Arbuscular mycorrhizal colonization in plant roots

DSE-4
UNIT-7

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AM Colonization in Root – A complex process

- **The invasion of plant roots by AM fungal hyphae is a complex and tightly controlled process.**
- **AM development is initiated by the exchange of signalling molecules between the plant & the root.**
- **Followed by growth of fungal hyphae towards the root, hyphopodium formation at the root surface, and entry through the epidermal cell layer into the cortex of the root.**

❖Initial fungal penetration of the host root is mediated via a specialized cytoplasmic assembly called the PrePenetration Apparatus (PPA), which directs AM hyphae through the epidermis.

❖Once inside the root, the colonization involves the spreading of hyphae **between cortical cells or via intracellular passage of cortical cells** before they penetrate an inner cortical cell to form a terminally differentiated, highly branched structure called the arbuscule.

❖**Arbuscules are the site of nutrient transfer between the plant and the fungus and are therefore of crucial importance for the AM symbiosis.**

❖**Fossil evidence indicates that arbuscules were already present in the earliest land plants, and might have played a key role in enabling plants to colonize land.**

Fungal Colonisation of the Root Surface

Establishment of the association requires a signal exchange, in which plant-derived strigolactones, a plant hormone, are perceived by the AM fungi, which in turn produce a mixture of chitooligosaccharides and lipochitooligosaccharides that appear to function as fungal signalling molecules to the plant

Following signal exchange between the plant and the fungus, attachment of fungal hyphae occurs on root epidermal cells, where the **hyphal tips differentiate to form hyphopodia**, before hyphal entry of the root. Also associated with penetration of root cells by the fungus are **rearrangements of the host cytoskeleton and the remodelling of organelles**

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- Upon fungal attachment to an epidermal cell, the plant cell nucleus moves to the site of hyphal contact before migrating across the cell to the opposite side.
- Simultaneous with the nuclear movement away from the fungal attachment site, **a specialised tunnel-like structure called the pre-penetration apparatus is formed.** This apparatus is derived from an accumulation of a dense network of ER cisternae, actin filaments and microtubules.
- Once the pre-penetration apparatus has assembled and spans the whole width of the cell, **the fungal hypha enters the cell lumen through this pre-formed cytoplasmic bridge and is guided across the cell on this pre-defined path .** The pre-penetration apparatus is associated not only with fungal entry of epidermal cells, but also with colonization of the root cortex during arbuscule formation.
- Following successful entry of fungal hyphae through the epidermal cell layer, the **hyphae spread** inside the plant root, primarily **intercellularly, until they reach the inner cortical cell where arbuscules are formed** terminally by extensive dichotomous branching.
- **The host plasma membrane** does not rupture. Instead, it **expands to envelop the hyphal branches and forms the so-called periarbuscular membrane, which separates the fungal hyphae from the host cytoplasm.**

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- **Arbuscules typically have a relatively short life span of about two to eight days before they rapidly collapse.** This degeneration of arbuscules can be followed by recolonization of the root and the formation of new arbuscules, sometimes in the same cells that previously accommodated arbuscules, resulting in simultaneous cycles of arbuscule formation and degradation.
- **AM fungi benefit the host plant by facilitating the uptake of water and an array of essential mineral nutrients, including phosphate and ammonium**, and in many ways the fungus can be considered as an extension of the root surface area.
- The thin, extraradical fungal mycelium is able to reach and mineralize soil nutrients much more efficiently than plant roots, and mycorrhization significantly improves the nutrient status of the plant.
- Periarbuscular membrane-localised proteins, such as phosphate transporters, help in nutrient exchange with the fungus

(A) PRE-SYMBIOTIC PHASE

I. RESPONSE OF AM FUNGI TO PLANT DERIVED SIGNALS

- **Strigolactones-** short lived compound, forms a conc. gradient, stimulates spore germination.
- 5-deoxy-strigol: identified by fungi, leads to-

i. Induction of branching
ii. Enhanced fungal growth
iii. Increased mitochondrial activity

II. RESPONSE OF PLANT TO FUNGI DERIVED SIGNALS

- *Myc* factors- soluble, fungus signalling molecule.

In plants-

- Induces transcriptional activation of plant symbiosis related genes.

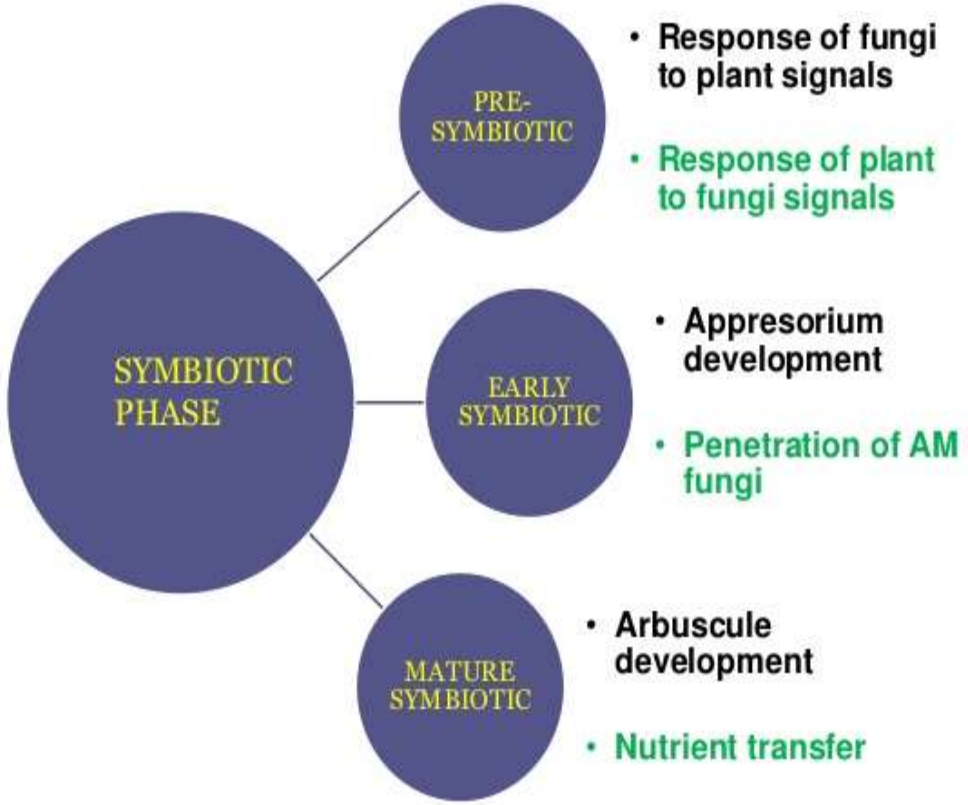
- attachment of fungal hyphae occurs on root epidermal cells

II. SYMBIOTIC STAGE

- Begins with the colonization of hyphae with compatible root.
- After attachment-

i. Appresorium formed (fungus enters in cortex).

i. Formation of specialized structures- inter- & intra-cellular hyphae, coils, arbuscules.

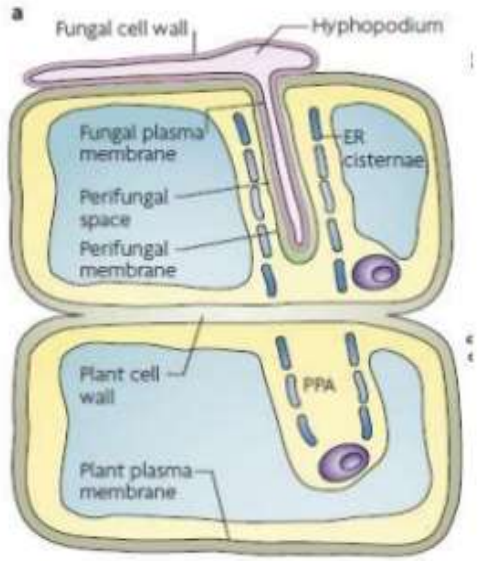


(B). EARLY SYMBIOTIC PHASE
I. APPRESORIUM DEVELOPMENT

- **Appresorium**- A flattened, hyphal organ that facilitates the penetration of cells or tissues of other organisms.
- AM fungi forms a special type of appresoria called as hyphopodia, developed from mature hyphae.
- Formation – 1st morphological sign due to successful pre-symbiotic recognition events.

II. PENETRATION OF AM FUNGI

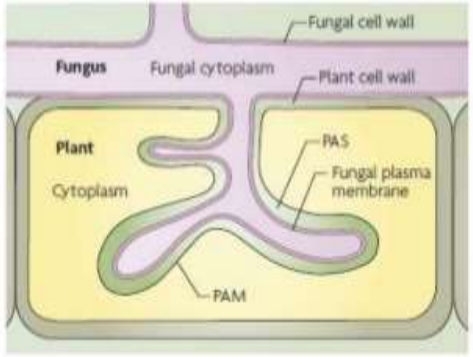
- Due to sequential chemical and mechanical stimulation, plant cells produce a PPA.
- Fungal hypha enters the PPA, guides the fungus through root cells towards the cortex.
- In inner cortex, the fungus leaves the plant cell, enters the apoplast, branches and grows laterally along the root axis.

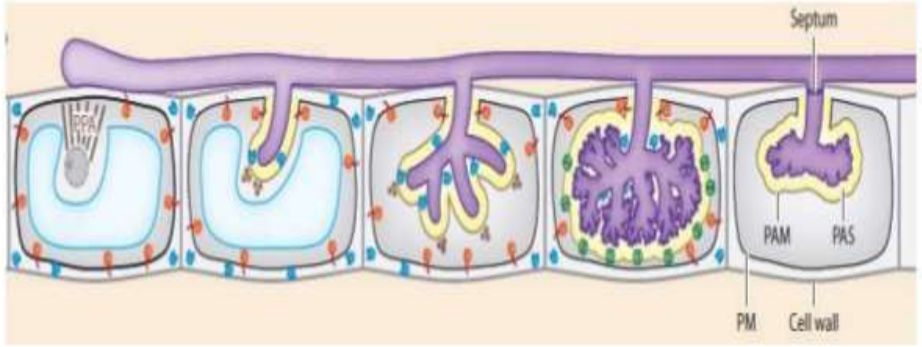


(C). MATURE SYMBIOTIC PHASE

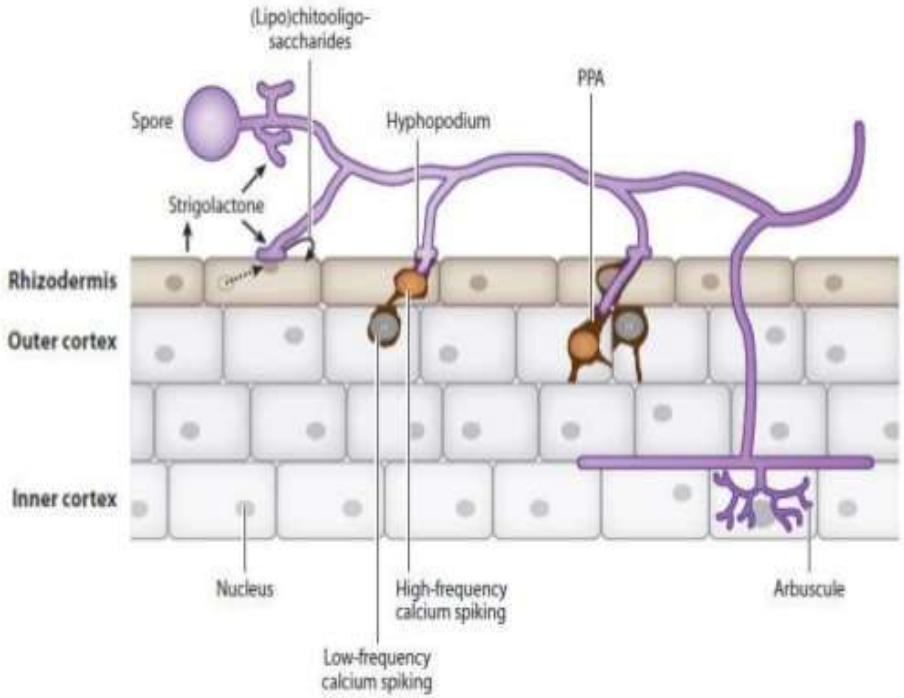
1. ARBUSCULE DEVELOPMENT

- Hyphae induce the development of PPA-like structures in inner cortical cells, enter the inner cortical cells and branch to form arbuscules.
- Vesicles, function as storage organs of the fungus.
- New spores are typically synthesized outside of the plant root at the leading tip of individual fungal hyphae.

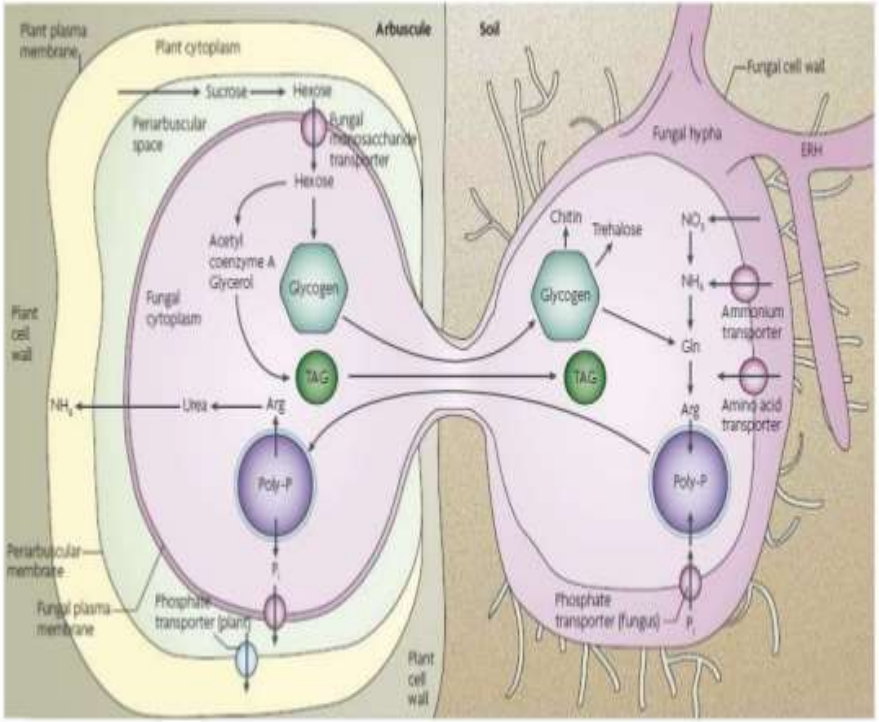




overview

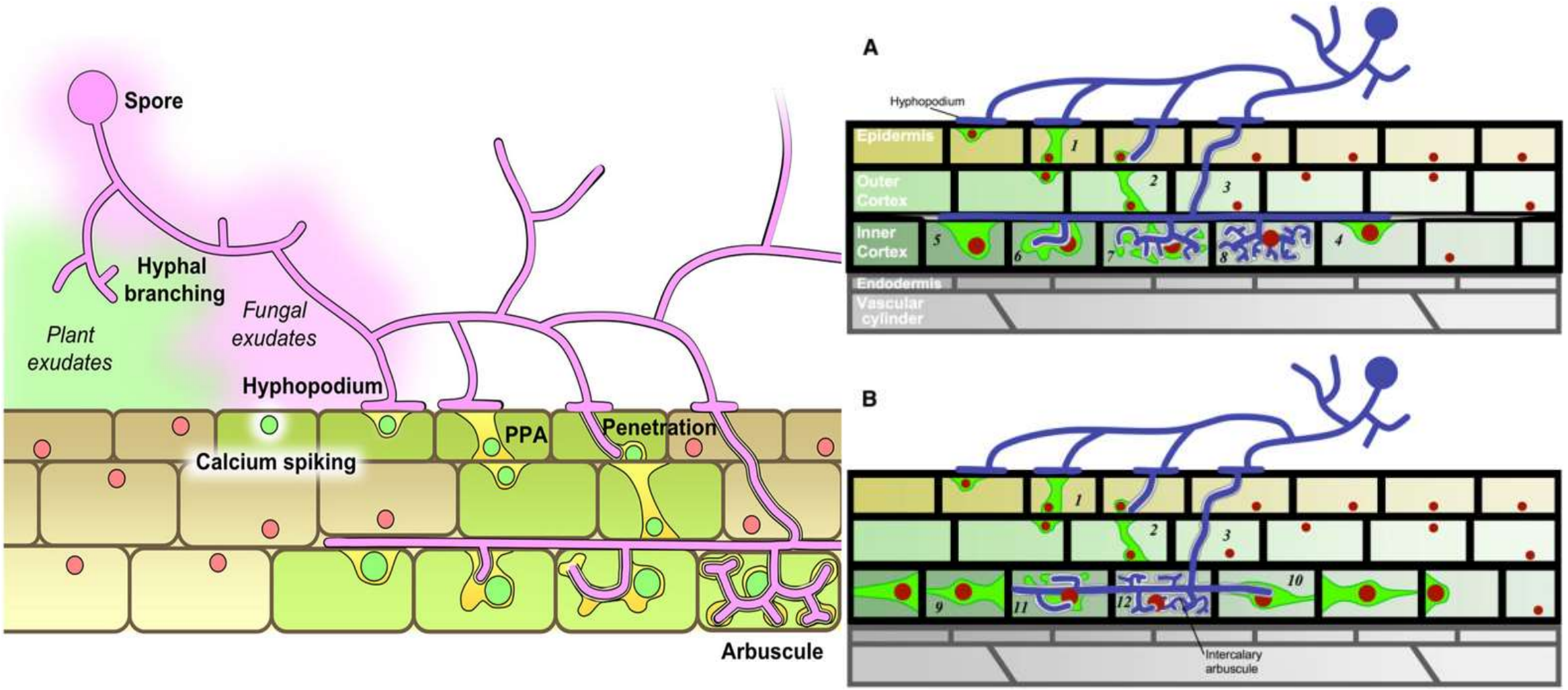


II. SYMBIOTIC INTERFACE AND NUTRIENT TRANSFER



After uptake into the fungal mycelium, phosphate and nitrogen are transported in the form of polyphosphates and arginine to the arbuscules, where they are released into the periarbuscular space as phosphate and ammonium, respectively

https://www.researchgate.net/publication/377394759/figure/fig1/AS:11431281217576944@1705282387074/Plant-root-colonization-by-arbuscular-mycorrhizal-fungi-AMF-Created-with-BioRender.jpg



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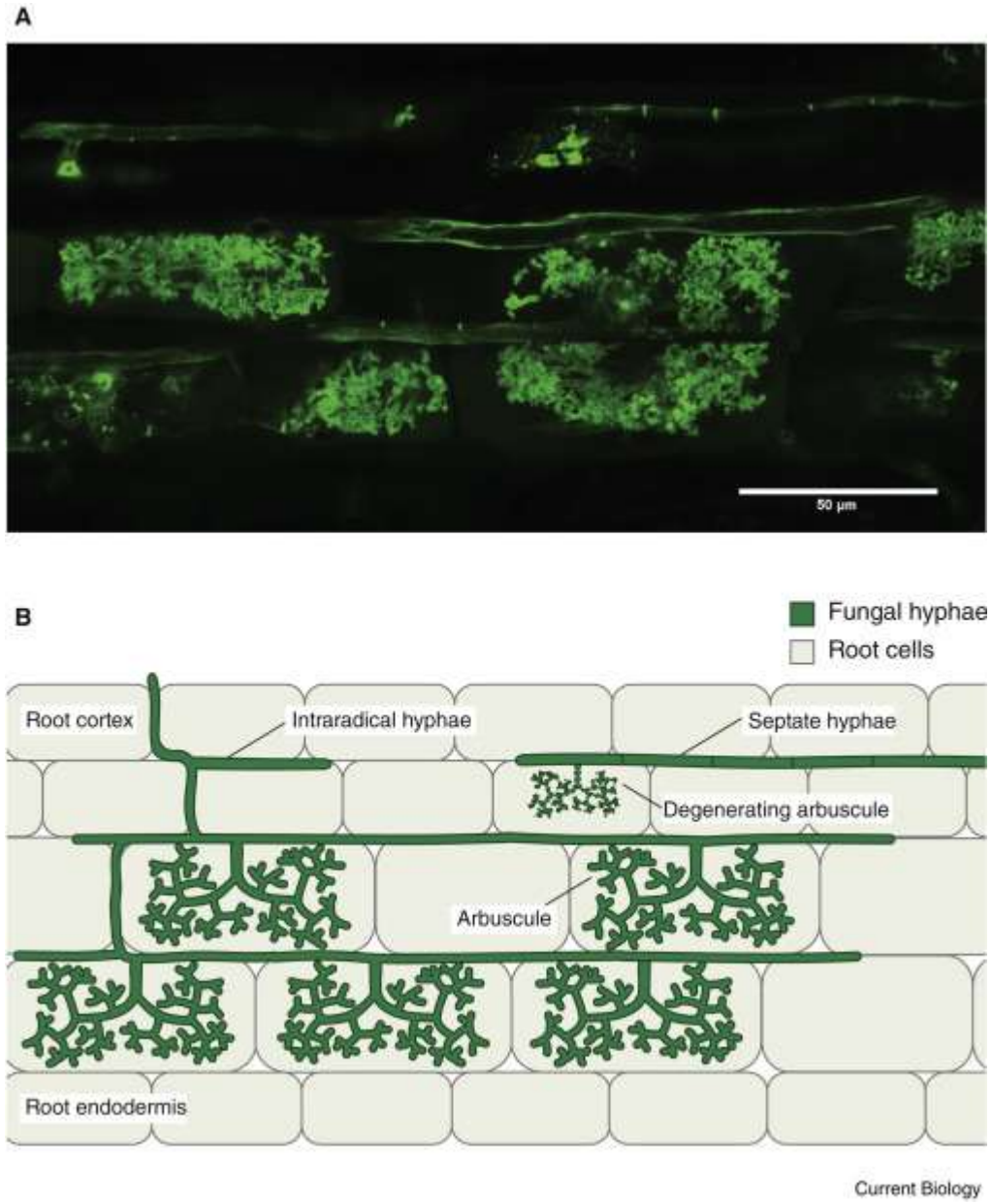
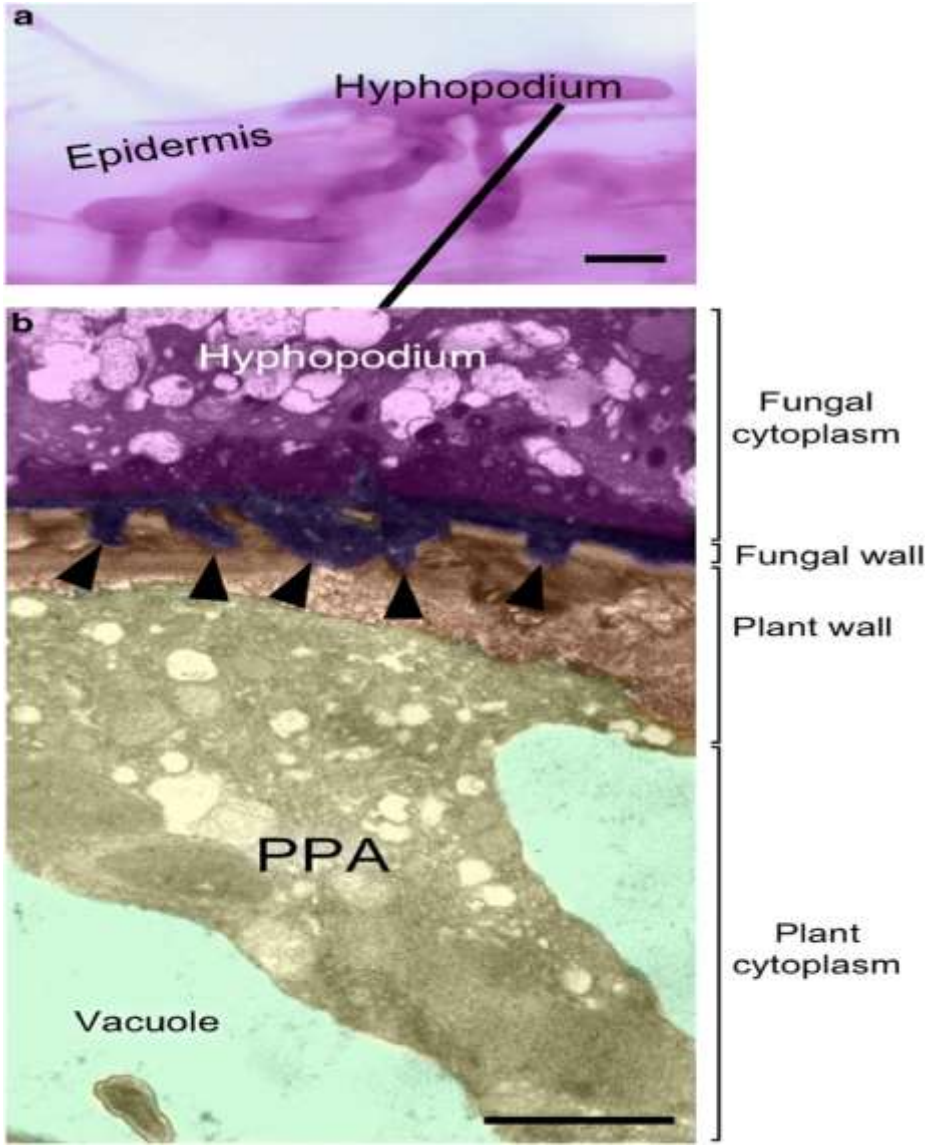

A
50 µm
B
Fungal hyphae
Root cells
Root cortex
Intraradical hyphae
Septate hyphae
Degenerating arbuscule
Arbuscule
Root endodermis
Current Biology


a
Hyphopodium
Epidermis
b
Hyphopodium
PPA
Vacuole
Fungal cytoplasm
Fungal wall
Plant wall
Plant cytoplasm