Fungi

Introduction: Thallophytes have evolved in two separate lines. In one evolutionary line green photosynthetic algae have evolved whereas in the other non photosynthetic chlorophyll less plants fungi have evolved. Due to great variability in characters it is very difficult to give a precise definition of fungi. The diagnostic characters by which this group plants could be identified and distinguished are summarized as follows:

- Fungi exhibit heterotrophic and absorptive mode of nutrition.
- Thallus may develop inside or outside the substratum. When parasitic growth of the thallus is found on the surface of the plant or animal it is called epibiotic. If such growth occurs inside the palnt cell or animal, it is called endobiotic. Thallus may be plasmodial amoeboid or pseudoplasmodial (Myxomycota). Sometimes may be unicellular and usually filamentous. Where the vegetative body is filamentous the filament is called mycelium. Mycelium may be septate(e.g. *Aspergillus*) or aseptate(e.g. *Rhizopus*). Some unicellular forms are motile (e.g. *Synchytrium*).
- Cell wall is well defined typically chitinised (cellulosic in Oomycetes).
- Cells are eukaryotic.
- Life cycle may be of simple or complex type.
- Distribution is cosmopolitan. Members may be saprophyte, symbionts, parasite or hyperparasites.

After going through this chapter learners can understand the extent of diversity exists within the fungi. They will be able to distinguish this group of plants from other plants which are also thallophytes. Learners will be able to acquire knowledge about the different modes of reproduction prevails in this group of plants. Also they would acquire knowledge about the application of those organisms in human welfare.

1. General characteristics: The kingdom Fungi is divided into two major divisions, one is Myxomycota and the other is Eumycota or True fungi. The members of Myxomycota are wall less. The vegetative body is multinucleate protoplasm exhibiting amoeboid movement and called plasmodium. In some cases vegetative body is an aggregation of separate amoeboid cells called pseudoplasmodium. Due to their slimy consistency, the plasomodium and pseudoplasmodium are called slime molds. The general characteristics o the members of **Eumycota or true fungi** are described below:

- **Thallus organisation:** In yeast or yeast like fungi thallus is unicellular (e.g. *Saccharomyces*, *Sporobolomyces*). In majority of fungi the vegetative body is made up of filaments called hyphae. The thallus made up of hyphae is expressed in a collective term called mycelium. The thallus may be differentiated into a vegetative part which absorbs nutrients and a reproductive part. Such thallus organization is called as **eucarpic.** In others, the thallus is vegetative but during reproduction the entire thallus is converted into a reproductive structure. Such thallus is called **holocarpic**. In certain parasitic fungi the entire thallus lives inside the host cell and during reproduction the entire thallus is converted into reproductive organ (eg. *Synchytrium*, *Olpidium*). Some fungi pathogenic to animals produce yeast like phase in the life cycle due to conversion of its usual filamentous form, depending upon the environmental conditions like CO_2 concentration and medium composition etc., such phenomenon is known as **dimorphism** (e.g. *Penicillium marneffei*). The mycelium may be **septate** or without any septa (**aseptate**). In the members of the class Oomycetes and Zygomycetes, the septa are generally absent in the hyphae whilst in Ascomyctes , Basidiomycetes and Deuteromycetes the hyphae are usually septate. Since crosswall or septum is absent in aseptate forms the nuclei are freely distributed in the cytoplasm of the hyphae. Such a condition is described as **coenocytic**. In case of septate mycelium, each cell may contain a single, haploid nucleus; such mycelium is known as **monokaryotic** mycelium. In Basidiomycetes, each cell of the mycelium contains two genetically distinct haploid nuclei; such mycelium is known as **dikaryotic** mycelium. Mycelium produced as a result of the germination of basidiospore is known as **primary mycelium.** The mycelim arises by dikaryotization of cells of the primary mycelim is known as **secondary mycelium.** The dikaryotization of the monokaryotic mycelium in some members of Basidiomycetes takes place with the help of another dikaryotic mycelium, this phenomenon is known as **Buller phenomenon**.The dikaryotic mycelium which is involved in the formation of fruit bodies is designated as **tertiary mycelium.(Fig.3.1)**

  In majority of the members of basidiomycotina, the diakaryotic mycelium grows following the process called **clamp connection.** During this process two nuclei of the dikaryotic mycelium divide and produce four daughter nuclei. A septum is then formed which separates the daughter nuclei into two compartments, the upper compartments bears two nuclei of opposite polarity whereas the lower one bears one nucleus of any one polarity. A lateral clamp is produced simultaneously from the upper compartment to which one nucleus migrates, the polarity of which is opposite to the single nucleus present in the lower compartment. The clamp gradually proceeds towards lower compartment as presented in the figure (Fig 3.2) and ultimately fuses with it to pass the nucleus present within it. Two daughter cells of dikaryotic nature thus produced.

Aggregations of hyphae: Fungal mycelia are aggregated to form various organized structures commonly called fungal tissue or plectenchyma. Fungal tissues are of two types such as: 1. **Prosenchyma or prosoplectencyma** and 2. **Pseudoparenchyma or paraplectenchyma.**

In the former type the hyphae compactly grow together in a parallel manner so that the individuality of the hyphal threads and their elongated cells are retained **(Fig 3.3 a)**. In the latter type the compactness of the hyphae are so much that the individuality of each thread is lost and when a cross section is made through the tissue it appears as aggregation of parenchymatous tisuue **(fig 3.3 b)** .

Sclerotium : It is dark brown or black, tough, cushion shaped resting body made up of pseudoparenchymatous tissue. The inner cells are hyaline and filled with reserve food whereas the outer cells are thick walled. Depending upon their size sclerotia are classified as micro (small microscopic) and macro (large visible in naked eye) sclerotia. Sclerotium germinates under favourable condition and produces pin head like bodies differentiated into two parts; the stipe (stalk) and spheridium (head). Reproductive structures are developed inside the spheridium (e.g. *Clavicepes*). **(Fig3.4)**

Stroma (plural: stromata): It is solid organization made up of prosenchyna or pseudoparenchyma. Reproductive structures or fructifications commonly develop inside this structure (e.g. *Daldinia*). **(Fig.3.5)**

Rhizomorph: It is a root like hyphal organization with well developed apical meristem and a central core of larger thick walled elongated cells. The entire structure remains covered by a rind made up of smaller thick walled darkly pigmented cells. This structure is observed in honey fungus or honey agarics named as *Armilariella mellea* (= *Armillaria mellea*).There are two kinds of rhizomorphs such as one dark, cylindrical type and the other paler, flatter type. The latter type is found beneath the bark of infected tree. Rhizomorphs are also found in dead tree and their diameter may be upto about 4 mm. They help the fungus to spread from root system of one host to another. **(Fig 3.6 A &B)**

- **Cell structure:a) Cellwall :** Chemical analysis of the fungal cell wall reveals that the major component of cell wall is polysaccharide (80-90%) and the remainder consisting of protein and lipid. Chitin is the major polysaccharide found in most fungal cell wall, but cellulose is present in cell wall of Oomycetes along with glucan. Chitin is a polymer of N-acetyl glucosamine whereas cellulose is a polymer of D- Glucose. **(Fig 3.7)** .Cell wall which form septa in hyphae may be of three types such as: septum that delimits the reproductive structure without having any perforation, transverse septum with simple perforation lying at right angle to the axis of the hypha(found in Ascomycetes and Deuteromycetes) and transverse septum with complex perforation(found in Basidiomycetes).In case of complex perforation surrounding the central pore of the septum there is a curved flange of wall material which is often thickened to form a barrel shaped or cylindrical structure. Such type of septum is known as **dolipore** septum **(fig 3.8 1&b)**.

  b) Cytoplasmic membrane: Like other eukaryotes the plasmalemma of fungal cell shows fluid mosic structure of a typical unit membrane. Typical invagination of plasmalemma is observed which is called lomasome. In between the cell wall and indented region of plasma membrane many discrete vesicles of spherical, ovoid and tubular shapes are found. Such vesicles may be derived either from the passage of vesicles through the plasmalemma or by the proliferation or budding off of the vesicular structure from the plasmalemma. The formar and the latter origin are described as **true lomasome** and plasmalemmasome respectively.

c) Cytoplasm: Apart from chloroplast the cytoplasm of a fungal cell contains familiar organelles characteristics of eukaryotic cell. Nucleus is surrounded by double membrane continuous with endoplasmic reticulum. The nuclear membrane is interrupted with numerous pores. When mitotic cell division occurs, the nuclear membrane does not always break down but may constrict in the middle to separate two sister nuclei. This process is known as **karyochoresis**. The structures of cellular organelles like mitochondria, ribosome, microbodies, vacuoles, lysosomes, microtubules etc. are more or less similar to other eukaryotic cells. A wide variety of cytoplasmic inclusions are found in the cell such as glycogen aggregates, carotenoid crystals, fatty acid synthetase body, sphaerosomes (lipid bodies) etc. In filamentous Ascomycota, a peroxisome derived dense core microbody with a unit membrane is found near the septae which is called **Woronin body**. It plugs the septal pore after hyphal wounding and restricts the loss of cytoplasm to the sites of injury.**(Fig 3.9)**

2. Reproduction in fungi: In fungi vegetative, asexual and sexual methods of reproduction are recognized.

- **Vegetative reproduction:** It takes place by different methods like fragmentation, budding and fission. In fragmentation the mycelium is separated into many pieces, and each segment grows into a new individual. Small bud like protuberances developed from mother cell in the process and known as budding. In yeast buds are formed in chains, each of them being separated from mother cell gives rise to new individual. When a vegetative cell simply splits into two daughter cells by development of transverse wall, the process is known as fission.**(Fig 3.10 a& b)**

- **Asexul reproduction:** Spore is the unit of asexual reproduction. In fungi different types of spores are produced. Spores are broadly classified into three categories such as: asexual spores; asexual spores related to sexual reproduction and spores produced as a result of sexual reproduction that is sexual spores. **(Word diagram 1)**The structural description of different types of spores is given below.

  Sporangiospore : the spores produced inside the sporangia are called sporangiospores. The sporangium is a sac like structure within which spores are produced. The spores produced in the sporangium may be motile or non motile and based on this criterion the sporangiospores are of two types:

  a)Aplanospore: These are non motile spores without any device for locomotion. The aplanospore producing sporangia are called aplanosporangia. The number of spores in aplanosporangia is variable. A few spored sporangia where spores are dispersed as a unit, such sporangia are called **sporangiola**. Aplanospores may be uni or multinucleate, smooth walled, globose or ellipsoid in shape.This type of spore production is the characteristic of Zygomycotina, specially the Mucorales. **(Fig 3.11)**

- **Zoospore:** Zoospores are motile spores produced in the structurecalled zoosporangium. Flagellum is the device of motility o zoospore. Each flagellum is made up of a central axoneme from which numerous small hairs or mastigonemes are produced. Within Eumycota, zoospores are of three types: posterior uniflagellate zoospores with flagella of whiplash type, anteriorly uniflagellate zoospores with flagella of the tinsel type and biflagellate zoospores with anteriorly or laterally inserted flagella- one of which is tinsel type and the other is whiplash type. The term **heterokont** is used where one flagellum is of whiplash type and the other is of tinsel type. The flagellum originates from a basal body called **kinetosome or blepharoplast**. In some uniflagellate zoospores (e.g *Blastocladiella emersonii*) the kinetosome is closely associated with a mitochondrion. Three striated bodies establish connection between the kinetosome and the mitochondrion which are called **flagellar rootlets, striated rootlets or banded rootlets**. This adaptation is to provide uninterrupted energy supply to maintain flagellar dynamysim. In tinsel type of flagella the main flagellar axis or axoneme remains covered with **flimmer hairs** or mastigoneme which are not at all the components of microtubules of flagella. The axoneme shows typical 9+2 arrangement of flagellar microtubules having nine doublet microtubules surrounding a central pair of single microtubules.**(Fig.3.12)** When zoospores produced by the species have only one swarming period, such zoospores are called **primary or monoplanetic** zoospores.**(Fig3.13)** Such zoospores after being released from zoosporangium swim for a certain period of time and bind to suitable substratum after flagellar retraction where they directly germinate and give rise to new mycelia. Such behaviroal pattern exhibited by a zoopore is known as **monoplanetism** (e.g. *Phythium*). Biflagellate zoospores produced by some species exhibit two periods of active movement separated by an encysted phase, such zoospores are called **diplanetic zoopores.** In *Saprolegnia*, the biflagellate primary zoospore comes out of the zoosporangium and begins to swim in the aquatic environment. After exhibiting a period of motility it retracts its flagella and comes to rest on a suitable substratum. Now it becomes covered by a thick wall to enter in to the encystment phase. After a few hours, another biflagellate pear shaped zoospore comes out from the cyst which is called **secondary zoospore**.**(Fig.3.14)** The latter, after being attached on the suitable substratum puts out a germ tube and develops a new mycelium. The behaviour of the zoospore of this kind is known as **diplanetism.** Repeated encysment and emergence stage of zoospore may occur in some species like *Dictyuchus* in their asexual cycle, such phenomenon is termed as polyplanetism and concerned zoospore is known as **Polyplanetic** zoospore.

- **Conidia: T**hese are non motile exogenously developed spores usually found at the apex of a stalk like structure called conidiophores. The conidiophores may be branched (e.g. *Penicillium*) or they may be unbranched (e.g.*Aspergillus*).This type of spore is found in many different groups of fungi but especially in Ascomycotina and Deuteromycotina. The conidia develop from an initial cell called conidial initial. If no enlargement of conidial initial takes place during the development of conidia, such type of development is called **thallic** and the concerned conidia are called **thallospores** (e.g. *Endomyces geotrichum*). The term **blastic** is used to denote the development of conidia where the enlargement of the conidial initial that occurs during development. The conidia produced as a result of blastic development are called **blastospores or true conidia**. The thallospores may be of two types such as **arthrospores** and **chlamydospores**. Arthsospores arise by close septation in basipetal succession. Each cell rounds off and sets free a thin walled arthrospore (eg. *Oidium)* **(Fig. 3.15)**. Chlamydospores are non deciduous, thick walled, dark brown coloured, unicellular endogenously originated spores. During their development the initiating terminal and intercalary cells round off and accumulate much reserve food materials. This kind of spore is found in *Fusarium, Mucor, Phytophthora* etc.**(Fig.3.16)**

  Blastic development of conidia is classified into two types such as **Holoblastic** and **Enteroblastic**. In holoblastic type both the outer and inner layers of conidiogenous cell contribute to the conidium formation (e.g. *Pleospora herbarum, Cladosporium herbarum*). In enteroblastic type only the inner wall layer is involved in conidia formation. This development again may be of two types such as **tretic** and **phialidic**. In tretic type the inner wall of conidiogenous cell balloons out through a narrow pore present on its outer layer. As the conidiospore comes out through the pore, it is called **porospore** (e.g. *Alternaria, Curvularia, Helminthosporium*). In phialidic type, the conidiogenous cell itself is a specialised cell, called phiallide. As the conidia are produced from such specialised bottle shaped cell i.e. phiallide therefore these are called as **phialospores** (e.g.*Penicillium*) **(Fig 3.17 A, B,C,D)**.

2.3 Conidial fructification: Conidia bearing conidiophores and other vegetative hyphae of the fungus together constitute a well organized aggregated structure called conidial fructification. The conidiophores which are very much distinct, elongated developed as a discrete unit and distributed throughout the mycelium, are called as **mononematous**. If the conidiophores are so small that they are not be distinguishable from vegetative hyphae, such conidiophores are called **micronematous**. In many fungi distinct elongated conidiophores are aggregated together to form an organization called **macronematous** conidiophores**.** The following are the different type of compound structures formed as a result of conidial aggregation:

a)**Synnema or coremium:** When the conidiophores become aggregated to form parallel fascicles of closely appressed hyphae, such aggregates of conidiophores are termed as synnema. Example –*Doratomyces, Graphium, Podosporium* etc.

b)**Sporodochium :** Sporodochium is a crust or disc or cushion shaped structure in which loose mass of conidiophores arises from a mass of aggregated hyphae or stroma. Conidiophores in this structure usually touch each other and may even overlap. Example – *Tubercularia vulgaris*, *Epicoccum purpurascens*.

c)**Acervulus:** It is a pseudoparenchymatous aggregate of hyphae that often develope beneath the host epidermal surface from which very small,superficial, open, flat bed of closely packed conidiophores bearing condia are formed. Though the conidiophores appear much closer to each other but in reality they do not touch each other. In some acervuli dark sterile hair like structures are found which are called setae.This type of asexual fruit body is found in *Colletotrichum graminicola* .

d) **Pycnidium :** These are flask shaped or globose hollow fructifications growing superficially or remaining immersed in the host tissue. The inner wall layer of the pycnidium is lined with a layer of conidiogenous cells of various types from which conidiophores bearing conidia develop. The whole structure opens to the exterior by a pore called **ostiole**. The conidia that develope in pycnidia are called as **pycnidiospores**. Several pycnidial cavities remain enclosed in a single fructification to form a structure called **pycnidial stroma**. Pycnidia are found in *Phoma*, *Ascochyta*,*Septoria* etc.**(Fig.3.18 A,B,C,D)**

2.4 Asexual spores related to sexual reproduction: In Ascomycetes and Basidiomycetes, spores are produced as a result of sexual reproduction. Such spores are ascospores and basidiospores respectively.

2.4.1 Ascospores are different shape and size. These are produced inside a club shaped structure called ascus. Usually the ascospores are globose to oval or elliptical in shape, usually eight in number per ascus. *Neurospora tetrasperma* is somewhat unusual in that it has four spored asci and the ascospores are binucleate. The walls surrounding the protoplast of ascospores are multilayered. The innermost layer is the endosorium, outside which is the episporium. The ribbed layer outside the episporium is known as **perisporium.** External to this layer smooth surface layer is present.**(Fig3.19)** The ascospores bearing asci are arranged in a layer to form a structure called **hymenium**. The hymenium layer is closely associated with other sterile hyphae to form a compact well organized structure called sexual fructifiation. In Ascomycotina three types of morphologically distinguishable fruit bodies or fructifications are found, such as: **a) Apothecium** : It is a cup or saucer shaped fruit body found in *Ascobolus*, where the hymenium is exposed on the upper side. The lower region of the fruit body which is made up of vegetative sterile mycelia is known as **excipulum**. The ascospore bearing asci remain intermingled with sterile paraphysis. **(Fig 3.20 a&b)** **b)Cleistothecium :** In this type of fruit body asci are developed endogenously within a spherical structure produced by compactly arranged vegetative hyphae. Example – *Penicillium*.**(Fig 3.21)** **c) Perithecium :** It is a flask shaped fruit body which opens to the exterior by an opening called ostiole. The fruit body is internally lined with a layer of asci which remain intermingled with sterile vegetative hyphae called paraphyses. Example - *Clavicepes* **(Fig 3.22)**.

Two different types of sex organ is produced during sexual reproduction in Ascomycotina, the male sex organ is known as antheridium and the female sex organ is known as **ascogonium** which contain male and female gametes respectively. Both the sex organs are connected with the help of a tubular connection called **trichogyne** through which male nuclei migrate into ascogonium. Inside the ascogonium nuclear pairs are formed. From the periphery of ascogonium many hyphae develop which are called **ascogenous hyphae** within which the paired nuclei migrate. So ascogenous hyphae are dikaryotic in nature. The cells of such hyphae serve as **ascus mother cells,** from which ascospore bearing asci are produced.**(Fig 3.23)**

2.4.2 Basidiospores are produced in the members of Basidiomycotina. The spores are unicellular; their shape may vary from globose, sausage shaped, fusoid etc. Their surface may remain smooth or highly ornamented. The colour of the basidiospore may vary greatly. Basidiospores are exogenously produced on a club shaped structure called basidium. On the basidium the basidiospores either remains attached directly (e.g. *Cyathus*) or they remain attached to a spine like projection developed on the apex of the basidium called **sterigma.(Fig.3.24)** Usually four basidiospores remain attached with the basidium except *Phallus impudicus* where there may be nine spores per basidium. The point at which the spore is attached to the sterigma is called as **hilum.** The latter is found at the tip of a short conical projection called hilar appendix. The term **balistospore** is used to describe basidiospores which are violently projected from sterigma. Like ascospores, the basidiospores also remain surrounded by multilayered wall, from inside to outward the layers are **endosporium, episporium, exosporium, perisporium, and ectosporium**.**(Fig3.25)** In some species of *Coprinus* the perisporium forms a loosely attached layer which surrounds the spore as a loose envelope called as the **perisporial sac**. When the basidium is aseptate, it is called **holobasidium** (e.g. *Agaricus*) and when it is septate either transversely or longitudinally, such basidium is called **phragmobasidium** (e.g.members of Uredinales and Ustilaginales). In the members of Dacrymycetaceae the tip of the basidium is prolonged into two long arms, such basidium is known as **tuning fork type** **(fig 3.26)**. The developmental precursor of basidium which is produced as a projection from secondary mycelium in which diploid nucleus is present is described as **probasidium.** The probasidium stage enters into next developmental stage called **metabasidium** in which the diploid nucleus of probasidium undergoes meiosis **(Fig 3.27)**.

2.5 Sexual reproduction in fungi: There are three distinct phases in sexual reproduction of fungi, such as plasmogamy, karyogamy and meiosis. These three phases occur in regular sequence and usually at specific point in the life cycle. **Plasmogamy** involves union of two protoplasts bringing the nuclei of opposite strains close together within same cell. When the vegetative cell of the mycelium is unicellular, the plasmogamy between two mycelia of opposite sexuality results in the formation of a cell with two genetically distinct nuclei. Such process is described as **dikaryotization**. **Karyogamy** is a process in which two opposite nuclei which are brought together by plasmogamy are fused. The process of karyogamy leads to the formation of diploid nucleus in a cell and the process therefore is called as **diploidization**. Diploid nucleus produced after the nuclear fusion sooner or later undergoes **haploidization** following the process called **meiosis**. The different methods of sexual reproduction in fungi are as follows:

- **Planogametic copulation:** It involves fusion of two gametes both of which may be motile or one of them is motile and the other is non motile. This type of sexual reproduction is found in the members of Mastigomycotina. There are three type of planogametic copulation such as: **isogamous, anisogamous** and **heterogamous**. In isogamous type both the copulating gametes are of identical size and morphology (e.g. *Synchytrium*). In anisogamous copulation though the gametes are morphologically identical but their sizes are different. Usually the male gametes are smaller and female gametes are larger in size in case of heterogamous copulation (e.g. *Allomyces*).The female gamete is large and nonmotile and the male is smaller and motile. The male gamete enters the oogonium and fertilizes the egg to produce oospore (*Monoblepharis*).**(Fig 3.28)**

- **Gametangial contact:** In this process two gametangia distinguished as male and female are involved in the process of sexual union. The antheridium contains many male nuclei which are never released from the antheridium but are freed into the oogonium developed in between the point of contactthrough a pore. Though many male nuclei migrate into the oogonium but only one of them fuses with the only female nucleus present within it. The product of sexual union is oospore. The antheridium is said to be **amphigynous** when it encircles the oogonial stalk, a condition brought on by the growth of the oogonial initial through the antheridial initial (e.g *Phytophthora infestans*). The antheridium is called **paragynous** when it attaches laterally on the oogonial wall, developed from same or different hyphae (e.g.*P.cactorum*). **(Fig 3.29)**

- **Gametangial copulation:** This is the fusion of the entire contents of the two contacting gametangia. Such fusion occurs in two ways, such as: In **hologamous copulation** where the entire male thallus acts as gametangium which attaches itself to female thallus and empties its entire contents into it through a pore developed at the point of contact between the two gametangia (*Polyphogus sp.*). Another mode of copulation is **direct fusion**, in which two gametangial cells fuse directly to result into one. The protoplast of the two gametangia mix in a common cell produced as a result of dissolution of the contacting wall (e.g. *Rhizopus, Mucor, Dipodascus*). **(Fig 3.30)**

- **Spermatization :** In some fungi spore like male reproductive units are produced which are called **spermatia.** Spermatia are carried by air current, insects or water and lodged on a special receptive hyphae or female reproductive organ or even to the somatic hyphae. A pore developed at the point of contact and the content of the spermatium is released into the female organ. Examples: *Puccinia graminis, Podospora*. **(Fig 3.31)**

- **Somatogamy:** In higher fungi such as Ascomycotina and Basidiomycotina sex organ formation does not take place, instead, two somatic hyphae of opposite sexuality fuse to bring together the compatible nuclei. This process is also known as **pseudomixis.** Pseudomictic copulation between a mother and daughter cell is known as **adelphogamy**. When a matured and immature cell is fused with each other the process is called **pedogamy**. In fungi from lower to higher group a gradual simplification of the reproductive structure is observed. Though sexual differentiation is lacking, in higher fungi the copulating mycelia retain their polarity. Thus simplification of sex organs with retention of polarity is known as **degeneration of sex**. **(Fig 3.32)**

  Sexual reproduction in many fungi does not require the interaction of different thalli that means every thallus is sexually self-fertile and self compatible. Such fungi are called **homothallic** fungi. In others, the thallus is not self compatible and requires a compatible thallus to exhibit sexual reproduction. Such fungi are called heterothallic fungi. The heterothallic fungi sometimes could be distinguished morphologically in respect of the structure of their sex organ; such heterothallism is called **morphological heterothallism**. In others, the heterothallism is governed by genetic factors. When the sexual compatibility is governed by a single factor and its two alleles such heterothallism is called as **bipolar** heterothallism. The heterothallism is described as **tetrapolar** or bifactorial when two factors with its four alleles are involved as a determinant of heterothallism. In a similar way the heterothallism may be **octapolar** where four factors with eight alleles are involved.

  Some fungi do not go through a true sexual cycle yet derive the benefits of sexual reproduction by a process called **parasexuality.** In this process plasmogamy, karyogamy and meiosis take place but not at specified points in the life cycle. In parasexual cycle, recombination occurs during the mitosis instead of meiotic cycle. This phenomenon was discovered by Pontecorvo and Roper (1952) in the fungus *Aspergillus nidulans*.

2.6 Sexual spores: The sexual spores in fungi are zygospores and oospores. Zygospores are produced by the members of Zygomycetes e.g. Mucorales. Zygospores are often large, thick walled, warty structure with large food reserves and are unsuitable for long distance dispersal. Oospores are produced as a result of gametangial copulation or markedly unequal gametic fusion. It is the characteristic of sexually produced spores of the Oomycetes. Oospores are produced from fertilized oosphere, or sometimes parthenogenetically.

3. Life cycle of Penicillium

Penicillium belongs to the class Ascomycetes. It is commonly known as green mould or blue moulds because it forms characteristic blue green colouration due to its colonial growth on the substrates like fruits, decaying vegetables etc. The genus has about 100 species and it is very commonly distributed. Though most of the species are saprophytic but *P. expansum* and few others are weak parasites causing rotting and spoilage of fresh fruits in storage. Some species are of great industrial value. *Penicillium roqueforti* and *P. camemberti* is used in hydrolysis of fats and to impart characteristic flavour to cheese. Some species are used as a source of medicine. The antibiotic penicillin was obtained from the species like *P. notatum*, *P. chrysogenum* etc. Important antifungal antibiotic griseofulvin is obtained from *P. griseofulvum*.

3.1 Vegetative structure: The vegetative body is made up of mycelium which is profusely branched and septate. The hyphae may grow deeply inside the substratum or may grow superficially and form mycelial felt. The cells of vegetative hyphae are thin walled, uni or multinucleate. The colonies appear as floccose, velvety or funiculose. The hyphae are usually coloured due to the presence of pigments on the surface of the cell wall. The cytoplasm is granulated and vacuolated and contains cell organelles like mitochondria, ER, ribosomes and globular type of reserve food materials. The vegetative mycelia often aggregated to form compact structure called sclerotium **(Fig3.33)**.

3.2 Reproduction: *Penicillium* reproduces vegetatively, asexually and sexually. Vegetative reproduction takes place by fragmentation. The vegetative mycelia are segmented into small pieces; each segment grows into a new vegetative mycelium.

3.2.1 Asexual reproduction: Asexual reproduction takes place by conidia formation. Conidia are produced on a specialised branched stalk called as conidiophores. The name *Penicillium* has been derived from Greek word penicilli which means a brush. The conidiophores with conidia give the appearance of a broom or brush for which the genus is so named. The conidiophore emerges as an erect branch which divides dichotomously at the apex and forms first whorl of branches called **rami** (Singular: ramus). Rami in turn divide dichotomously to form another whorl of branches called **metulae.** Metulae are terminated by many bottle shaped uninucleate structures called **phialides**. On the phialides conidia are produced in a basipetalous chain. The conidia are green and dry and dispersed by wind. In *P. claviforme* the individual conidiophores may be aggregated together into a club shaped fructification called **coremia** **(Fig 3.34)**.

3.2.2 Sexual reproduction: Most species of *Penicillium* is homothallic except some like *P.luteum* is heterothallic. The sexual reproduction is basically of gametangial contact type. Two distinct sex organ formations occur during sexual processes; the male sex organ is called antheridium and the female sex organ is called ascogonium. The latter is multinucleate usually elongated erect structure. The antheridia formation though observed in most species but the they are functionless. The sexual reproduction has been studied well in *P.vermiculatum*. In this species, the ascogonium is formed as an erect multinucleate branch adjacent to which from the same hypha antheridial branch is produced which coils around the ascogonial branch. A septum is developed at the tip of the slender antheridial branch which forms the anthridium proper. The antheridium comes in contact with the ascogonial wall, at the point of the contact, the contact wall is dissolved but no nuclear migration from the antheridium to ascogonium is reported. The multinucleate ascogonium undergoes septation to form a row of bi nucleate cells. Each bi nucleate cell grows into an elongated branched ascogenous hypha. Simultaneously with the development of ascogenous hyphae, sterile elongated vegetative hyphae grow up around the sex organs from the adjacent hyphal cells. Such sterile hyphae by their compact growth around the sex organs form a globose two layered ascocarp called **cleistothecium**. (Fig 3.35 a) The cleistothecium is usually yellowish in colour. Within the ascocarp asci are formed which are globose or pear shaped. Each ascus bears eight haploid ascospores. Though the details of the development of asci from ascogenous hyphae are unknown but nuclear fusion or karyogamy followed by meiosis occurs in ascus mother cells leading to the development of eight spored ascus. Matured asci are irregularly distributed within the cleistothecium. The ascospores are set free from asci by the disintegration of the wall of asci. The free ascospores lie within the ascocarp and the same are released outside by the degeneration of the wall of ascocarp **[Fig 3.35(b)]**.

3.2.3 Systematic position (Ainsworth ,1973):

Kingdom : Mycota
Division : Eumycota
Subdivision : Ascomycotina
Class: Plectomycetes
Order ; Aspergillales
Family : Aspergillaceae
Genus : *Prnicillium*

4. Life cycle of Agaricus

Agaricus is a saprophytic fungus belonging to the class Basidiomycetes. It commonly grows on straw heaps, manure heaps, and horse dung and other decomposed matter. Many species are cultivated as edible mushroom such as *Agaricus campestris, A. bisporous, A. rodamani* etc. Many species of this genus are highly toxic such as *A. sylvaticus, A. placomyces, A. xanthodermus* etc.

4.1 Vegetative body: The vegetative body is made up of septate much branched hyphae. Basidiospore germinates to produce primary monokaryotic mycelium. The primary mycelium undergoes somatogamy to produce diploid secondary mycelium. The hyphae of such secondary mycelium intertwine together and form a compact mass called rhizomorph. Another type of mycelia are found which play role in the construction of basidiocarp, such mycelia are called tertiary mycelia. The subterranean secondary mycelium grows from a central point and form a circular area of mycelial growth. At the periphery of such circular mycelial region, the fruit bodies or basidiocarps are formed. It is imagined that such circular ring formed by the growth of basidiocarp represents the path of dancing fairies and therefore it is called fairy ring. **(Fig 3.36)**

4.2 Reproduction: *Agaricus* reproduces by vegetative, asexual and sexual method.

4.2.1 Vegetative reproduction: The diploid vegetative mycelia grow inside the suitable substratum and form a mycelial chunk called spawn. This spawn is considered as seed for the production of fruit body. Spawn are allowed to grow inside the soil supplemented with suitable organic matters to develop into fruit bodies.

4.2.2 Asexual reproduction: Under unfavourable condition the dikaryotic mycelia produce terminal or intercalary thick walled dormant spore called chlamydospore. It germinates during favourable condition and forms dikaryotic mycelium.

4.2.3 Sexual reproduction: Sex organ formation does not occur during sexual reproduction of *Agaricus*. Two vegetative hyphae of opposite polarity fuse with each other by the process called somatogamy and produce dikaryotic mycelium. The entire process of somatogamy involves three steps such as plasmogamy, karyogamy and meiosis. In plasmogamy, the cytoplasm along with nuclei of two vegetative cells of two compatible hyphae is mixed to produce a dikaryotic mycelium. Next, the two compatible nuclei of each dikaryotic cell are fused to form diploid cell and the mycelium of diploid nature thus produced is called secondary or diploid mycelium. Meiosis occurs inside the basidium soon after karyogamy and forms four haploid nuclei which are differentiated into four basidiospores. The latter develop at the apex of sterigma.

4.2.4 Development of basidiocarp: The underground secondary mycelia form white coloured hypahal knots which are pseudoparenchymatous in nature. Such hypal knots develops into button stage. During development, the button differentiates into an apical hemispherical region and a basal cylindrical solid stalk. The former is called pileus and the latter is called stipe. Towards the base of the hemispherical region, some hyphae are drawn apart and form a ring like cavity called prelamellar chamber.At the upper surface of chamber there are alternating bands of slow and rapidly diving cells. The latter serve as gill primordia which by further growth form downwardly hanging radiating membranous structure called gill. Due to gradual expansion of pileus, interspaces are formed between the gills. The margin of the pileus remains attached with the stipe be a tissue called velum which is distorted due to expansion of pileus and leaves a ring like membranous scar on the stipe called annular ring.

4.2.5 Structure of Basidiocarp: The matured basidiocarp is umbrella shaped, differentiated into two parts, lower stalk like part or stipe and expanded convex region i.e. pileus (5-12 cm in diameter).(**Fig 3.37**)

Pileus : The colour of the pileus may be light brown or sometimes creamy white. The surface is smooth and dry. On the lower surface of the pileus there are many radiating membranous structures which hang downward called gills. Gills are pink in colour when immature but converted into dark brown colour on maturity. On both this surfaces of the gill, fertile layer or hymenium is present. The VLS of the gill shows the following tissue regions:

- **Trama**: It is the central region of the gill and made up of numerous loosely arranged interwoven hyphae running from the pileus.
- **Sub hymenium**: On both sides of trama this layer is present. It is made up of hyphae develop laterally from trama. The cells are more or less isodiametric.
- **Hymenium**: This is the fertile region of the basidiocarp made up of club shaped basidia and sterile paraphyses. The diploid cell of the secondary mycelium protrudes as a club shaped outgrowth in the hymenium region. This is the probasidium which contains diploid nucleus within. The diploid nucleus undergoes meiosis and form four haploid nuclei, two of + and two of – strain. Four spine like projections develop at the apex of the basidium through each of which one haploid daughter nucleus migrates and differentiates into basidospore. Such spine like structure is called sterigma. Thus, four basidiospores differentiate exogenously on each basidum. The wall of basidiospore is made up of chitosan, chitin and β glucan. (**Fig3.38**)

Dispersal of basidiospores: On maturity, the basidiospes are released from sterigma by a mechanism called water droplet mechanism. During release of spore a water droplet appears at the hilar appendage which gradually enlarges and creates pressure on the basidiospore. Such pressure helps in the detachment of basidiospore from the sterigmata.

Germination of basidiospores : After falling on suitable substratum basidiospores germinate and produce primary mycelia. Four basidiospores from each basidium give rise to two different types of mycelia, two of + strains and two of – strains.**(Fig 3.39)**

4.2.6 Systematic position (After Ainsworth,1973):

Kingdom : Mycota
Division : Eumycota
Subdivision : Basidiomycotina
Class: Hymenomycetes
Order ; Agaricales
Family : Agaricaceae
Genus : *Agaricus*

5. Mycorrhiza

It is a symbiotic association between fungus and roots of higher plants or between fungus and gametophyte of lower groups of plants in which the associated fungus and host both are mutually benefitted. A. B. Frank was the first person who coined the term **mycorrhiza** in 1885. There are three types of mycorrhizae, such as a) Ectomycorrhiza b) Endomycorrhiza and c) Ectendomycorrhiza.

- **Ectomycorrhiza:** The salient features of ectomycorrhiza are as follows :
    - Host fungus specificity is very rare in ectomycorrhiza that means one host plant may simultaneously get infected by many fungi. Thus it is observed that more than 5000 Asco and Basidiomycetous fungi can form ectomycorrhizal association in 2000 woody plants.
    - Ectomycorrhizal association is found only in 5% of vascular plants and it is predominant in the families like pinaceae, Fagaceae, Betulaceae, Juglandaceae, Myrtaceae and in other tropical and temperate families.
    - The mycelial growth doesn't proceed beyond the endodermis.
    - The mycelia form a thick layer on the root surface which may vary from 20-40 mm depending upon the species. Such thick covering is called mantle which prevents root to come in direct contact with soil particles. The fungal mycelia also form a network of hyphae in the cortical tissue; such hyphal network is known as hartig net.
    - Morphogenetic changes of the root may occur due to ectomycorrhizal association. The infected roots may appear nodular, forked, biforked, multiforked etc.
    - The fungi forming ectomycorrhiza mostly belongs to agaric Basidiomycetes, Gasteromycetes, Ascomycetes, fungi imperfecti and occasionally Phycomycetes. (Examples: *Amanita muscaria, Boletus edulis, Laccaria laccata, Inocybe rimosa, Pisolithus tinctorius*). **(Fig 3.40)**
- **Endomycorrhiza :** The fungi involved in endomycorrhizal association not only show their growth on the surface of the root system but also their mycelia grow rapidly inside the deeper layer of the tissue, even beyond the endodermis and form various structures during their intra and inter cellular growth. Unlike ectomycorrhiza, host specificity is noted in this type of mycorrhizal association. Based on their host specificity and structures produced during their growth inside the host tissue the following types of endomycorrhizae are found:
    - **Vesicular arbuscular mycorrhiza (VAM):** This is the most common type of mycorrhiza found in the vascular plant. Over 90% of the vascular plants of world flora form this kind of mycorrhizal association. VAM is also known as arbuscular mycorrhiza or glomeromycotan mycorrhiza. This kind of mycosymbiotic association is very common in cultivated and wild species and also found in bryophytes, pteridophytes and gymnosperms (except Pinaceae). VAM forming

fungi mostly belongs to the family Endogonaceae of Zygomycotina. The mycelia exhibit both inter and intra cellular growth. During intracellular growth the mycelia are dichotomously branched and severely folded to form a structure called **arbuscule**. These are considered as the sites for exchange of nutrients between host and fungus. The mycelia during their growth inside the host tissue form thin or thick walled oil rich spherical bodies filled with huge amount of reserve materials called vesicles. VAM are formed by hundreds of fungal species which belongs to six genera viz. *Acaulospora, Gigaspora, Glomus, Entrophospora, Sclerocystis* and *Scutellospora*. (Fig3.41&42).

- **Ericoid mycorrhiza:** Ericoid mycorrhiza occurs throughout the fine root systems in the tribe Ericoidae of the family Ericaceae (except tribe Arbutoidae). *Hymenoscyphus* (*Pezizella*) *ericae* was first discovered as an ericaceous mycosymbiont. The plants like *Ephachris*, *Leucopogon*, *Monotoa*, *Rhododendron*, *Vaccinum*, etc. develop ericoid mycorrhizae. The fine root systems of these plants are usually infected. The mycelia usually do not produce arbuscules. The fungi forming Ericoid mycorrhiza mostly belong to ascomycetes, for example *Pezizella*, *Glvaria* spp. etc.

- **Arbutoid mycorrhiza:** This type of mycorrhiza was first discovered in the plant *Arbutus unedo*; a plant belongs to the tribe Arbutoidae of the family Ericaceae. Mostly the roots of woody shrubs and trees are infected by this type of fungi. The roots are called **herorhizic** because infected short roots develop distinct sheath and hartig net. The fungal mycelia form extensive coils of hyphae inside the cortical cells of root. The mycosymbionts mostly belong to Basidiomycetes.

- **Monotropoid mycorrhiza:** This type of mycorrhiza is found in the members of the family Monotropaceae (e.g. *Monotropa hypopitys*). The plants of this family completely depend on mycorrhizal fungus for carbon and energy. The plant *Monotropa* characteristically forms root ball within which fungal mycelium grows enclosing the mycorrhizal roots of neighbouring green plants. The root ball serves as the survival organ of the plant during winter and on returning of favourable condition it gives rise to flowering shoots. *Monotropa* and associated trees are often connected by mycelium of a common mycorrhizal fungus *Boletus*.

- **Orchid mycorrhiza:** It is a symbiotic association between roots of the plants belonging to Orchidaceae and a variety of fungi. In nature orchid seeds could not germinate without the help of mycorrhizal association. As the orchid seeds are non endospermic, the embryo requires the help of mycorrhizal fungi as the source of carbon and energy. The non germinated seeds develop a stage in the life cycle called **protocorm** which is usually infected by mycorrhizal fungus. The infected protocorm grows into adult orchid plant. The fungi that form orchid mycorrhizae typically belong to the class Basisiomycetes. The range of taxa that belong to this class include *Sebacina*, *Ceratobasidium* (*Rhizoctonia*), *Tulasnella*,*Rusulla* etc. **(Fig 3.43)**

5.3 Ectendomycorrhiza: This type of mycorrhiza shares the characters of both ecto and endomycorrhiza. The mycelia grow on the root surface to form mantle from which some peg like hyphae penetrate into the cortex and perform intracellular growth. Both ectotrophic and endotrophic behaviour is noted in these fungi. This type of mycorrhizal association is found in the members of the order Pezizales (e.g. *Wilcoxina* spp. and *Sphaerosporella brunnea*). In some fungal symbionts of this type though hartig net formation does not occur but intercellular hyphal coils in the cortical cells are noted.

Significance of mycorrhizae: Mycorrhizae play significant role in agriculture and forestry which are summarized below:

- The stability of mycorrhizal roots is more than that of normal roots. The covering layer i.e. mantle formed by the fungal mycelia surrounding the roots help to retain moisture so that such roots could survive in drought condition.

- The mantle layer surrounding the mycorrhizal roots increase the surface area and the roots become more capable of absorbing water and nutrients from the soil. Besides, the same layer on the mycorrhizal roots prevents frictional injury of the root surface. It is observed that the supply of different mineral elements like P, K, Zn, Cu etc. to the host plant having mycorrhizal infection in the roots is greater than the plants having normal uninfected root system.

- In *Pinus* the root system lacks of sufficient number of root hairs. Such deficiency of the number of root hairs is compensated by the hyphae of mycorrhizal fungus which is the symbiotic inhabitant of the roots. The fungal mycelia growing on the root system absorb water from the soil and supply them to the underlying tissue of the root. Having water holding capacity the mantle forming mycelia prevent the roots from desiccation due to dryness.

- Mycorrhizal fungi produce wide variety of biochemical compounds which are released into the rhizosphere of the host plant and induce the growth of diverse type of beneficial microbial population. Such beneficial microbial biomass includes nitrogen fixers, phosphate solubilizers, siderophore producers etc. The enhanced growth of beneficial microbes in the rhizoecological niche is known as **mycorhizospheric effect**. Such effect is therefore considered as the indirect impact of mycorrhizae on the growth and productivity of the host plant.

- Mycorrhizae play significant role in the solubilisation of insoluble phosphate in the soil. The soil in which available phosphate is low in respect of total P content, application of mycorrhizae in such soil has been proved very much effective to increase the availability of phosphate. In this regard the role of mycorrhizae may be direct or indirect. Indirectly, the mycorrhizae interact with the phosphate solubilising bacteria and by enhancing their population increase the availability of phosphate to the host plant. As a direct effect it has been proved experimentally that mycorrhizae produce some organic acids which help to solubilise insoluble phsosphate and make it available to the host plant. The vegetative mycelium of mycorrhizal fungus stores phosphate in the form of polyphosphate granules with the help of the enzyme polyphosphate kinase. Then inorganic phosphate is transferred to the host plant with the help of the enzyme phosphatase. In this way phosphate accumulates in the mantle and hartig net and thereafter gets transferred from hartignet to the host tissue. In this, the roles of VAM fungi are very important since they not only increase the phosphate availability of the host plant but also protect the host plant from phytopathogenic infection. It has been observed that inoculation of VAM in tomato plant doubles its growth and increase the number of leaves eight fold. It also lessens the number of days to flower than non-mycorrhizal plant. Significant increase in the height, panicle length, number of grains per panicle is observed in case of the rice plant inoculated with *Glomus.* Thus VAM fungi may reduce the negative effect of stress caused by water and nutrient deficiency.

- Mycorrhiza plays very important role in the transfer of nutrients from host to host. The photosynthates are transferred from host to fungal symbiont and the same could be transferred to other different host where the fungal symbiont is a shared symbiont.
- In horticultural practices mycorrhizae help in the induction of rootings of cuttings. This action is performed by the production of IAA from the mycorrhizal hyphae. The same hormone produced by the mycorrhizal fungi play immense role in morphogenesis and longevity of the roots.
- Antagonistic substances released by the mycorrhizal fungi in the rhizosphere of the host plant prevents the growth of pathogenic microorgagnisms particularly root infecting pathogens and protect the host plant from different types of diseases. It has been proved that *Leucopaxillus ceralis* var. *piceina* produces antibiotic like substances which prevent the pathogenic infection of pine root.

- In floriculture, mycorrhizal fungi are applied for orchid plant production. In nature orchid seeds could not germinate due to lacking of stored food in the seeds. Artificially, mycorrhizal fungi are applied to such seeds to induce germination.

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Exercise (Unit –III)

Objective multiple choice questions:

- The ascocarp of *Penicillium* is known as : a) Apothecium b) Cleistothecium c) Perithecium d) None of the above.
- In Ascomycotina karyogamy occurs in : a) Ascogonium b) Antheridium c) Ascus d) Ascogenous hypha.
- Which of the following is a coprophilous fungus? – a) *Ascobolus* b) *Puccinia* c)*Saccharomyces* d) *Penicillium.*
- Which type of fruit body in fungi looks like a cup or saucer? – a) Apothecium b) Perithecium c) Cleistothecium d) Sclerotium.
- Pseudomycelium is found in : a) *Synchytrium* b) *Rhizopus* c)*Mucor* d) *Saccharomyces.*
- Ascogenus hyphae is produced from : a) Antheridum b) Ascogonium c) Ascogonium and antheridium both d) Ascus.
- What is hysterothecium? a) unilocular perithecium b)Unilicular cleistothecium c) Unilocular ascostroma d) Bilocular and multilocular ascostroma.
- The four nucleate stage of basidium is known as : a) Probasidium b) Metabasidium c) Holobasidium d) Basidum.
- Dolipore septum is the characteristic feature of a)Ascomycetes b) Basidiomycetes c) Discomycetes d) Phycomycetes.
- Which of the following type of spore is produced as a result of sexual reproduction ? a) Zygospore b) Zoospore c) Conidia c) Chlamydospore.
- Fairy ring producing fungus is : a) *Rhizopus* b) *Mucor* c) *Penicillium* d) *Agaricus*.
- The fertile region of the fruit body of *Agaricus* is a) Pileus b) Hymenium c) Stipe d) Rhizomorph.

- Where basidium is found in *Agaricus*? A) Gills b) Pileus c) stipe d) Rhizomorph.
- Which class of fungi is known as 'Fungi imperfecti'? a) Zygomycetes b) Ascomycetes c) Basidiomycetes d) Deuteromycetes.
- Which of the following processes is related to the growth of the mycelium? A) Clamp formation b) Binary fission c) Genome duplication and cell division c) clamp connection.
- Which of the following mycelia plays major role in the formation of fruiting body? a) Primary mycelium b) Secondary mycelium c) Tertiary mycelium d) Secondary and tertiary mycelium.

Answers: 1(b), 2(d), 3(a), 4(a), 5(d), 6(b), 7(c), 8(b), 9(b), 10(a), 11(d), 12(b), 13(a), 14(d), 15(d), 16(c).

Answer the following questions:

- Write the diagnostic features of fungi. (Ans. See the introduction section)
- Define primary, secondary and tertiary mycelium in fungi. [Ans. See section1.0(i)]
- What is clamp connection? [Ans. See section 1.0(i)]
- What is sclerotium? (Ans. See section 1.0)
- What is stroma? (Ans. See section 1.0)
- What is rhizomorph? (Ans. See section 1.0)
- What is meant by dolipore septum? [Ans. See section 1.0(ii)]
- What is lomasome? (Ans. See section [Ans. See section 1.0(ii)b]
- What is Woronin body? [Ans. See section 1.0 (ii) c]
- Wha is karyochoresis? [Ans. See section1.0(ii)c]
- What are the characteristics of the zoospore in fungi? [Ans. See section 2.2(i)]
- Classify conidia on the basis of its developmental pattern. [Ans. See section 2.2(ii)]
- Describe different types of conidial fructification produced in fungi. (Ans. See section2.3)
- Describe different types of ascocarp with diagram. (Ans. See section 2.4.1)
- Define sterigmata. (Ans. See section 2.4.2)
- Classify basidia on the basis of their structural morphology. (Ans. See section 2.4.2)
- What is perisporal sac? (Ans. See section 2.4.2)
- What are ascogenous hyphae? (Ans. See section 2.4.1)

- Write short notes on : a) Gametangial contact. (Ans. See section 2.5)b) Gametangial copulation(Ans. See section 2.5) c)Spermatization (Ans. See section 2.5) d) Somatogamy. (Ans. See section 2.5)
- Draw and describe the conidial structure of *Penicillium*. (Ans. See section 3.2.1)
- Draw and describe different types of sexual reproduction in fungi. (Ans. See section3.2.2)
- Draw and describe the structure of basidiocarp of *Agaricus*. (Ans. See section 4.2.5)
- Define mycorrhiza. Classify mycorrhizae according to their structure. (Ans. See section 5.0)
- What is VAM? Characterise VAM. (Ans. See section 5.2)
- Describe the significance of mycorrhizae in agriculture and forestry. (Ans. See section 5.3).

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