Advanced fungal physiology

Nutrition and morphological adaptations

PhD level

Prof. Dr. Inaam Alrubayae

Morphological adaptations to the absorptive nutrition of fungi

- . Fungi grow within their food supply.
- Structures have evolved that facilitate the exploitation of the substrate.
- Parasitic fungi, in addition, have developed a wide variety of structural features that aid in the penetration of the host and the subsequent ramification through its tissues

Modification of mycelia and hyphae

A. Modifications Associated with Nutrient Procurement.

- Pathogenic fungi of plants have modified special hyphae called haustoria.
- A pathogen growing on the surface of a plant will at intervals produce hyphae which penetrate the host cell wall and ramify intracellularly as haustoria.
- As the haustorium grows it distends the plasma membrane of the host cell but does not enter the cytoplasm.
- The host cell secretes a polysaccharide sheath as response to this invasion
- The sheath lies between the haustorial wall and the host cytoplasm.

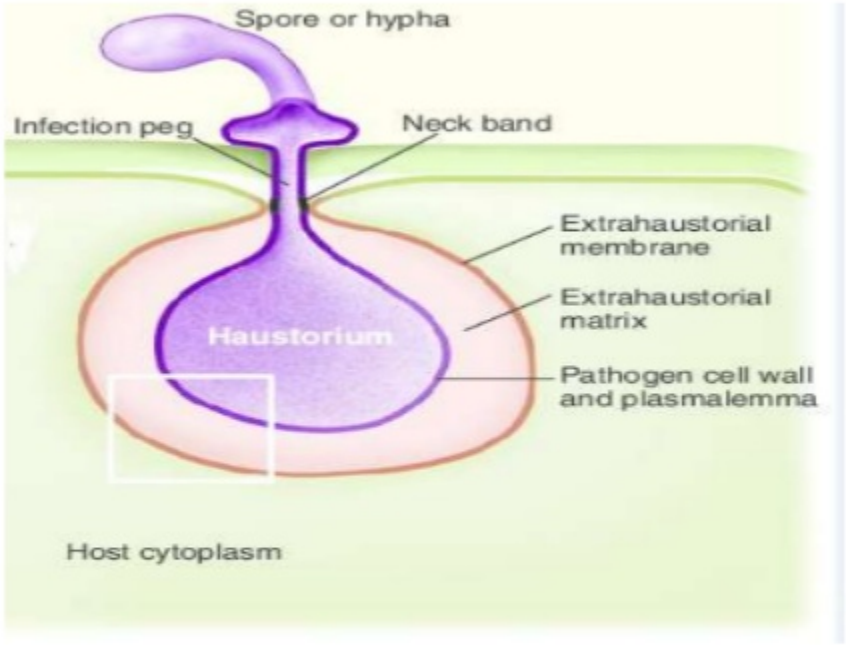


Fig: Showing invagination of host cell and uptake of nutrients by fungal haustorium

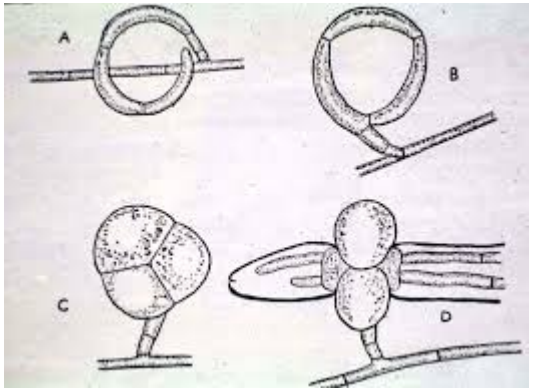
- Haustoria are the structural adaptations for

1-bringing the fungus into an intimate association with the host cell.

2- for increasing the surface area available for nutrient absorption.

3- Because the haustorium does not penetrate the plasma membrane and thus does not immediately kill the cell, the pathogen can "tap" nutrients from the host for an extended period of time.

- The hyphae of certain other fungi are modified into structures used for trapping invertebrate animals, particularly nematodes.
- Some of these hyphal traps are networks of loops and constricting rings that snare a nematode as it attempts to pass through.



- Modifications Associated with Nutrient Transport.
- Strands and rhizomorphs are aggregations of parallel hyphal strands that aid in the transport of nutrients over relatively long distances.
- In a strand the hyphae are loosely associated but may fuse at intervals in an anastomosing pattern.
- Such strands grow in diameter by the addition of hyphae at the base.
- Rhizomorphs, though similar in appearance to strands, are much more highly organized and grow from an apical meristem in a manner resembling the growth of a plant root.

- The rhizomorph is an autonomous structure that involves a greater degree of coordination among component hyphae than that found in strands.
- Strands and rhizomorphs are usually subterranean structures that infect roots of higher plants.
- The rapid rate at which nutrients are transported via these structures enables a pathogen to infect a host at some distance from its original food supply.

- What are Rhizomorphs?

- A rhizomorph is a rope-like aggregation of many hyphal strands. The word “rhizomorph” literally means “root form”. Rhizomorphs are so named because they resemble plant roots. Rhizomorphs in a backyard or forest are a sign of a vibrant fungal community. You may have seen them in soil, under the bark of dying trees, or wrapped around decaying stumps.

Are Rhizomorphs Good or Bad?

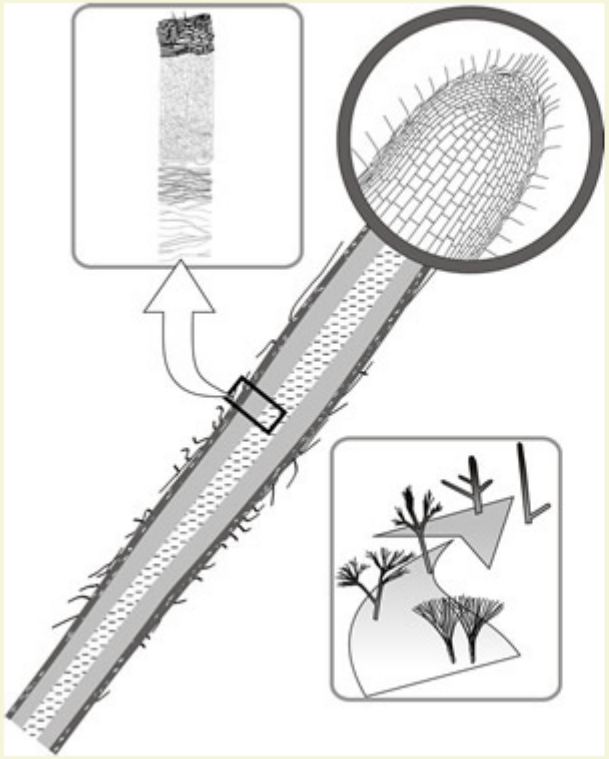
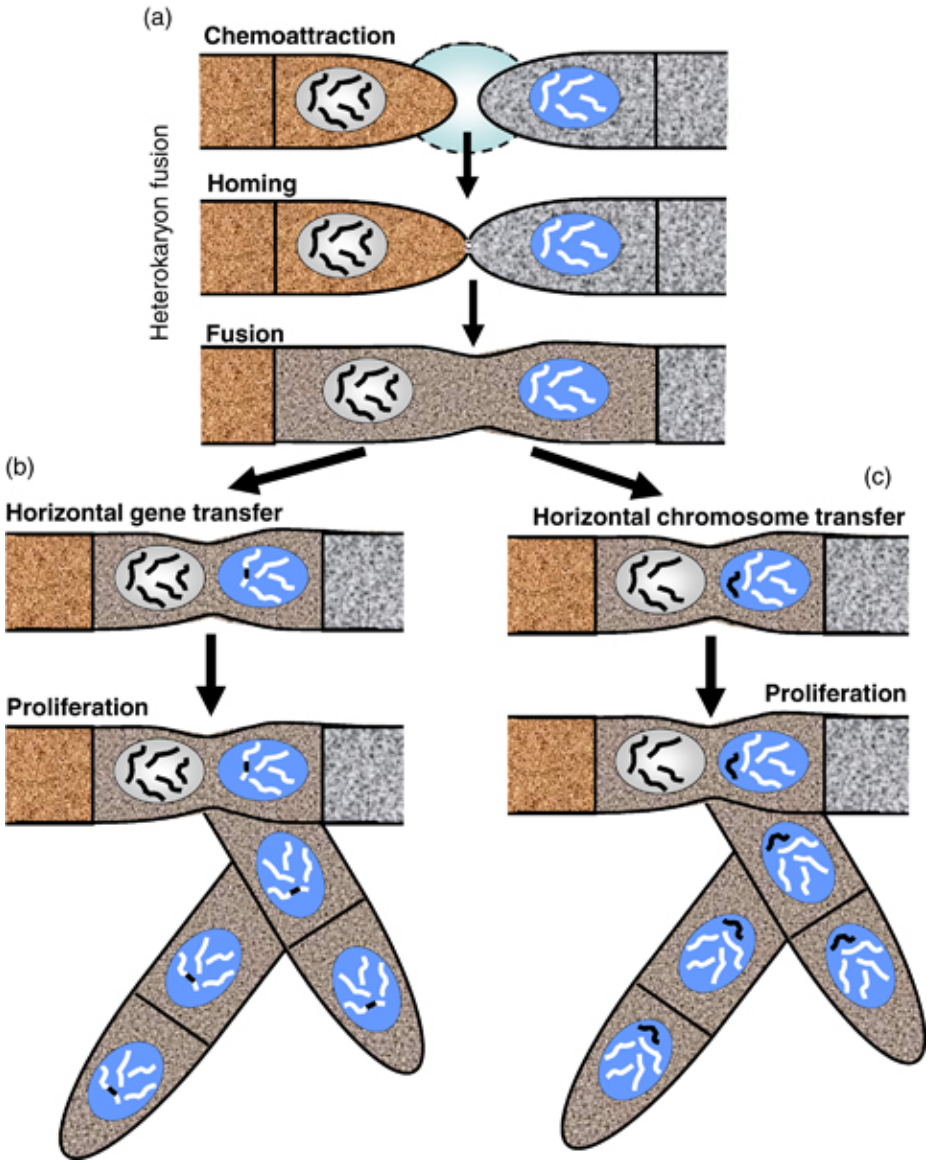


Fig. 14. Rhizomorph structure. The diagonal diagram is a sectional drawing showing general structure, with the apical region magnified to show the appearance of a growing point of tightly packed cells. Behind the tip is a medullary zone containing swollen, vacuolated and often multinucleate cells surrounded by copious air- or mucilage-filled spaces. The medullary region forms a central channel through the rhizomorph and, in mature tissues, is traversed by narrow fibre hyphae and wide-diameter vessel hyphae, the microscopic appearance being indicated in the drawing in the top left panel. The panel at bottom right depicts mycelial fans, strands, cords and rhizomorphs as a series showing increasing apical dominance (Rayner *et al.*, 1985). Modified from Moore, 1995.

- Anastomosis is the process by which fungal cells fuse together. This process is very important for filamentous fungi because it allows them to form networks and is a key part to sexual reproduction.
- Anastomosis predominantly occurs in older parts of the mycelium, which tend to have hyphae that are close together and have fewer available nutrients (because the fungus has already consumed most of those resources).

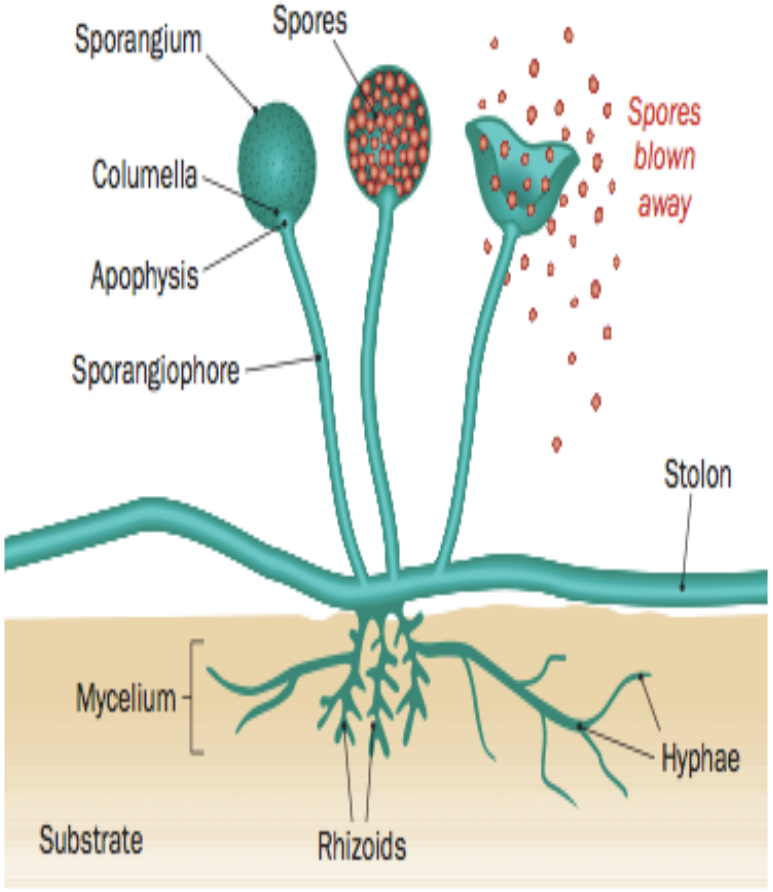
- In these areas, hyphae anastomose when growing close together.
- This results in the formation of links between different hyphae, thus creating a true reticulating network.
- Such a network has multiple links between its different sections, like a net or a web.
- This allows the fungus to transfer resources and communication molecules from one part of the mycelium to any other part, which lets the mycelium to act as a single organism.


(a)
Chemoattraction
Heterokaryon fusion
Homing
Fusion
(b)
Horizontal gene transfer
Proliferation
(c)
Horizontal chromosome transfer
Proliferation

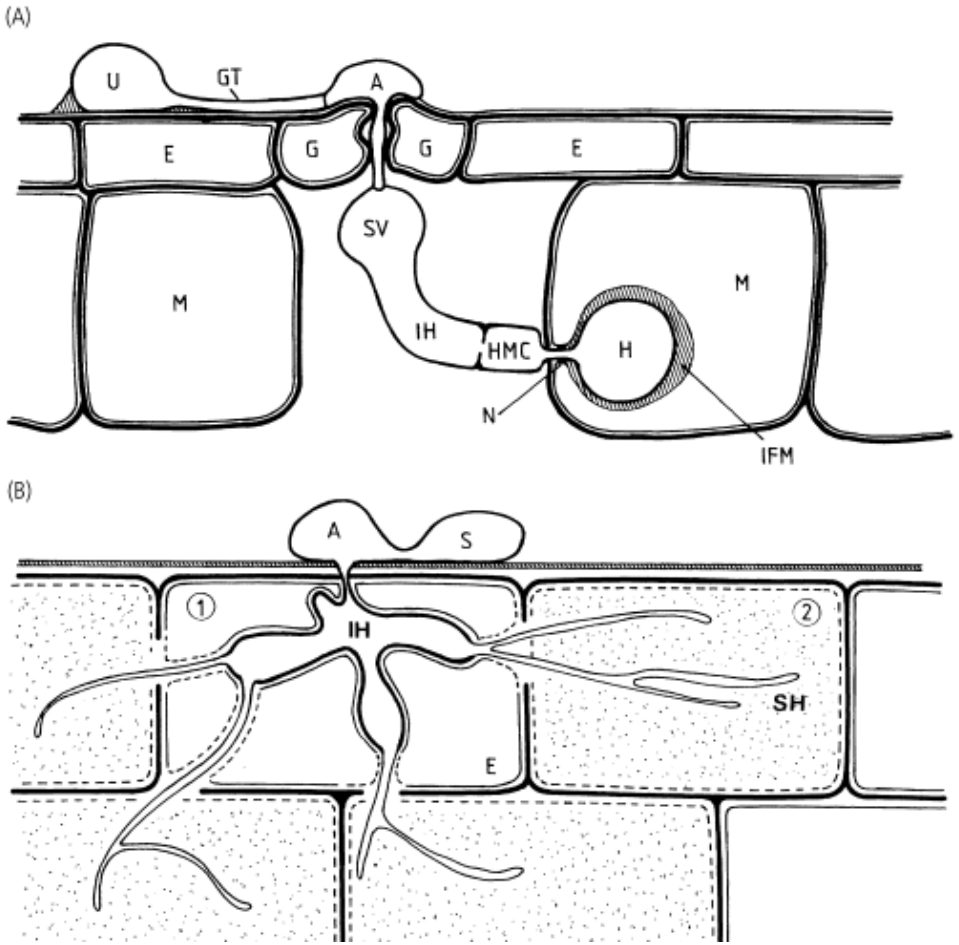
Mechanism of Nutrition

- In saprophytic fungi the hyphae (*Mucor mucedo*) or rhizodial hyphae (*Rhizopus stolonifer*) come in intimate contact with nutrients in the substratum and absorb soluble smaller molecules such sugars and amino acids.
- Insoluble complex substances such as proteins, lipids and Poly are first broken into soluble monomers (digested) by secreting extra-cellular enzymes and then absorbed.

- The fungal hyphae secrete enzymes which convert insoluble complex food materials in the substratum to soluble ones.
- The latter are then absorbed by direct diffusion either through the hyphal walls of the hyphae that penetrate the substratum or by the rhizoidal hyphae



- The mycelium of the parasites is rarely ectophytic but frequently it grows inside the host.
- The hyphae either ramify in the intercellular space between the host cells and called intercellular hyphae
- or penetrate into the host cells and called latter intracellular hyphae.


(A)
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- The intercellular hyphae obtain nutrition through the cell walls or membranes of the host cells. This they do by secreting an enzyme upon the plasma membrane of the host cell.
- It makes the membrane more permeable to the contained solutes. The latter diffuse out and are absorbed by the hyphal walls. The hyphal walls of the intracellular hyphae come in direct contact with the host protoplasm and obtain food by direct diffusion

- The intercellular hyphae of some highly specialized (obligate) plant parasites give out slender lateral outgrowths. The hyphal outgrowth punctures the host cell wall making a minute pore through which it enters the host cell. Within the host cell, it enlarges to form a globose, lobed, or branched absorptive organ

Properties of Haustoria

- This type of feeding organ of the parasitic fungi is called a haustorium.
- It is markedly specialized in structure to absorb nutrition from the host tissues.
- The haustonum is intracellular and thus robs the host of its food without killing it.
- Haustoria are characteristic of obligate parasites.

Types of Haustoria

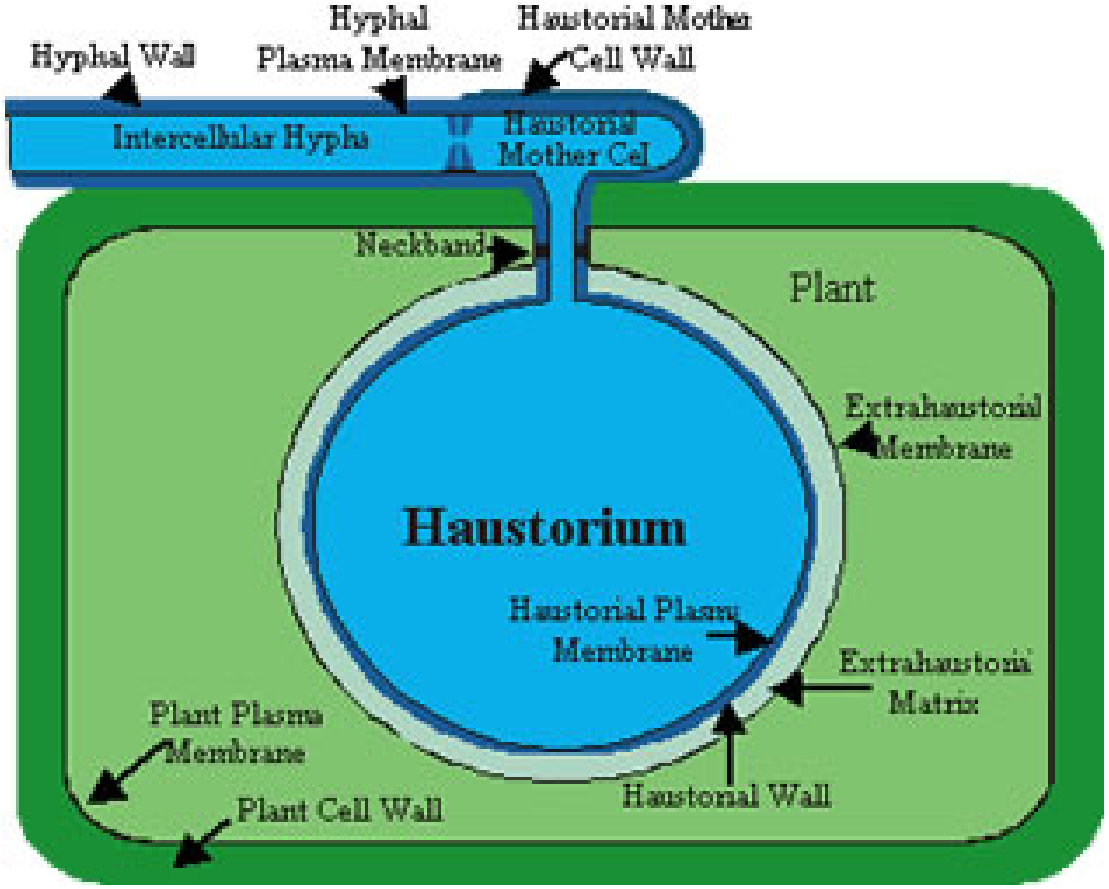
- In *Albugo* the haustorium is a button-like or spherical structure.
- *Peronospora parasitica* has sac-like haustoria in the leaf cells of *Capsella*.
- *Peronospora calotheca* produces branched filamentous haustorium in the stem cells of *Galium* .
- *Erysiphe graminis* forms an elongated branched haustorium inside the host cell

Structure of Haustoria

- Each haustorium usually consists of two parts, 1- A constricted region which is in the form of a narrow penetration tube and the expanded or branched region on the host cell.

2- The penetration tube is usually clasped by a 'collar' of host wall material.

- The enlarged or expanded region of the haustorium causes Invagination of the cytoplasmic membrane of the host cell. The latter remains closely appressed to the wall of the haustorium. There is a zone of apposition enclosing the haustorium between the fungal wall and the unbroken cytoplasmic membrane of the host. Its origin is in dispute.


Hyphal Wall
Hyphal Plasma Membrane
Haustorial Mother Cell Wall
Intercellular Hypha
Haustorial Mother Cell
Neckband
Plant
Extrahaustorial Membrane
Haustorium
Haustorial Plasma Membrane
Extrahaustorial Matrix
Plant Plasma Membrane
Haustorial Wall
Plant Cell Wall

- The secretion from the haustorium upon the plasma membrane of the host makes it permeable to solutes contained in the sap cavity.
- They diffuse out and are then absorbed by the haustorium, (parastic fungi do not produce haustoria in artificial cultures).
- The haustoria are also not produced by fungi which live as parasites on animals.

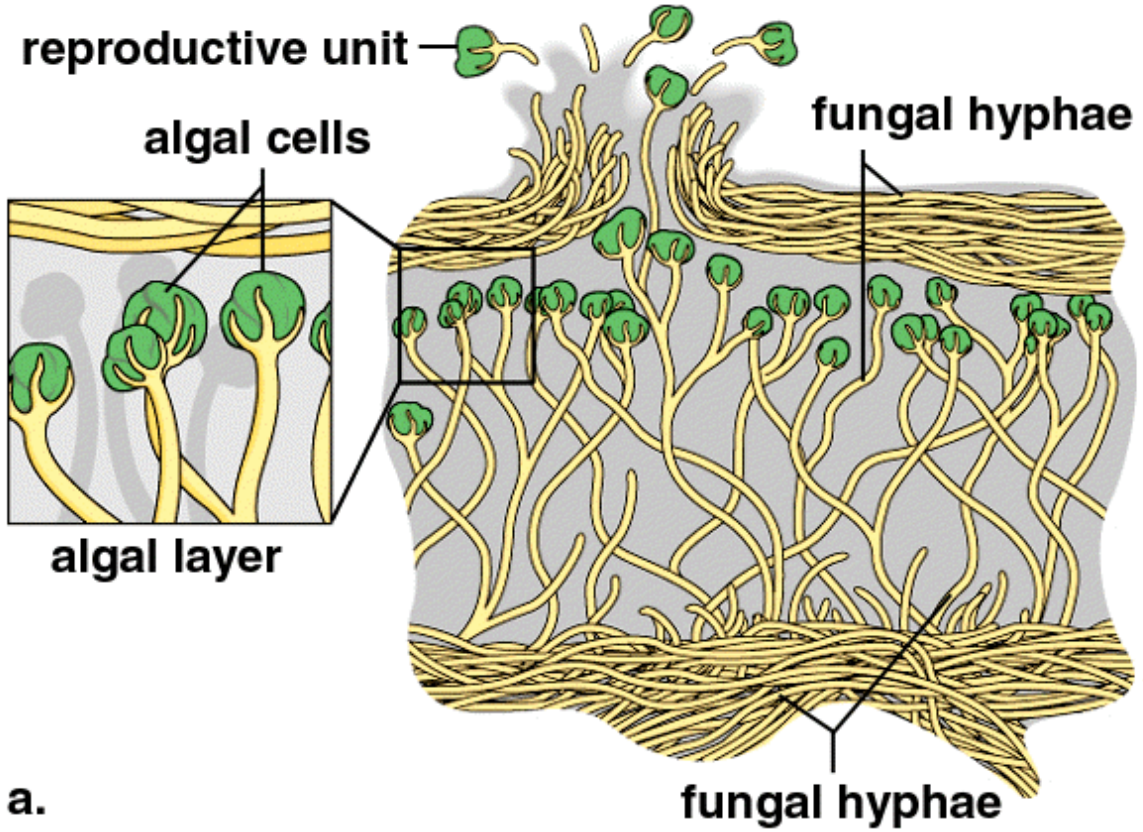
Mutualistic associations of fungi with other plants

- Many fungi obtain nutrition by living in mutually beneficial associations with other plants.
- The Association is not causal but permanent and is established during long process of evolution.
- The two best known examples of mutualistic associations of fungi with other plants are Symbiosis and Mycorrhiza.

Symbiosis

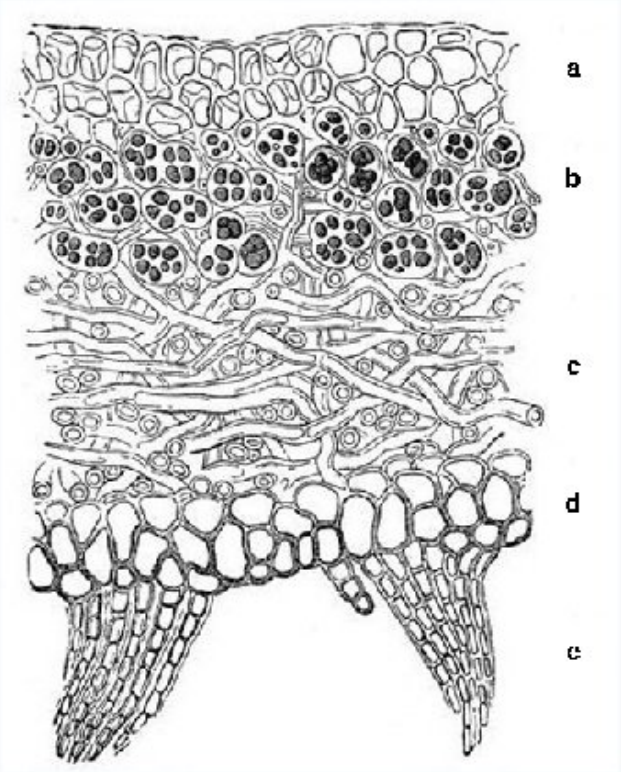
- The common example of symbiosis is an association of a fungus and an alga in a lichen thallus.
- The two organisms in this association are so intertwined as to form a single composite thallus plant which different from either of the partners in form and habit.
- The duty of alga in this partnership is to synthesize food with the help of green chloroplasts and share it with its fungal partner.
- The fungus absorbs minerals in solution and water from the substratum and press on to the alga. The fungal hyphae which form the bulk of the lichen thallus provide shelter to the alga, in addition.

Lichen morphology



Lichen Structure

This cross-section of a lichen thallus shows the (a) upper cortex of fungal hyphae, which provides protection; the (b) algal zone where photosynthesis occurs, the (c) medulla of fungal hyphae, and the (d) lower cortex, which also provides protection and may have (e) rhizines to anchor the thallus to the substrate.

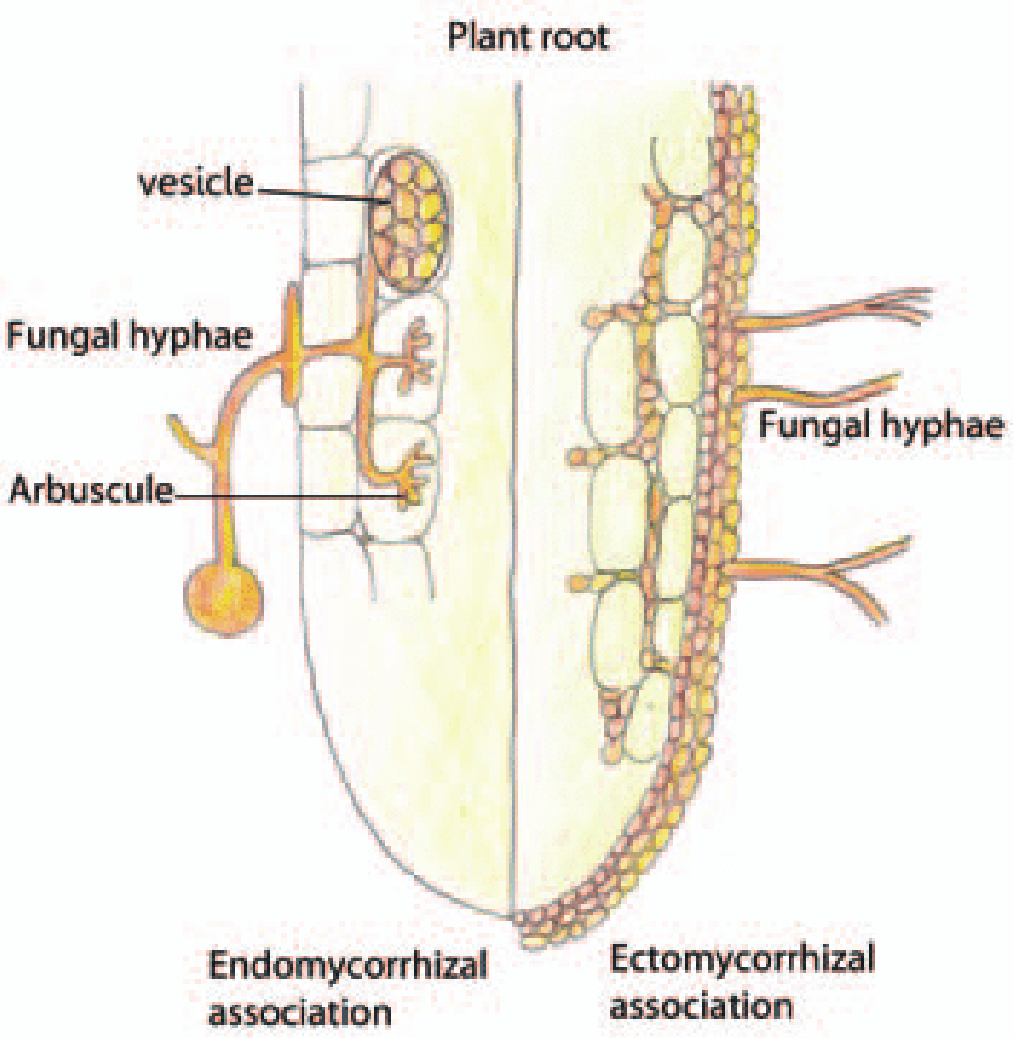


Mycorrhiza.

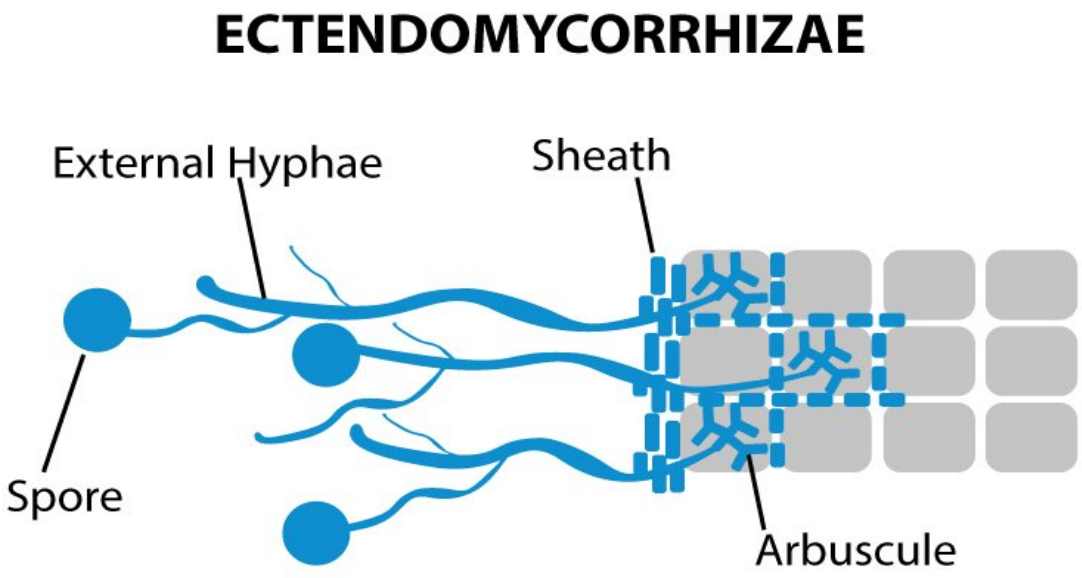
- It is defined as the symbiotic association between the hypha of certain fungi and roots of plants.
- It is of three types:
- 1. Ectomycorrhiza,
- 2. Endomycorrhiza,
- 3. Ectoendomycorrhiza.

- **Ectomycorrhiza**:
- The fungal hyphae in this case form a complete envelope around the root tip and also penetrate and extend into the first few cortical layers to form an intercellular network of hyphae known as the Hartignet.
- The hyphal strands that extend into the substrate from the envelope absorb water and nutrients from the soil and pass them on to the roots of the plant through the Hartig's net.
- The presence of the fungus thus increases root absorption. In return the fungus receives food and shelter.

- **Endomycorrhiza:**
- The fungal hyphae, in this case, penetrate root hairs, epidermis and reach the cortex where they grow intracellularly forming fungal knots in the cortical cells.
- A portion of the mycelium lives in the soil but it forms no dense hyphal growth (envelope on the surface of the root).


Plant root
vesicle
Fungal hyphae
Arbuscule
Fungal hyphae
Endomycorrhizal association
Ectomycorrhizal association

- Ectoendomycorrhiza:
- It is a combination of the two. The fungal hyphae form a sheath at the surface of the root. Within the root, they grow intracellularly and intracellularly.

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