BIOLOGY AND DIVERSITY OF VIRUSES, BACTERIA AND FUNGI (PAPER CODE: BOT 501)

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OBJECTIVES

The main objective of the present lecture is to cover the topic and make it easy to understand and interesting for our students/learners.

BLOCK – III : FUNGI – I

Unit –12 : Nutrition in Fungi

In this lecture we will discuss about the nutritional requirements, essential elements, sources of macro elements, modes and mechanism of nutrition in fungi.

CONTENT

- Nutritional Requirements
- Essential Elements
- Sources of Macro Elements
- Mode of Nutrition
  - Saprophytes
  - Parasites
  - Symbionts
  - Predacious fungi
- Mechanism of Nutrition:
- Key points of the lecture
- Terminology
- Assessment Questions
- Bibliography

NUTRITIONAL REQUIREMENTS OF FUNGI

- Fungi are achlorophyllas, heterotrophic eukaryotic thallophytes. The nutrition requirement of the fungi is discussed below:

❑ Nutritional Requirements:

- The fungi utilize both organic compounds and inorganic materials as the source of their nutrient supply.
- In other words, organic and inorganic compounds constitute their food.
- No fungus is able to make any increase in its dry weight in the absence of organic food materials, why? Because lacking chlorophyll the fungi are unable to photosynthesize or use carbon dioxide to build up organic food materials.
- They are, thus heterotrophic for carbon (organic) food compounds which they in their natural habitats obtain by living as saprophytes or parasites from dead or living plants, animals or micro-organisms or their wastes.

❑Essential Elements:

- The constituent elements of the organic and inorganic substances which fungi make use of are C, O, H, N, P, K, Mg, S, P, Mn, Cu, Mo, Fe and Zn. Calcium is required by some fungi but not all.
- These elements which fungi require as food are termed the essential elements. Some of these, the fungi need in extremely small trace amounts and the others in comparatively larger amounts.

- The former are called the trace or micro elements and the latter macro elements.
- The fungal growth is adversely affected or the fungus fails to grow if any one of the essential elements is lacking in the culture medium.
- Examples of the macro elements are C, N, O, H, S, P, K and Mg. The macro elements are body builders and provide energy for metabolic processes.

Sources of Macro Elements:

- The organic substances usually utilized by fungi are very varied in nature. Yeasts, for example, can use acetates as sources of carbon but for most fungi the chief sources of carbon are the carbohydrates.
- The carbohydrates are needed for building up the body and also as a source of energy.
- In a typical fungus, 50% of the dry weight is carbon of the carbohydrate source of carbon, most fungi use simple sugars.
- Glucose, for instance, is suitable for almost all fungi. Next in preference are the fructose.
- Less commonly used are the hexose sugars and some pentoses. Xylose among the pentoses has been reported to be superior to glucose for some fungi.
- Mannitol is equivalent to glucose for many fungi. Maltose which occurs in nature as a byproduct of starch hydrolysis is utilized by many fungi.
- Sucrose is also a good source of carbon for some.

- From among the polysaccharides, starch and cellulose are utilised by a fewer fungi which can synthesize the appropriate hydrolytic enzymes.
- Some fungi are able to make good growth on fats as the only source of carbon.
- Organic acids are generally poorer sources of carbon for most fungi.
- Basidiomycetes include most of the lignin-utilizing fungi.
- Proteins, lipids some organic acids and higher alcohols are utilized by some fungi as a sole energy source of growth, however, is always better on a substance containing a suitable carbohydrate.
- Besides carbon, fungi require nitrogen. To obtain nitrogen, they utilize both organic and inorganic materials as the source.
- The chief organic sources of nitrogen are protein, peptide or an amino acid.
- Certain groups of fungi show specializations in respect of certain nitrogen sources. For example, the Saprolegniaceae and Blastocladiales include a number of species which grow only with organic nitrogen such as amino acid.
- In nature, fungi decompose proteins and other materials to obtain their supply of nitrogen.
- In pure cultures amino acids, peptides, or peptones gelatin, casein and egg albumin can serve as sources of organic nitrogen for building up protoplasm.
- Urea is also considered as a utilisable nitrogen source for some fungi.
- Many fungi, however, obtain nitrogen from inorganic sources.

- A number of fungi are known which use both nitrate and ammonium salts. Example: *Absidia* sp., *Mucor hiemalis*, *Lenzites trabea* and *Marasmius* sp. use ammonia but are incapable of utilizing nitrate salts.
- Fewer fungi are able to utilize nitrate salts.
- Organic sources of nitrogen can also serve as sources of carbon.
- There is not much evidence to support nitrogen fixation in saprophytic fungi. Metcalfe and Chayen (1954) reported that soil inhabiting *Rhodotorula* and yeast-like *Pullularia pullans* fix atmospheric nitrogen. However, nitrogen fixation is not a widespread ability in fungi.
- Hydrogen and oxygen are supplied in the form of water which is the major constituent of fungus mycelium forming about 85-90% of the entire weight.
- The chief among the inorganic nutrients which the fungi require in fairly large amounts for their mineral nutrition are sulphur, phosphorus, potassium and macronutrients the fungi obtain from simple inorganic salts or sources such as suIphates for sulphur, and phosphates for phosphorus.
- These must be supplied in any culture medium. Calcium is not known to be needed by the fungi in general. Some, however, require it as a micronutrient.
- Some fungi are reported to require only minute traces of iron, zinc, copper, manganese and cobalt and molybdenum.
- These trace elements or micronutrients are considered essential of growth. The form in which the major and the minor metallic element requirements are utilised is the anion.
- Fungi store excess food in the form of glycogen or lipids.

- The fungi like all other organisms require minute amounts of specific, relatively complex organic compounds for growth. These are the vitamins or growth factors.
- Many fungi synthesize their own supply of appropriate growth factors from a simple nutrient solution of defined composition. Such fungi are thus autotrophic for vitamins and are called need no exogenous supply.
- There are others which depend in whole or in part on an external source because they are unable to synthesize one or more of the essential growth substances.
- The fungi heterotophic for their needs of growth factors are termed auxo-trophic. There are marked difference between the vitamin demands of the different species of a genus or even the strains of a single species.
- The important fungal vitamins, which may function in enzyme systems include thiamine (B_1), biotin, pyredoxine (B_6) and riboflavin (B_2).
- A few fungi also need nicotinic acid and pantothenic acid. The vast majority, however, require thiamine (B_1).
- **To sum up, the basic nutritional needs of fungi are:**

  - A suitable organic compound as a source of carbon and energy.
  - A suitable source of nitrogen.
  - Inorganic ions of sulphur, phosphorus, potassium and magnesium in significant amounts.
  - Inorganic ions of iron, zinc, copper, manganese and molybdenum only in minute traces,
  - Certain vitamins or organic growth factors in trace amounts.

❖ Besides the nutritional requirements listed in the previous slides, the growth of fungi is habitat factors such as temperature, oxygen supply, moisture, pH value and by-products of metabolism.

❑Mode of Nutrition:

❖ The fungi lack chlorophyll. They are, therefore, unable to synthesize carbohydrate food from inorganic materials and get it readymade from themselves.

❖ These heteromorphs according to their method of obtaining food are divided into 4 categories, namely, (i). Saprophytes or saprobes, (ii). Parasites, (iii). Symbionts and (iv). Predacious

❖ The fungi which obtain their food from dead organic materials are called the saprophytes, whereas the fungi obtaining their prepared food from living plants or animals are called the parasites. The living beings on which the fungi parasitize are called the hosts.

❖ Some grow in the association of other plants and are mutually beneficial. This association is called the symbiosis and the participants are symbionts.

✓ **Saprophytes:** The saprophytic fungi live on dead organic materials produced by the decay of animal and plant tissues.

❖ They grow upon dead organic matters such as rotten fruits, rotten vegetables, moist wood, moist leather, jams, jellies, pickles, cheese, rotting leaves, plant debris, manures, horse dung, vinegar, moist bread and many other possible dead organic materials.

❖ *Saprolegnia, Mucor, Rhizopus, Penicillium, Morchella, Aspergillus, Agaricus* and many others are good examples of saprophytic fungi.

- ✓ **Parasites:** The parasitic fungi absorb their food material from the living tissues of the hosts on which they parasitize. Such parasitic fungi are quite harmful to their hosts and cause many serious diseases.

- ❖ These fungi cause the great losses to the human beings or indirectly. Many diseases of the important crops are caused by parasitic fungi. The rusts, smuts, bunts, mildews and many other plant diseases are important examples of fungal diseases of crops.

- ❖ Their mode of life is parasitic and the relation of host and parasite is called the parasitism.

- ❖ The parasites which survive on living hosts and only on living hosts are called the obligate parasites. Such parasites cannot be grown upon dead organic culture media, e.g., *Puccinia*, *Peronospora*, *Melampsora*, etc.

- ❖ The parasitic fungi which usually live on living hosts and according to their need they adopt saprophytic mode of life for some time are called the facultative saprophytes, e.g., *Taphrina deformans* and some smuts.

- ❖ Some parasitic fungi usually pass saprophytic mode of life, but under certain conditions they parasitize some suitable host and are called the facultative parasites, e.g., *Fusarium*, *Pythium*, etc. The parasitic fungi absorb their food from the hosts in different ways.

- ❖ The fungus having the mycelium outside the host is called the ectoparasite, e.g., *Erysiphe*, whereas the fungus having the mycelium embedded in the host tissue is called the endoparasite.

- ❖ In the former type certain cushion-like appressoria develop on the surface of the host and from each appressorium a peg-like structure develops which penetrates the host epidermal cell giving rise to a branched or unbranched absorbing organ called the haustorium.

SOME PARASITIC FUNGI

Puccinia on host plant

Albugo candida on host plant

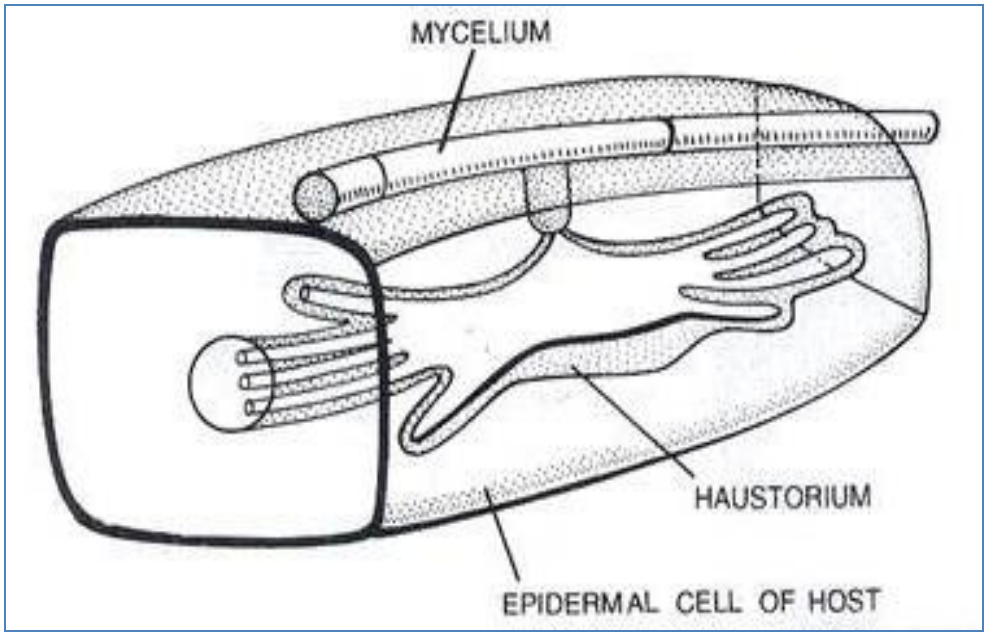
Brown rust

Parasitic fungi on insect host

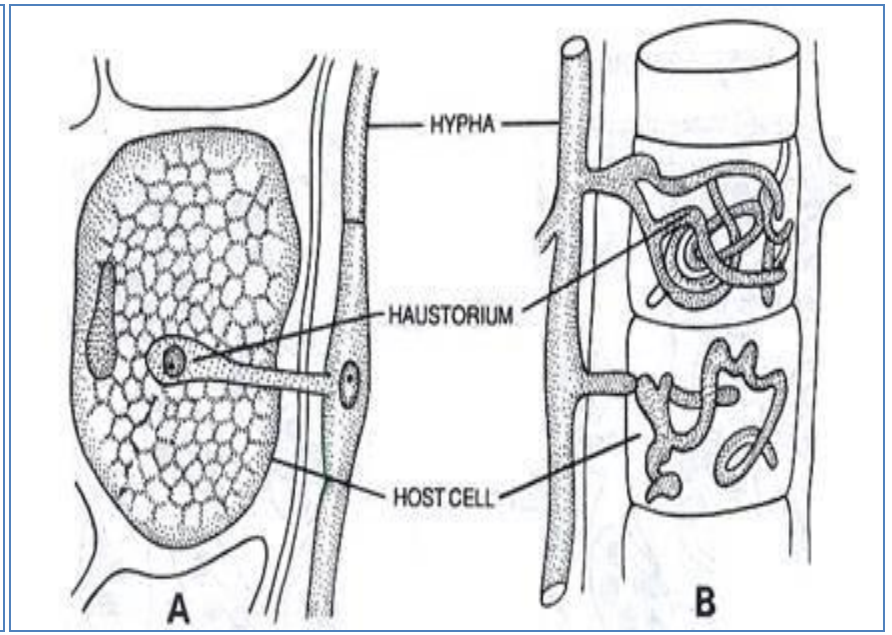
Parasitic fungi on bug

Fungal disease in human

- The haustoria may also develop from the mycelium of endoparasites. The haustoria vary in their shapes. They may be small, rounded, and button-like as in Albugo, branched and convolute as in *Peronospora* and highly branched as in *Erysiphe*.
- In the case of rusts and mildews the mycelium remains confined in the pustules and not in the whole body of the plant. This type of fungus is called the localized fungus.
- When the mycerlium prevails in the whole of the plant it is said to be systemic fungus, e.g., smuts. When the mycelium is confined to the intercellular spaces it is called intercellular mycelium and in other cases the mycelium penetrates the host tissue and said to be intracellular.
- Usually the former bears haustoria and the latter does not.



Three dimentional diagram of an infected epidermal cell with a branced haustoria of *Erysiphe* sp.



Haustoria: A. Elongated capitate haustorium, B. Branched or digitate haustorium

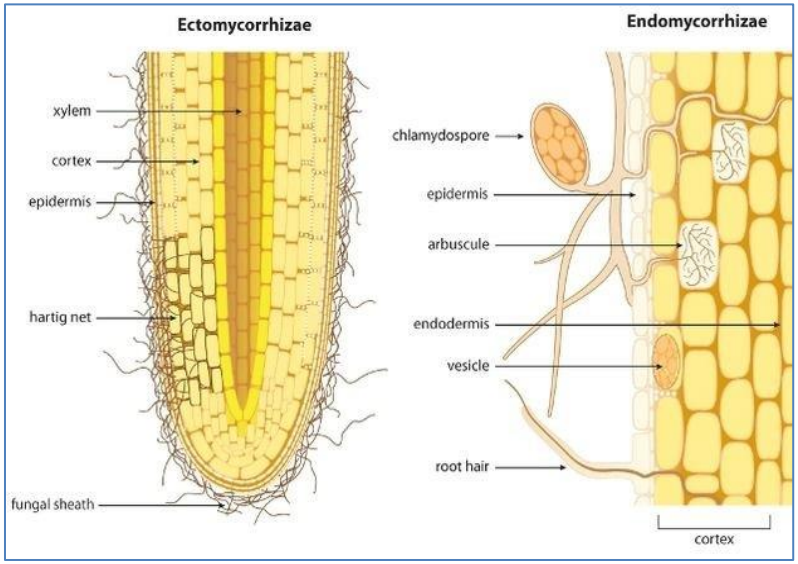
✓ **Symbionts:** Some fungi live in close association of other higher plants where they are mutually beneficial to each other. Such relationship is called the 'symbiosis' and the participants the 'symbionts'. The most striking examples are the lichens thallus and mycorrhiza. The lichens are the resultants of the symbiotic association of algae and fungi.

❖ **Lichen thallus: a symbiotic association:** 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.

❖ Here, both live together and are beneficial to each other. The algal partner synthesizes the organic food and the fungal partner is responsible for the absorption of inorganic nutrients and water.

❖ **Mycorrhiza (pl. Mycorrhizae or mycorrhizas):** It is defined as the symbiotic association between the hypha of certain fungi and roots of plants. Certain fungi develop in the roots of higher plants and the mycorrhiza are developed. Here fungi absorb their food from the roots and in response are beneficial to the plants. The mycorrhiza may be three types ;

- **Ectomycorrhiza:** In this case fungal hyphae 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).
- **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 intercellularly and intracellulary.



- ✓ **Predacious fungi:** There are many animal trapping fungi which have developed ingenious mechanisms for capturing small animals such as eel worms, rotifers or protozoa.

- ❖ The mechanisms is adopted by the fungi which utilizes a rapidly constricting ring around a nematode which holds it captive while the hyphae sink haustoria into the body of the victim. Several species of fungi in the genera *Arthrobotrys, Dactylella* and *Dactylaria* employ this method.

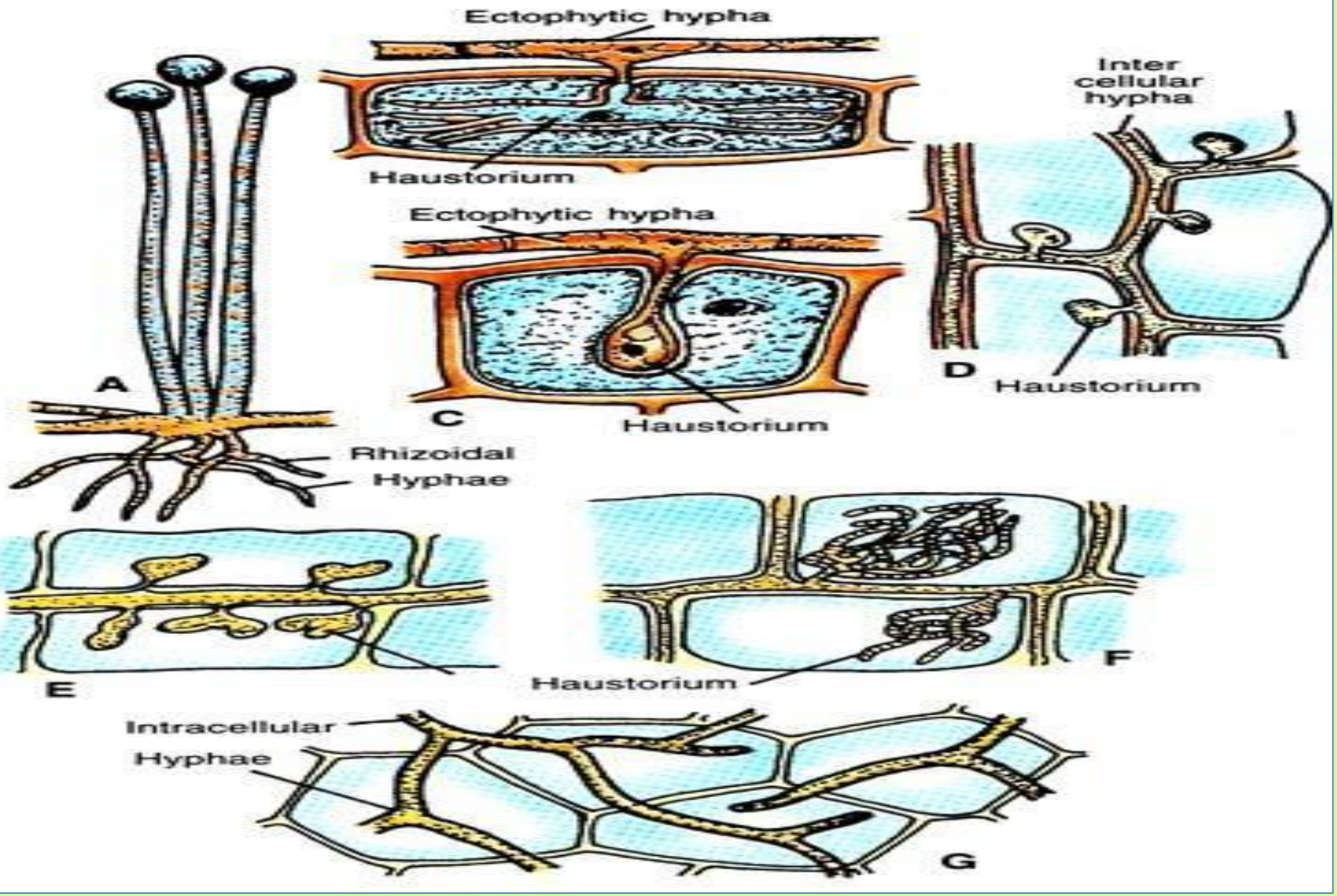
- ❖ It is assumed that the amount of osmotically active material in the ring cells increases greatly as a result of stimulation and causes water to enter the cells increasing their turgor pressure. The ring cells swell rapidly and the ring closes around the eelworm which is thus held tightly in the trap.

- ❖ Some predacious fungi secrete a sticky substance on the surface of their hyphae to which a passing small animal adheres. Haustorium like hyphae then grow into the body of the animal and absorb food and animals ultimately die.

❑Mechanism of Nutrition:

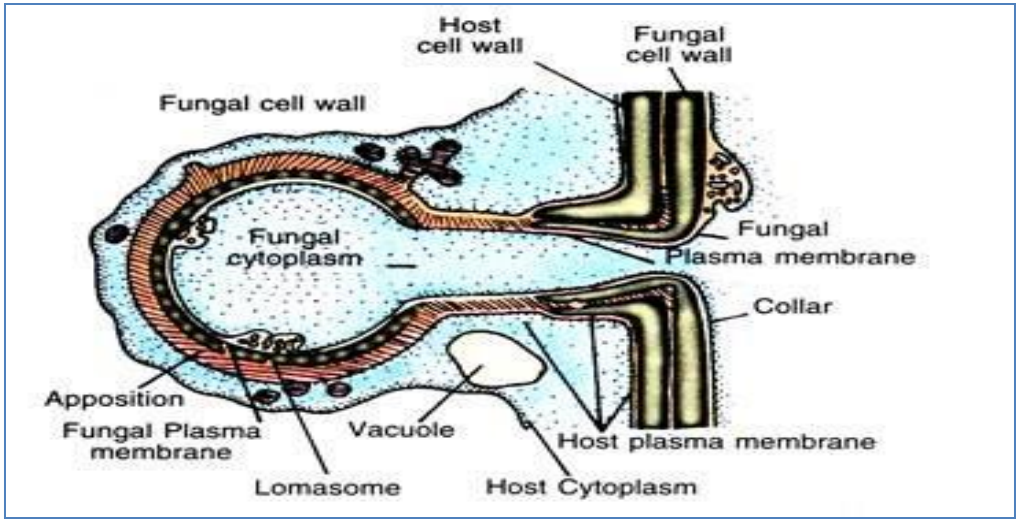
- ❖ The whole mycelium may have the power to absorb these nutrients or this task may be assigned to special portions of the mycelium.
- ❖ In saprophytic fungi the hyphae (Mucor mucedo) or rhizodial hyphae (Rhizopus stolonifer) come in intimate contact with nutrients in the substratum (A) and absorb soluble smaller molecules such sugars and amino acids.
- ❖ Insoluble complex substances such as proteins, lipids etc 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 (D) or penetrate into the host cells (G). The former are called intercellular hyphae and the latter intracellular hyphae.
- ❖ 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 (G) and obtain food by direct diffusion.
- ❖ The intercellular hyphae of some highly specialised (obligate) plant parasites give out slender lateral outgrowths.

MECHANISM OF NUTRITION IN FUNGI



- 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 (D), lobed (B), or branched (F) absorptive organ.
- 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.
- They vary in shape and size in different fungi. In Albugo the haustorium is a button-like (D) or spherical structure. Peronospora parasitica has sac-like haustoria (E) in the leaf cells of Capsella. Peronospora calotheca produces branched filamentous haustorium in the stem cells of Galium (F). Erysiphe graminis forms an elongated branched haustorium inside the host cell (B).

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



A section through an haustorium of *Albugo candida* based on an electron micrograph. (After Berlin and Bowen)

- 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.
- 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 haustona are also not produced by fungi which live as parasites on animals.
- The fungi, as mentioned above, are unable to synthesize sugars from carbon dioxide and water.
- They, however, can synthesize from soluble sugars the more complex carbohydrates which is the chief components of their cell walls.
- They are also able to synthesize proteins and eventually protoplasm if supplied with carbohydrates and simple nitrogen compounds such as ammonium salts.
- Besides ammonium salts, they can absorb and utilize many complex but soluble organic nitrogenous compounds.
- 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 mutualisitc associations of fungi with other plants are Symbiosis .

KEY POINTS OF THE LECTURE

- Fungi are achlorophyllas, heterotrophic eukaryotic thallophytes.
- The fungi utilize both organic compounds and inorganic materials as the source of their nutrient supply.
- The constituent elements of the organic and inorganic substances which fungi make use of are C, O, H, N, P, K, Mg, S, P, Mn, Cu, Mo, Fe and Zn.
- Examples of the macro elements are C, N, O, H, S, P, K and Mg. The macro elements are body builders and provide energy for metabolic processes.
- The carbohydrates are needed for building up the body and also as a source of energy.
- In a typical fungus, 50% of the dry weight is carbon of the carbohydrate source of carbon, most fungi use simple sugars.
- Glucose, for instance, is suitable for almost all fungi. Next in preference are the fructose.
- Organic acids are generally poorer sources of carbon for most fungi.
- Proteins, lipids some organic acids and higher alcohols are utilized by some fungi as a sole energy source of growth.
- In nature, fungi decompose proteins and other materials to obtain their supply of nitrogen.
- Many fungi, however, obtain nitrogen from inorganic sources.
- There is not much evidence to support nitrogen fixation in saprophytic fungi. Metcalfe and Chayen (1954) reported that soil inhabiting *Rhodotorula* and yeast-like *Pullularia pullans* fix atmospheric nitrogen.

KEY POINTS OF THE LECTURE

- The chief among the inorganic nutrients which the fungi require in fairly large amounts for their mineral nutrition are sulphur, phosphorus, potassium and macronutrients the fungi obtain from simple inorganic salts or sources such as suIphates for sulphur, and phosphates for phosphorus.
- Fungi store excess food in the form of glycogen or lipids.
- Many fungi synthesize their own supply of appropriate growth factors from a simple nutrient solution of defined composition. Such fungi are thus autotrophic for vitamins and are called need no exogenous supply.
- Fungi are heteromorphs according to their method of obtaining food are divided into 4 categories,
- **Saprophytes:** The saprophytic fungi live on dead organic materials produced by the decay of animal and plant tissues.
- **Parasites:** The parasitic fungi absorb their food material from the living tissues of the hosts on which they parasitize. Such parasitic fungi are quite harmful to their hosts and cause many serious diseases.
- **Symbionts:** Some fungi live in close association of other higher plants where they are mutually beneficial to each other. Such relationship is called the 'symbiosis' and the participants the 'symbionts'. The most striking examples are the lichens thallus and mycorrhiza. The lichens are the resultants of the symbiotic association of algae and fungi.
- **Predacious fungi:** There are many animal trapping fungi which have developed ingenious mechanisms for capturing small animals such as eel worms, rotifers or protozoa.

TERMINOLOGY

- **Ascomycetes:** A - Class of fungi that produce their spores in sac-like cells called asci
- **Appressed:** (often used to describe scales) flattened down onto a surface
- **Arbuscular Mycorrhiza** (AM): (a mycorrhiza) where fungi from the Glomeromycota penetrate the roots of a (usually herbaceous) plant and provide the plant with water and nutrients while the plant supplies sugars to the fungus
- **Coprophilous:** growing on dung
- **Depressed:** (describing a cap) where the central region is lower than the margin
- **Ectomycorrhiza (EM):** (a mycorrhiza) where the fungus forms sheathes around plant rootlets (often of a tree), growing between but not penetrating the cells of the plant root, and providing the plant with water and nutrients while the plant supplies sugars to the fungus
- **Endomycorrhiza :** mycorrhiza in which fungal hyphae penetrate cell walls of host plant
- **Endophyte :** fungus living within a plant without causing visible symptoms of harm
- **Hypha:** (pl., hyphae) filamentous thread of fungal mycelium
- **Lichen:** organism comprising a fungus and an alga or a cyanobacterium
- **Mycelium:** body of a fungus, most of which is underground or hidden within wood
- **Mycobiont:** the fungal component of a lichen or of a mycorrhizal partnership
- **Mycorrhiza:** structure by which a fungus and a plant exchange nutrients mutually
- **Parasitism:** process whereby an organism feeds at the expense of another (host)
- **Photosynthesis:** process by which plants convert carbon dioxide and water to sugars
- **Rhizomorph:** a root-like mycelial strand comprising bunched parallel hyphae
- **Ring:** membranous remains of the partial veil attached to a stem
- **Saprophyte:** an organism that obtains its nutrients from dead organic material
- **Slime Moulds:** a group of fungus-like organisms that use spores to reproduce
- **Thallus:** (pl., thalli) the body of a fungus or a lichen

SOME QUESTIONS RELATED TO THE LECTURE

- **Question 1:** Write a note on nutritional requirements of fungi.
- **Question 2:** Describe the essential element of fungi nutrients.
- **Question 3:** Discuss the source of macro elements of fungal food.
- **Question 4:** Write a note on mode of nutrition in fungi
- **Question 5:** Write a short note on saprophyic fungi
- **Question 6:** Discuss the parasitic nature of fungi in detail.
- **Question 7:** Write a short note on fungi hausterium.
- **Question 8:** Discuss the beneficial association of fungi with other plants.
- **Question 9:** Write a detail note on mycorrhiza .
- **Question 10:** Discuss the mechanism of nutrition in fungi.
- **Question 11:** What do you understand by predacious fungi.

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