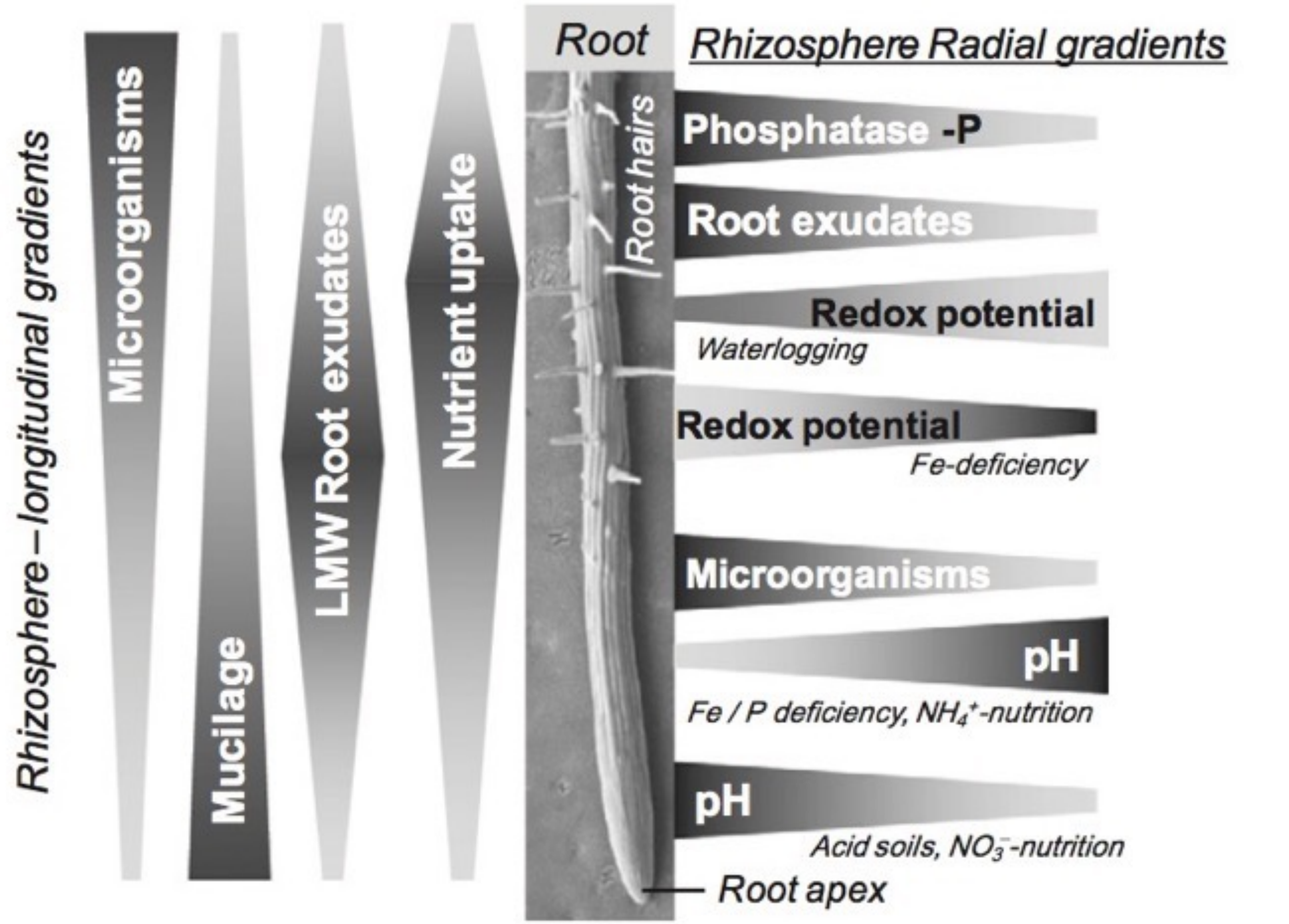


FIGURE 14.2 Physico-chemical and biological gradients in the rhizosphere.

O desenvolvimento radicular

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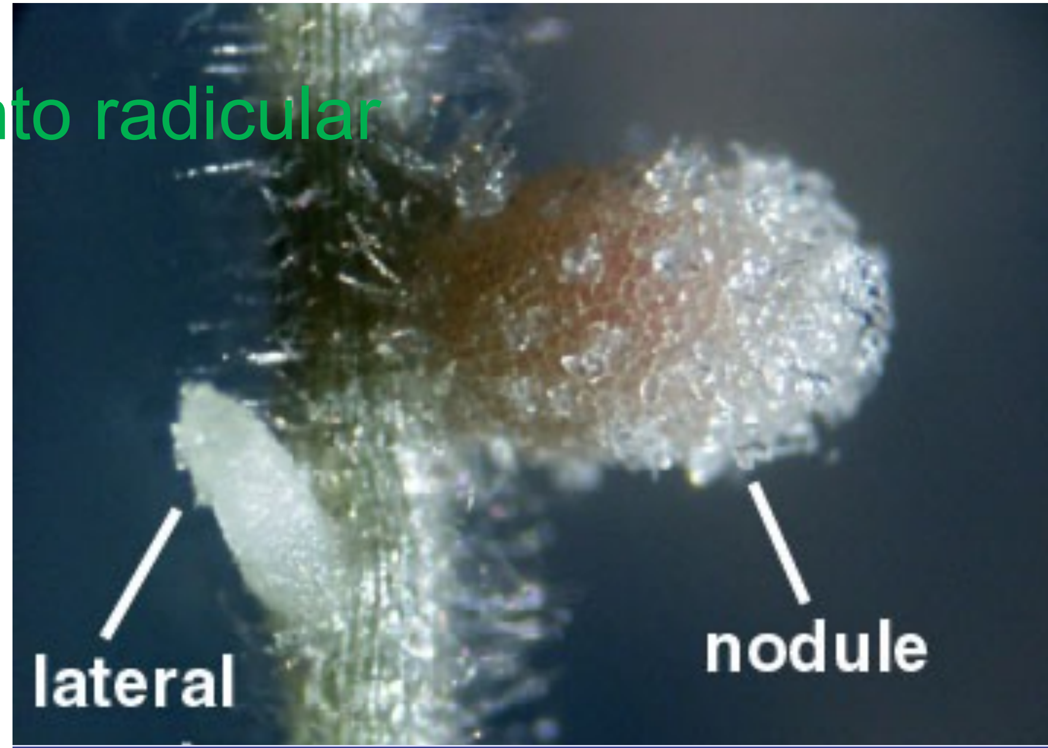
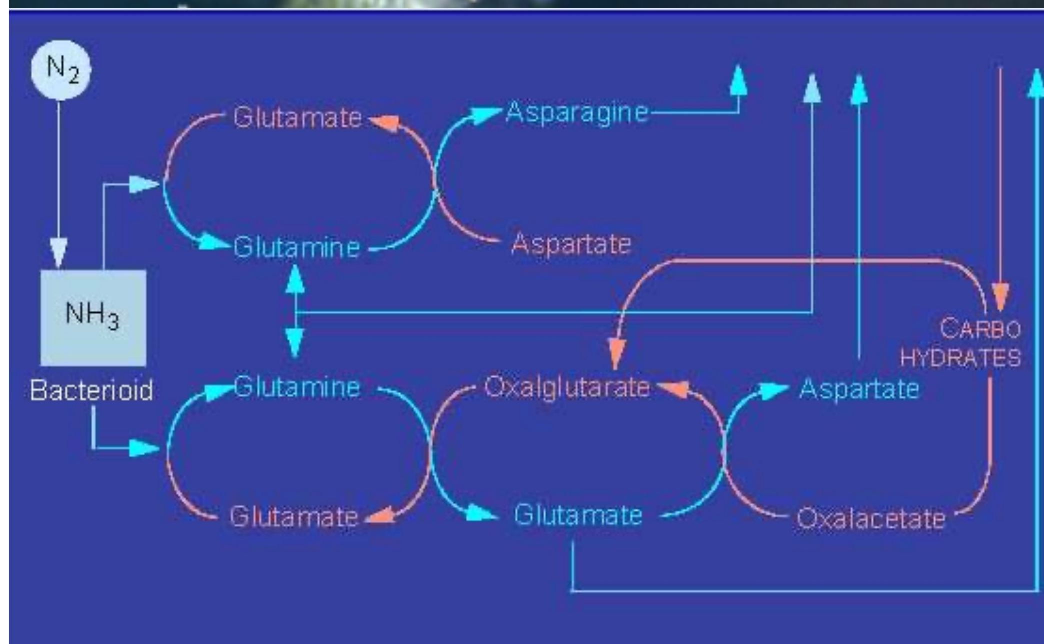
IN Biological N Fixation

Ammonia is the compound transferred from the nodule to the plant

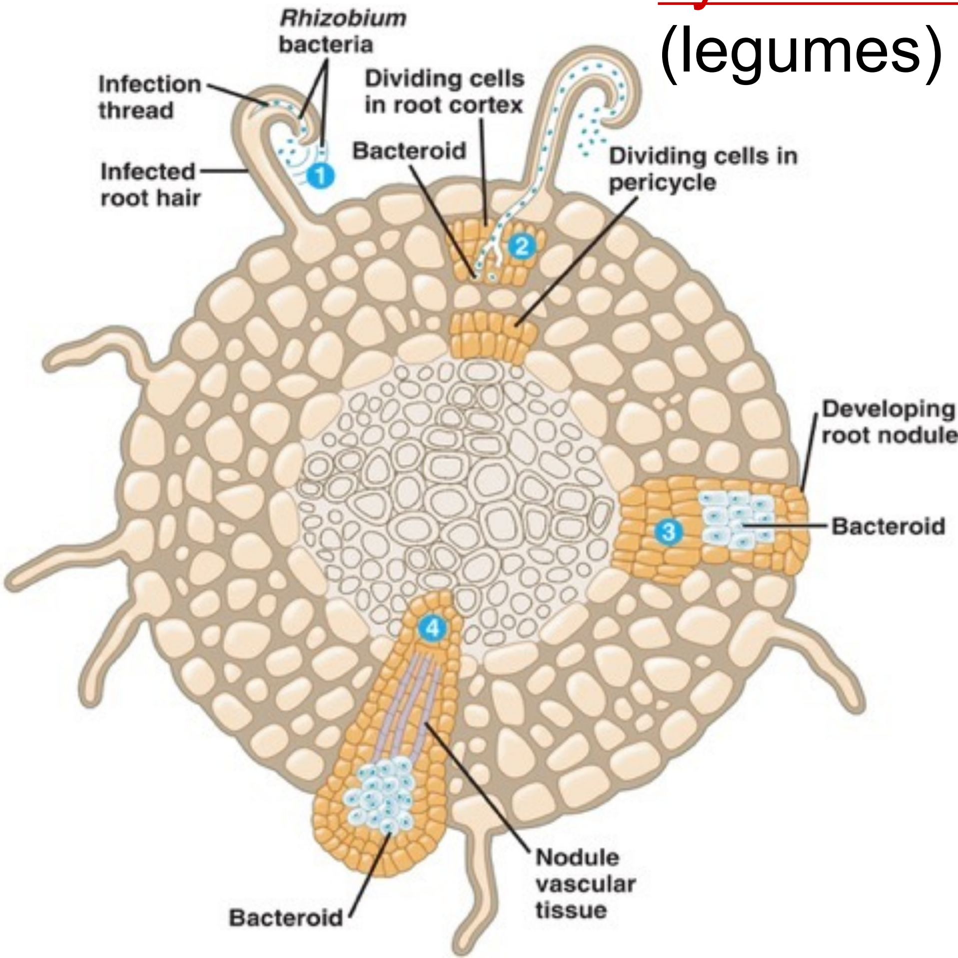


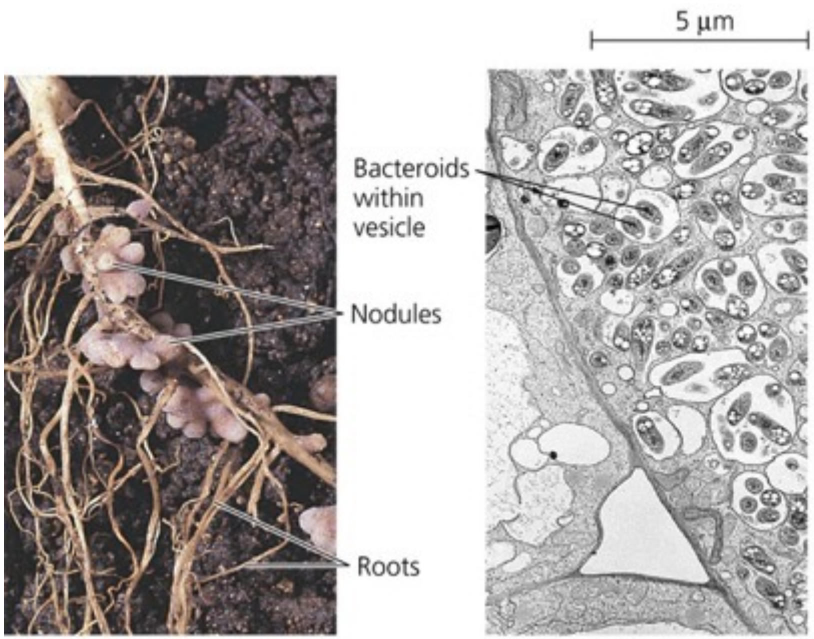


O desenvolvimento radicular

O desenvolvimento radicular

- N fixation by *Rhizobium* bacteria
  - symbiotic relationship with bean family (legumes)





(a) Pea plant root. The bumps on this pea plant root are nodules containing *Rhizobium* bacteria. The bacteria fix nitrogen and obtain photosynthetic products supplied by the plant.

(b) Bacteroids in a soybean root nodule. In this TEM, a cell from a root nodule of soybean is filled with bacteroids in vesicles. The cells on the left are uninfected.

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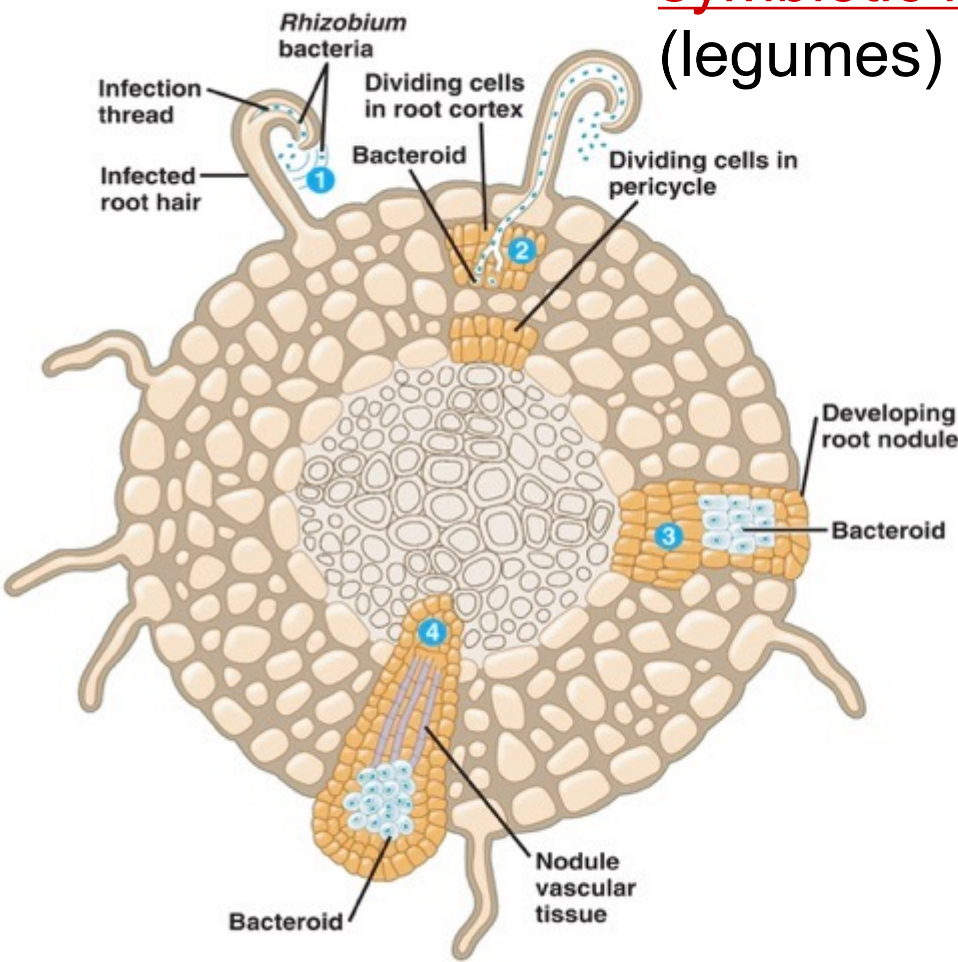

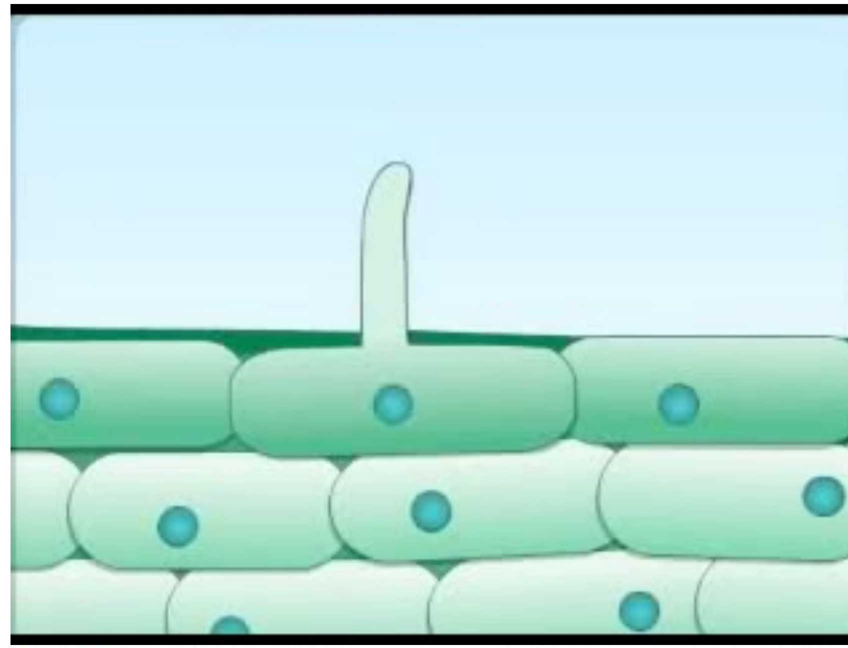

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• Strigolactonas

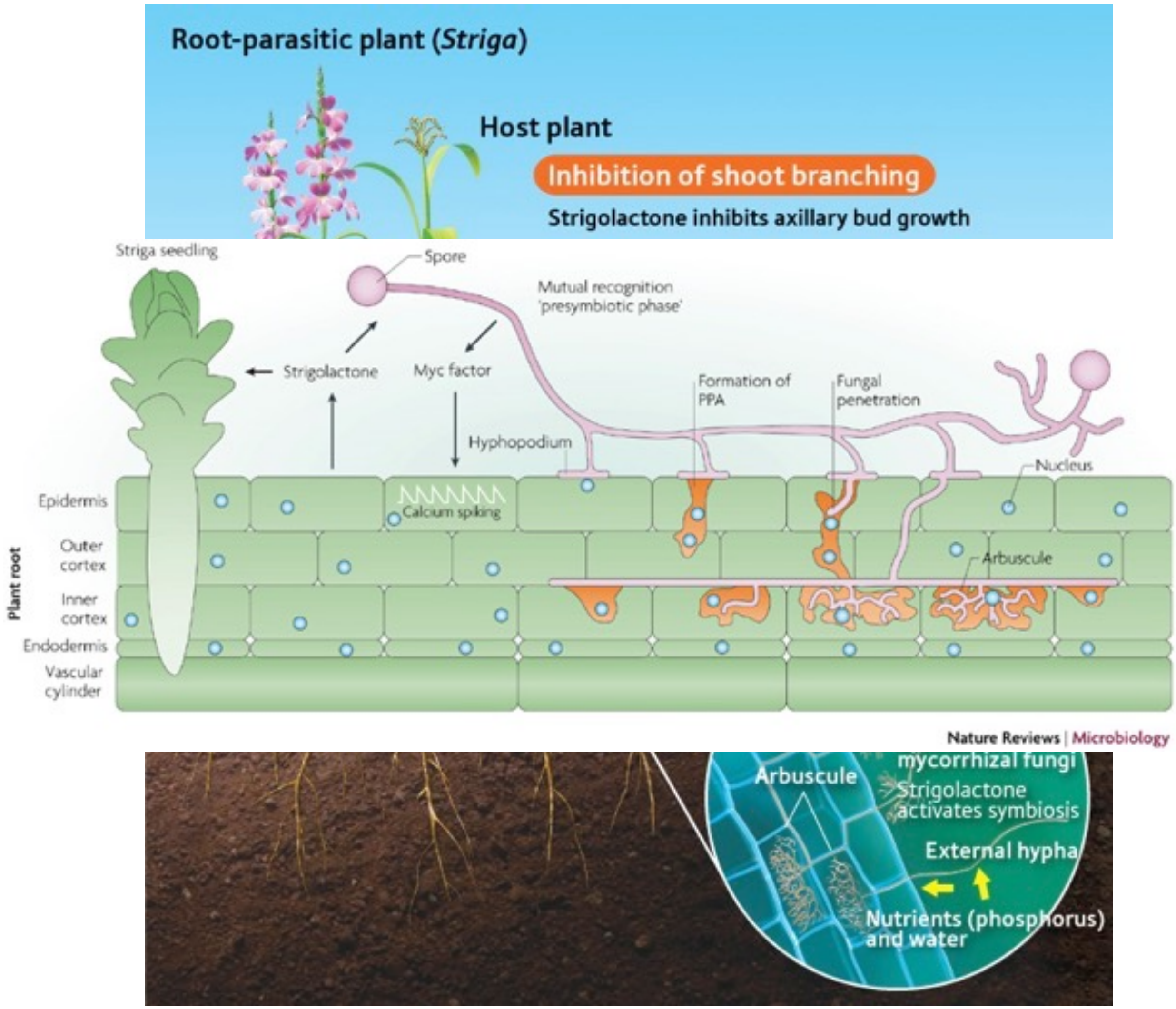
Hipótese:

Disponibilidade de P ↑

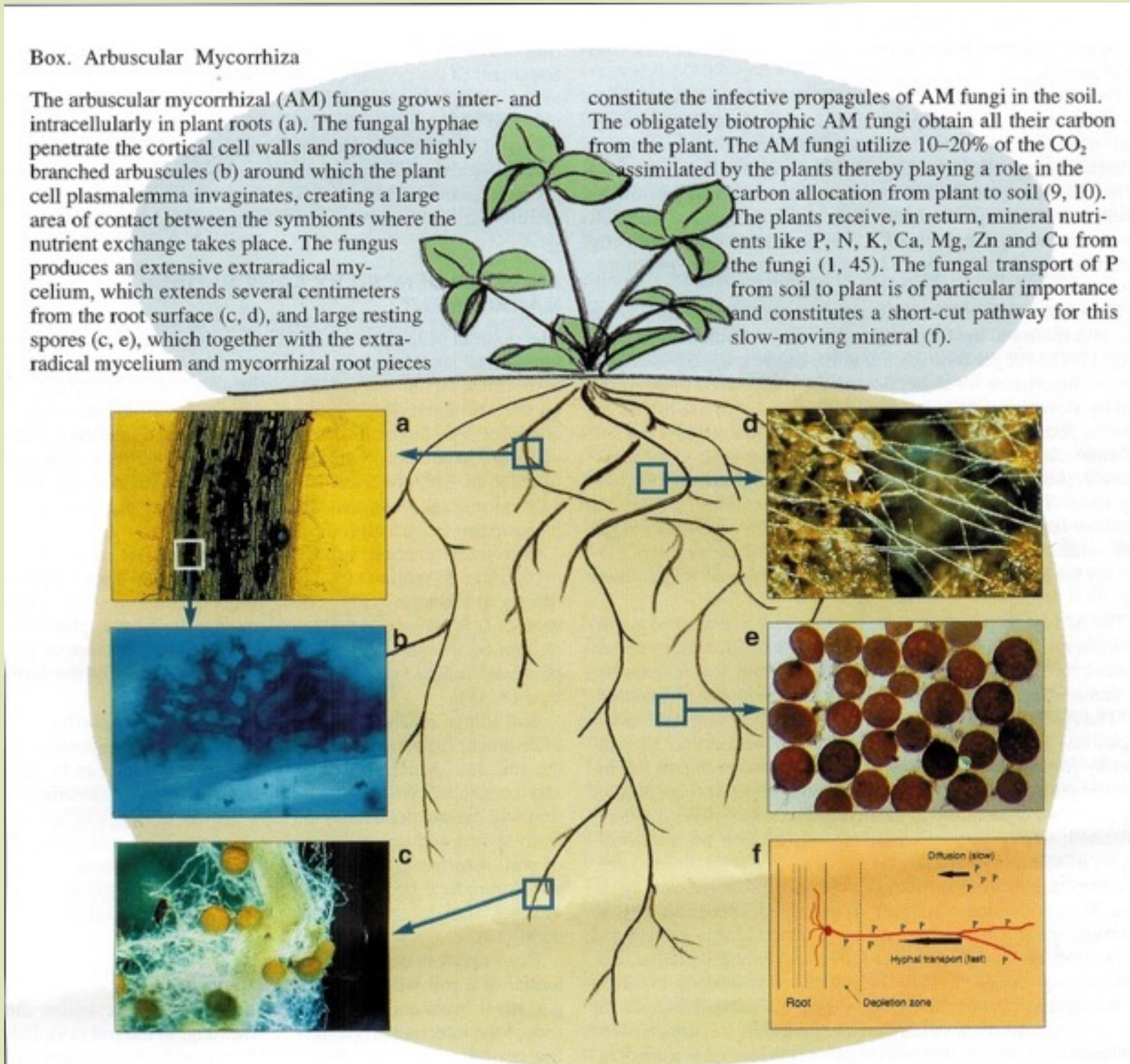
- **↓ Strigolactonas**

⬇

- **↓ AMF**



Raízes - Rizosfera



Box. Arbuscular Mycorrhiza

The arbuscular mycorrhizal (AM) fungus grows inter- and intracellularly in plant roots (a). The fungal hyphae penetrate the cortical cell walls and produce highly branched arbuscules (b) around which the plant cell plasmalemma invaginates, creating a large area of contact between the symbionts where the nutrient exchange takes place. The fungus produces an extensive extraradical mycelium, which extends several centimeters from the root surface (c, d), and large resting spores (c, e), which together with the extra-radical mycelium and mycorrhizal root pieces constitute the infective propagules of AM fungi in the soil. The obligately biotrophic AM fungi obtain all their carbon from the plant. The AM fungi utilize 10–20% of the CO_2 assimilated by the plants thereby playing a role in the carbon allocation from plant to soil (9, 10). The plants receive, in return, mineral nutrients like P, N, K, Ca, Mg, Zn and Cu from the fungi (1, 45). The fungal transport of P from soil to plant is of particular importance and constitutes a short-cut pathway for this slow-moving mineral (f).

Jakobson et al, New Phytologist 2001

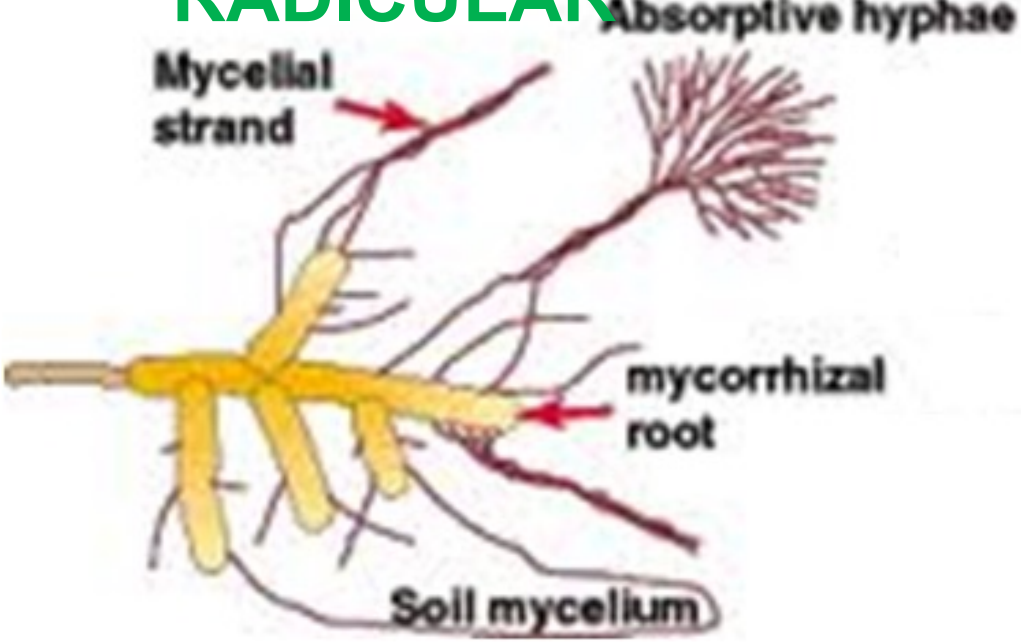
RIZOSFERA

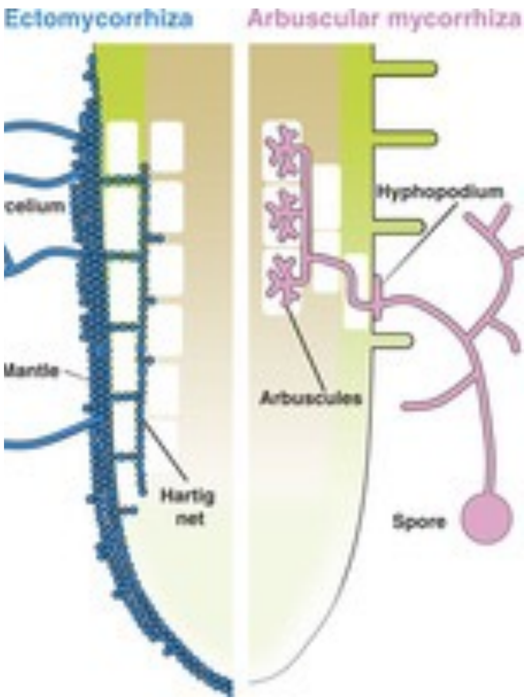
- Do grego, “Raiz - fungo” (Frank, 1885)
- Relações simbióticas entre fungos e raízes de plantas
- Existem em 80-90% das plantas vasculares

Originaram-se há cerca de 460 MA, vitais para a colonização da terra pelas plantas

The rizhosphere

THE RIZHOSPHEREO DESENVOLVIMENTO RADICULAR





O desenvolvimento radicular

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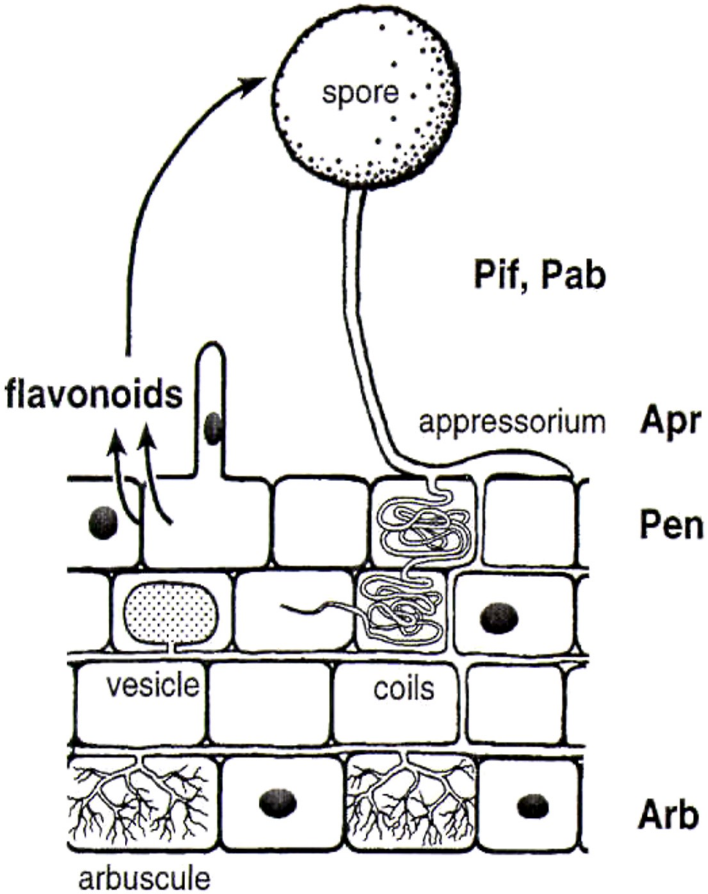

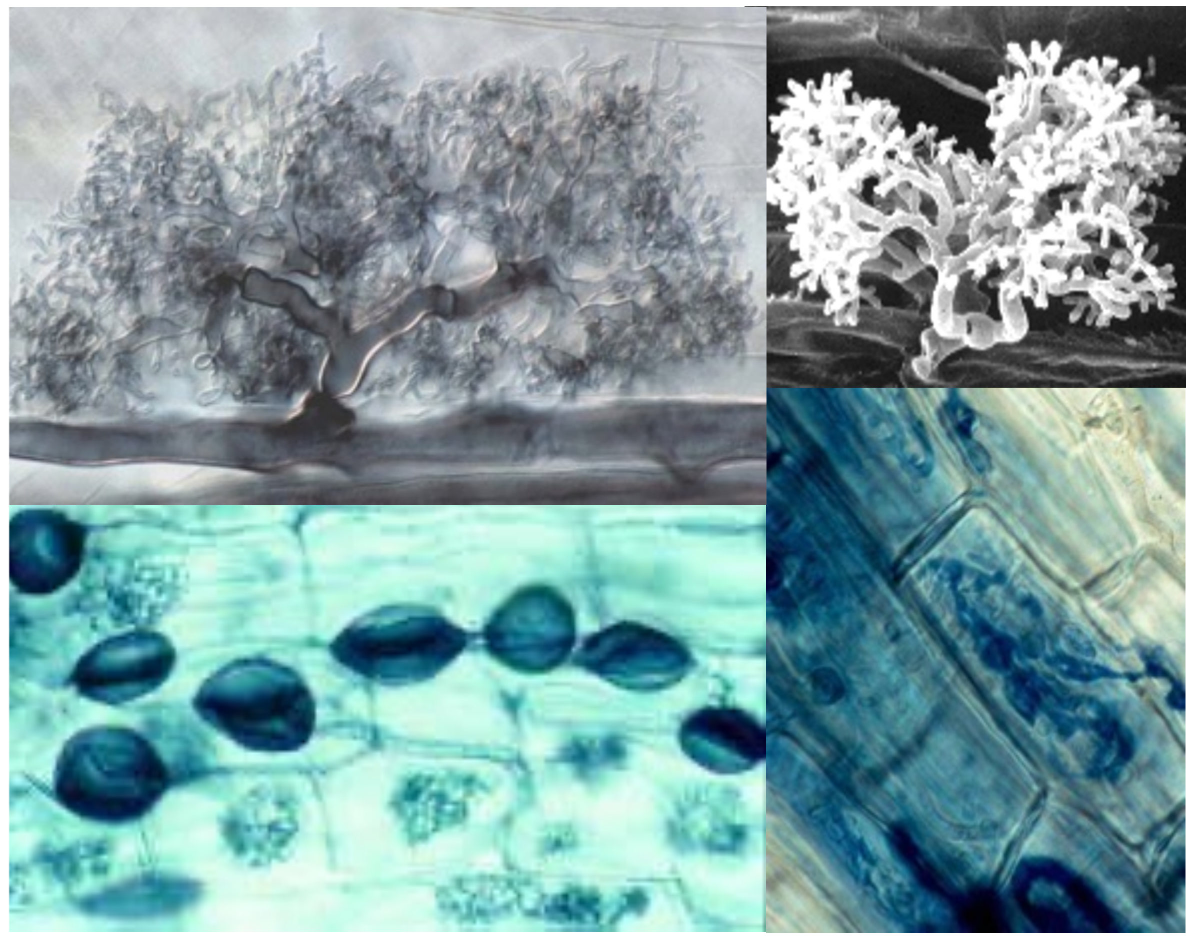

O desenvolvimento radicular

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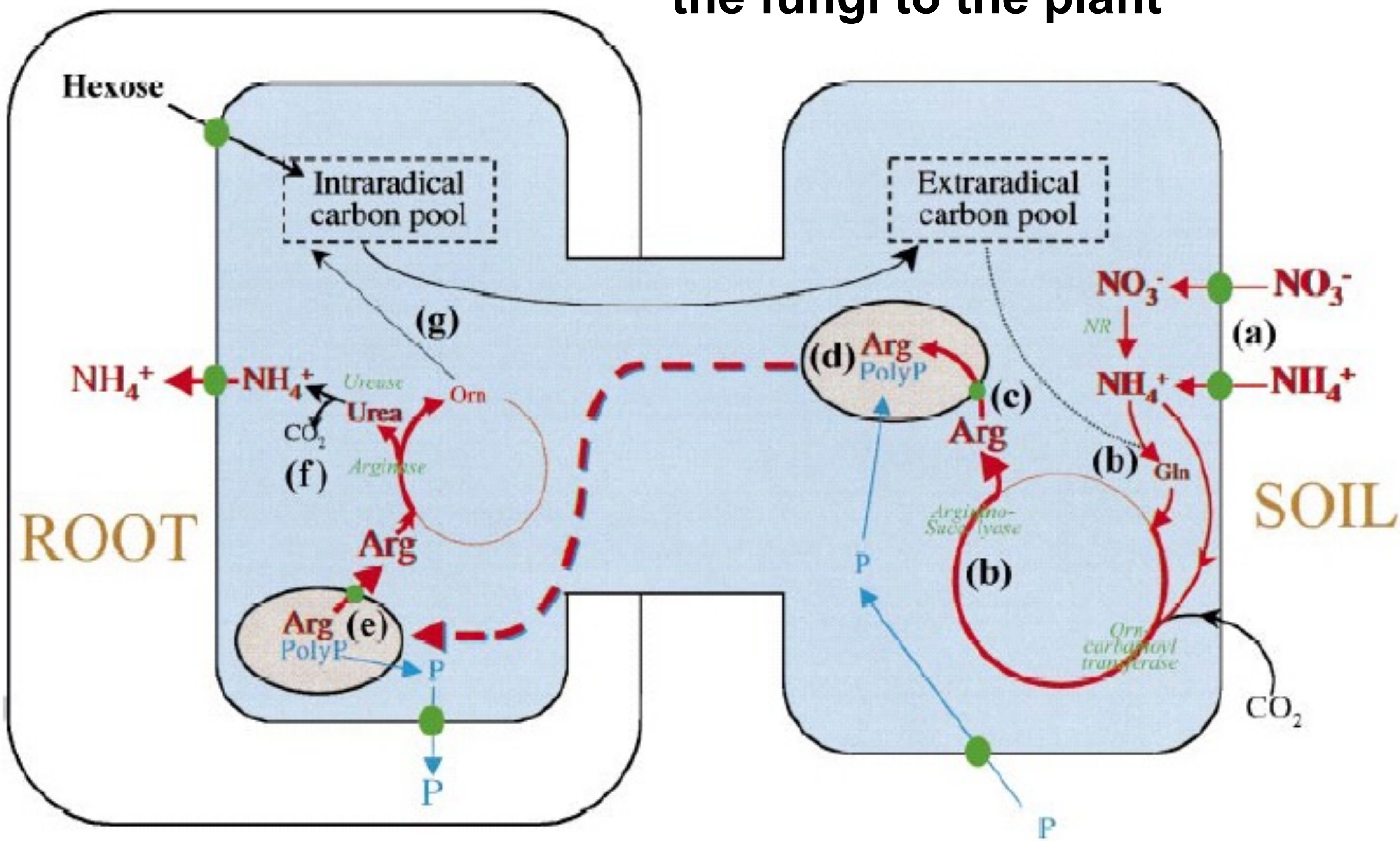
Putative model for N transference from the fungi to the plant



Plant nutrition