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College of Science
Department of Biology

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المرحلة الثالثة ـ الدراستين الصباحية والمسائية
الفصل الدراسي الثاني

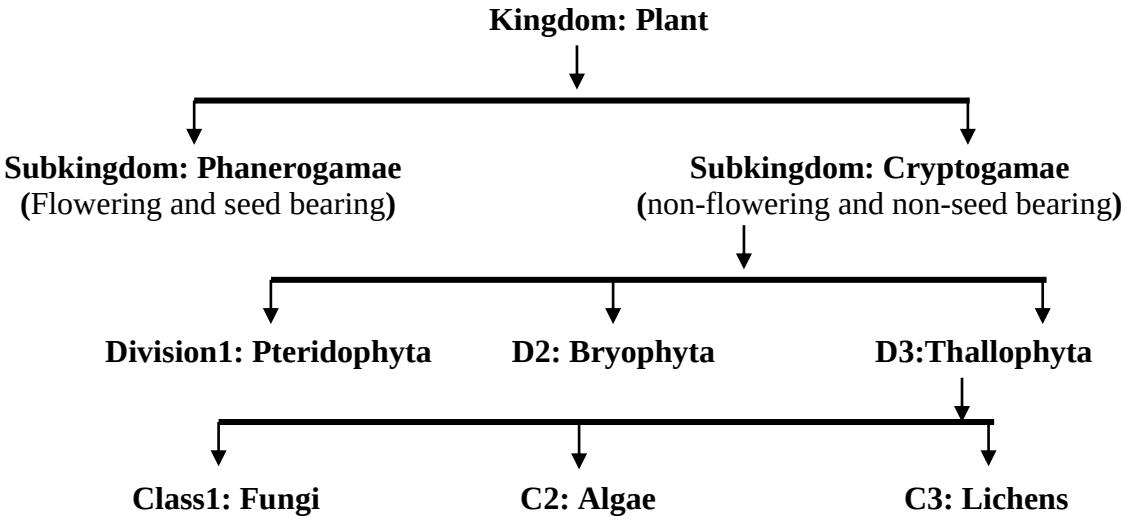
تدريسي المادة :

أ.م.د. علاء محسن الاعرجي
أ.م.د. رسل محمد جاسم
أ.م.د. اسراء احمد علي
أ.م.د. ماجدة هادي مهدي

Importance of Fungi:

1. Fungi are the agents responsible for much of the disintegration of organic matter and such they affect us directly by destroying food, fabrics, leather and other consumer goods manufactured from materials subject to fungal attack; they cause majority of plant disease, and many diseases of animals and humans
2. They are the basis of a number of industrial processes involving fermentation, such as making of bread, wines, beers, the fermentation of cacao bean and the preparation of certain cheeses.
3. Production of many organic acids of some drugs such as ergotamine and cortisone and some vitamin preparations and are responsible for manufacture of a number of antibiotics,notably penicillin and grisofulvin.
4. Many fungi are particularly important in the decomposition of plant debris because of their ability to utilize cellulose.
5. Some of them are good for human such as *Agaricus bisporus*-edible mushroom
6. Use it as important research tools in cytologists, Geneticists, and Biochemists such as *Neurospora*.

The **first classification system** of fungi has been created by Eichler in 1883 who classified fungi as a class in kingdom plant as following:-



This classification system was rejected for many reasons:

1-Fungi have not chlorophyll, so the nutrition of fungi need ready media supply-Saprophyte- or some fungi are parasites.
2- Cell wall contains large amount of chitin except some of flagellates.
3- The growth in fungi by hyphal tips.
4- The fungal mycelium contains septum – in most fungi.
5- The growth rate, mitosis and life cycle are differing from plants.

The second classification system was done by Whittaker in 1969, who divided the organisms into five kingdoms as following:-

Kingdom 1: Monera: This involves the unicellular or multicellular organisms but prokaryote such as Bacteria and cyanobacteria.

Kingdom 2: Protista: This involves the unicellular or multicellular organisms but Eukaryote such as Protozoa.

Kingdom3: Mycetae : Mycota: This involves fungi , unicellular or multicellular organisms but heterotrophs.

Kingdom 4: Metaphyta: This involves all higher plants.

Kingdom 5: Metazoa: This involves all animals.

What are fungi?

At present, Biologists use the term fungi – fungus- to include: Eukaryotic, spore-bearing, Achlorophyllous organisms that generally reproduce sexually and asexually, and usually filamentous branched. Somatic structures are typically surrounded by cell wall containing chitin, cellulose or both.

How fungi differ from Bacteria:

1. All true fungi are aerobic, that mean they need oxygen for their development, reproduction and metabolisms, while bacteria are aerobic, anaerobic and facultative.
2. Cell type: Fungi are Eukaryote they have nuclear materials which is organized into chromosomes- nuclei of fungi are similar to the nuclei of mammalian cell- while bacteria are prokaryotic type – lack nuclear membrane.
3. Hydrogen ion concentration-pH- : In contrast to bacteria, fungi prefer an acid medium for growth, pH range for fungi between 3.8-5.6, with a pH 5.5 being near the optimum for most species investigated. While bacteria need pH for growth between 7.0-7.6 .
4. Temperature: Most fungi grow well between 0-35ºC, but optimal temp. range is 20-30ºC – Room temp. There are number of thermophilic fungi –have a maximum temp. for growth at above 50ºC and a minimum at or above 20ºC. While bacteria need 37ºC- Human body temp.-
5. Cell wall structure: Cell wall contains large amount of chitin, cellulose, hemicellulose-N-acetyl glucosamine, 5-10% protein, 50-60% carbohydrate -Glucan-, While bacteria contain peptdoglycan. Furthermore, it has been shown

that external factors such as composition of the media, pH value, and temp. may influence the composition of the fungal cell wall.

6. All fungi require very high sugar concentrations in the Lab. Media for the growth- 4-5%- While bacteria require 1.5% of sugar.
7. All fungi are Gram positive structure.
8. All fungi are sensitive to antifungal agents and resist to antibacterial agents according to cell wall structure.

Morphology of fungi:

When fungi are grown on suitable medium , produce long, branching filaments, those called Mold. Each filament is called hyphae. Hyphae are long, slender transparent, wall filled or lined with a large of protoplasm varying in thickness. Generally 3-10 microns in diameter. If hyphae have cross wall, the fungus is said to be septate, if not aseptate or non septate or coenocytic hyphae Figure 1.

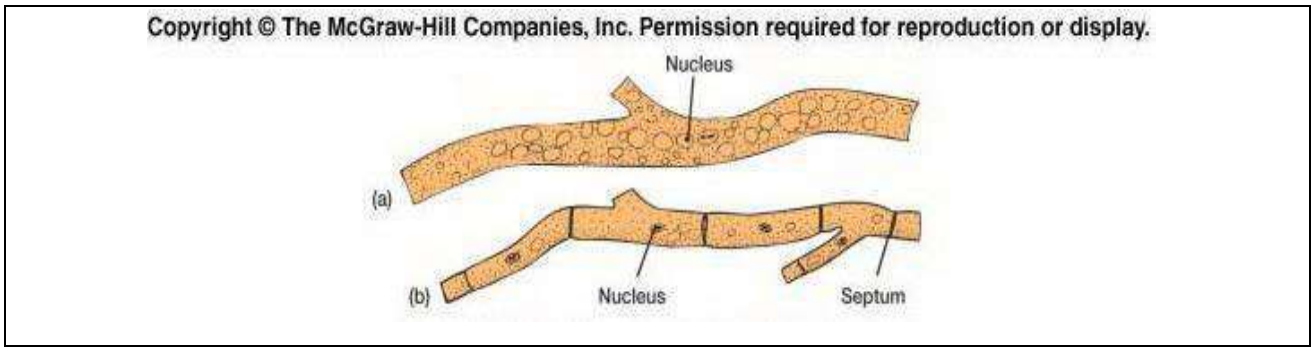


Figure 1

The presence or absence of these cross wall can be important in differentiating between certain classes. Hyphae may become divided into a chain of cells by the formation of septa- septum. As the hyphae continue to growth and branched a mat of growth called mycelium. The part of growth which project above the surface of substrate called aerial mycelium which hold the spores.

The part which penetrate into the substrate and absorbs food is known vegetative mycelium. The mycelium of parasitic fungi grows either by spreading between the cells or penetrating into them. The mycelium of fungus generally beings as a short-germ-tube emerging from a germinating spore. Fungal colony tend to be circular in out-line on solid medium, while the mycelium has a tendency to grow more or less equally in all directions from central point, and to develop colony- you can observe this by growing certain fungi on liquid and solid media-Figure 2.

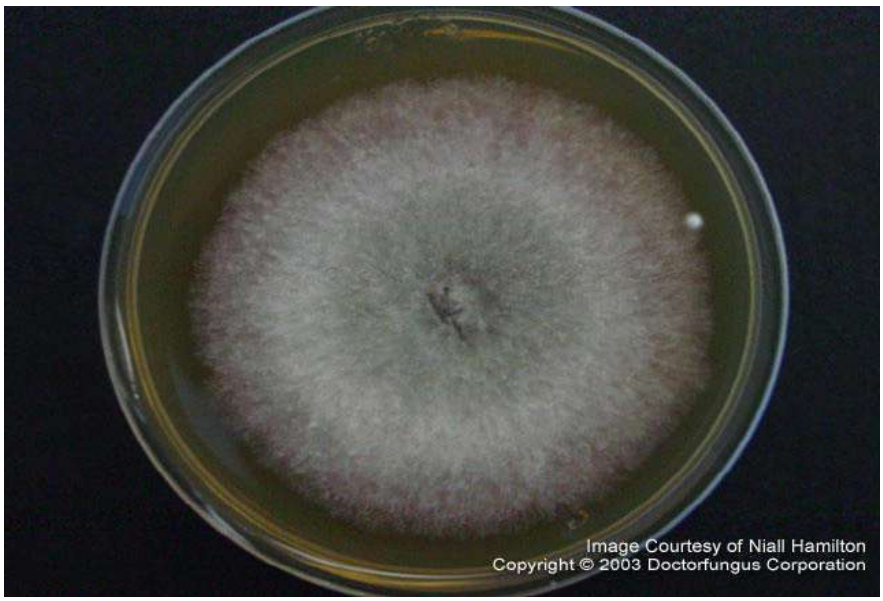


Figure 2

Fungi can be classified into four groups according to their morphology:

1. Mold – Mould: Which grow as branching filaments (hyphae) and produce the mycelium.
2. Yeast: Unicellular cells which appears as round cells, do not form spores but reproduce by budding of the parent cells. This process of budding results in the production of two cells. Most are single celled structure with a thick cell wall such as *Cryptococcus neoformans* Figure3.
3. Yeast-like fungi: Also reproduce by budding and grow as non branching filament- pseudohyphae- such as *Candida albicans* Figure 4.
4. Dimorphic fungi: They grow as yeast form in tissue when incubated at 37ºC *in vitro*, but when incubated at 22ºC grow as mycelium form. This group of fungi have two phases of growth – Dimorphic such as:- *Histoplasma capsulatum ; Blastomyces dermatitidis.*

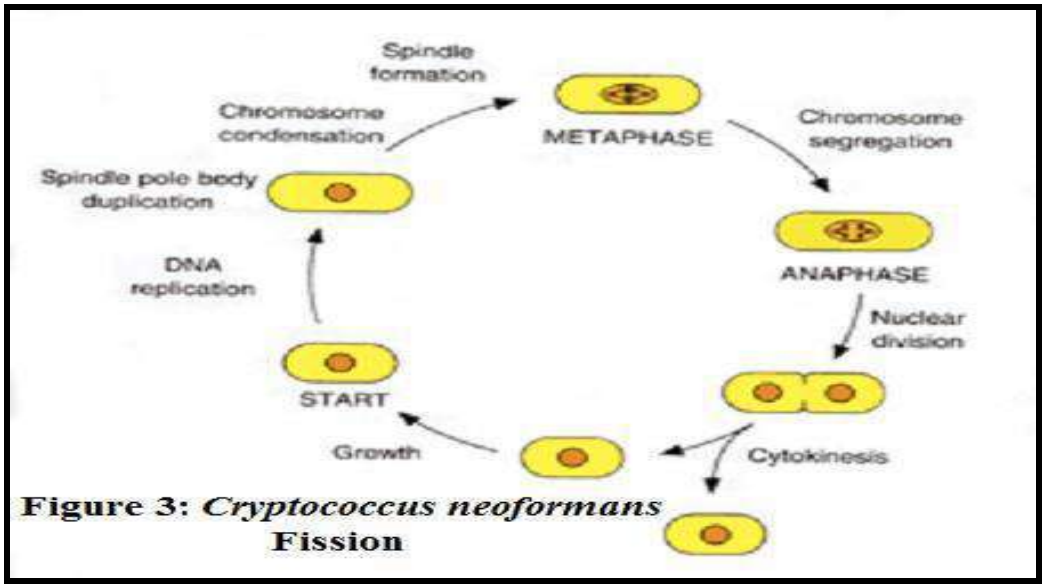
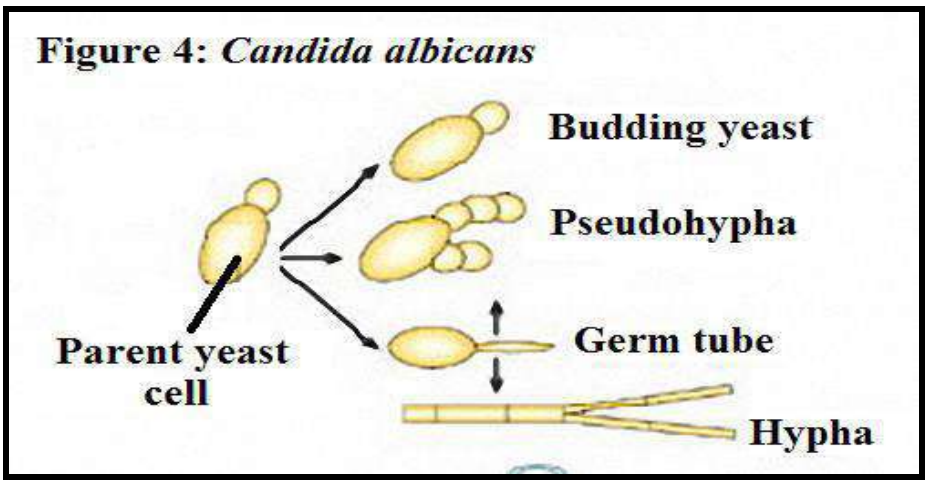


Figure 3: *Cryptococcus neoformans* Fission



Reproduction:

Most fungi reproduce by forming spores. Spore – seed- : a simple propagating unit without an embryo that serves in the production of new individuals of the same species. Fungi do not posses stems, roots, or leaves; they are usually filamentous and multicellular. Spores are similar to the seed of higher plants in their functions.

There are two types of spores:

1 - Asexual spores:- Which occurs by the process of mitosis. This is most common process by which spores are reproduced in fungi.

There are four types of medically important:

a. **Blastospores:** The type of spore develop by budding.
b. **Chlamydospores:** In some fungi the hyphal cell become specialized spore when the cell enlarged and develop thick walls.
c. **Arthrospores:** Other hyphal cells break apart and produce arthrospores. Fragmentation may also happen naturally by the action of wind, soil movement or insects.
d. **Conidia:** A conidium is produced on a specialized structure called conidiophore. A spore which is produced directly on a hyphae or hyphal tips is called Aleuriospore, when a fungus produce two sizes of aleuriospores : The large one is called Macro- aleuriospore., The smaller one is called Micro-aleuriospore.

2- Sexual spores: Reproduce by meiosis

a. **Ascospores:** Usually 4-8 spores found in a cell called ascus- asci.
b. **Basidiospores:** Usually 4- spores found in the surface of cell called basidium.
c. **Zygosopores:** Large-thick walled spore formed on hyphae.
d. **Oospores:** This type of spore formed inside cell called oogonium.

Living mode of fungi :

In nature fungi obtain their food :

1. **Parasites:** by infecting living organisms this including:
   a. **Obligate parasites**: these can't live except on living protoplasm.
   b. **Facultative parasites**: these can live on living protoplasm or on dead matter
2. **Saprobes:** by attacking dead organic matter this including:
   a. **Obligate saprobes**: These can live on dead matter and incapable of infecting living organisms.
   b. **Facultative saprobes:** These can live on dead matter and capable of infecting living organisms.
3. **Symbiotic**: by relationships with plants as in Lichens and mycorrhiza (Ecto and Endotrophic).

A living organisms infected by parasite is known as the host.

Cultivation of fungi :

Fungi which we can cultivated them on nutrient media are (saprobes and facultative parasites), and those fungi cultivate on different culture media such as:

1. **Natural media**: They are plant extract such as wheat extract, potato extract, carrot and others vegetable extract, also we can use fruit to prepare this kind of media.
2. **Synthetic media:** The main compositions of this medium are certain chemicals and some salts such as Czapek`s Dox Medium .
3. **Semi synthetic media**: they are mixed of two kinds of media (natural and synthetic) such as Potato Dextrose Media.

These three types of culture media are liquid so we can solidify them by adding **(1.5 – 2.0 %)** agar.

What are the important elements for fungal growth?

1. **Carbon sources:** (carbohydrates) such as monosugar (glucose and fructose) or di sugar such as sucrose and maltose and multi-sugars such as starch.
2. **Nitrogen sources:**
   a. **Organic source**: such as Amino acids and peptone.
   b. **In organic source**: such as nitrate and ammonia.

The salts are added according to fungi requirements.

A. Macro elements: which add in large quantities such as Na, Mg, k, Zn.

B. Micro elements: which add in trace quantities such as Sc , Mn.

Environmental conditions suitable for fungi cultivation :

1. **Temperature**: Fungi are living in wide range of temperature and according to it, fungi classified in to :
   a. **Mesophilic fungi**: The range is (10–40ºC) and the optimum is (25 – 35ºC)
   b. **Psychrophilic fungi**: The range is (5–25ºC) and the optimum is (15ºC)
   c. **Thermophilic fungi**: The range is (20 – 50ºC) and the optimum is (40ºC)
2. **Hydrogen Ion concentration: pH**: (as mention before).
3. **Aeration**: All fungi prefer living in aerobic condition.
4. **Light**: is not necessary for fungal growth but it is (some time) important to form sexual and asexual structures.
5. **Humidity: a.** Some fungi are water mold.
   b. Some fungi need some water for growth.
   c. Some fungi are capable to growth in near-dry condition.

Reproduction:

Reproduction is the formation of new individuals having all the characteristics typical of the species. Two general types of reproduction are recognized:

Sexual and asexual. Asexual reproduction sometimes called somatic or vegetative, does not involve the union of nuclei sex cells or sex organs. Sexual reproduction on the other hand, is characterized by union of two nuclei. In the formation of reproductive organs, either sexual or asexual, the entire thallus may be converted into one or more reproductive structure, so that somatic and reproductive phases do not occur together in the same individual, fungi that follow this pattern are called (Holocarpic). In the majority of fungi, however the reproductive organs arise from only a portion of the thallus, while the remainder continuous its normal somatic activities, the fungi in this category are called (Eucarpic).

Asexual Reproductio:

In general, asexual reproduction is more important for the propagation of the species because it results in the production of numerous individuals, and particularly since the asexual cycle is usually repeated several times during the season, whereas the sexual stage of many fungi is produced only once a year. The asexual methods of reproduction commonly found in fungi may be summarized as follows:-

1. Fragmentation: Each fragment growing into a new individual. Some fungi employ fragmentation of hyphae as a normal means of propagation. The hyphae may break up into their component cells that behave as spore. These spores are known as arthrospores. If the cells become enveloped in a thick wall before the separate from each other or from other hyphal cell, they are often called chlamydospores Figure 5.

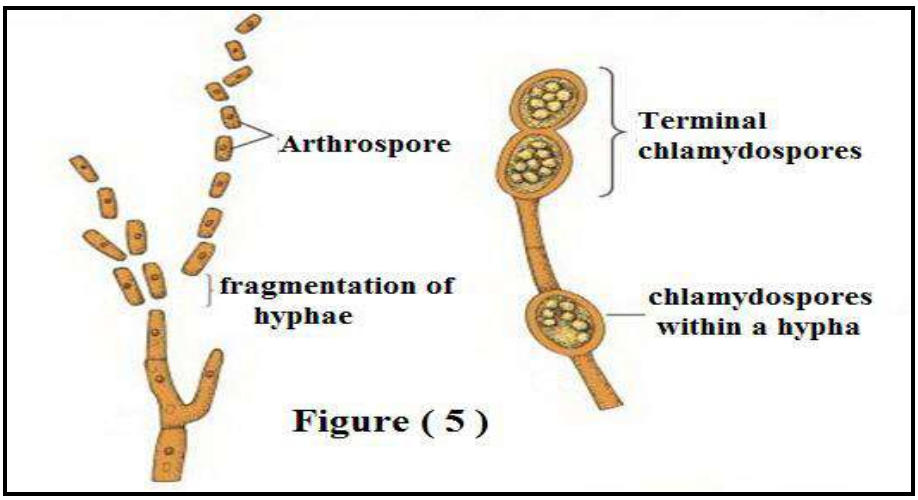


Figure (5)

Fragmentation may also occur accidentally by the tearing off of parts of the mycelium through external forces. Such pits of mycelium under favorable conditions will start a new employ mycelia fragmentation to keep fungal cultures growing on artificial media by transferring a bit of mycelium to fresh media and thus starting a new colony.

2. **Simple fission of somatic cells into daughter cells:** Fission, the simple splitting of a cell into two daughter cells by constriction and formation of a cell wall, is characteristic of a number of simple organisms including some yeast.

3. Budding of somatic cell or spores: Each bud producing a new individual. As the bud is formed, the nucleus of parent cell divides and one daughter nucleus migrates into the bud. The bud increases in size while still attached to the parent cell and eventually breaks off and form a new individual Figure 6.

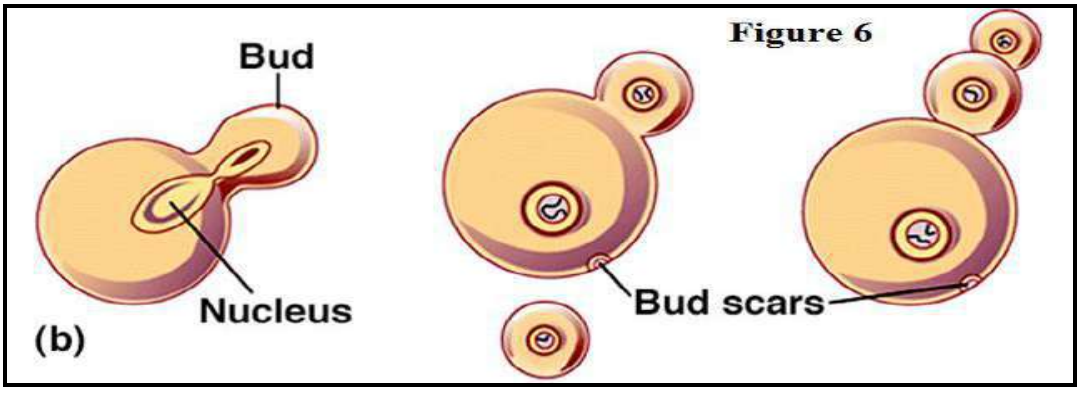


Figure 6

4. Spore formation: The most common method of asexual reproduction in fungi is by means of spores. Spores vary in color from hyaline through green, yellow, orange, red, brown to black; in size from minute to large; in shape from globes through oval, oblong, needle-shape to helical; in number of cell, from one to many; in the arrangement of cells; and in the way in which the spores them-self is borne Figure7.

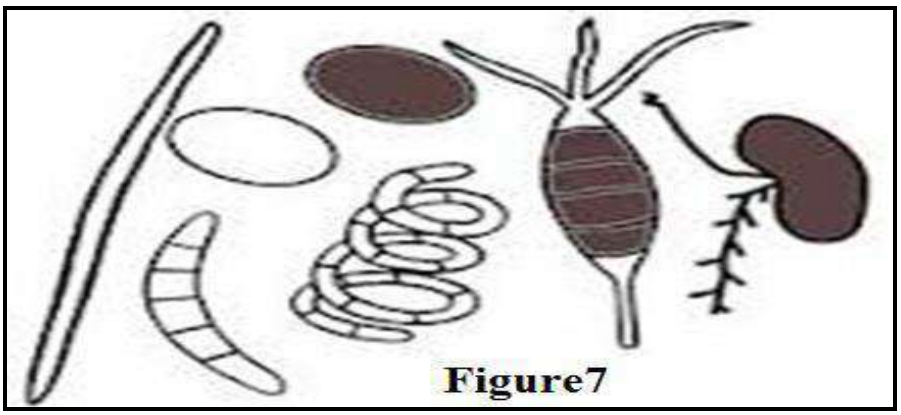


Figure7

Some fungi produce only one type of spore, whereas other produces as many as four types. Fungal spores produced asexually are either borne in sporangia (sporangium) and then are called sporangiospores Figure8, or are produced at the tips or sides of hyphae in various ways and are then called conidia (conidium) Figure 9.

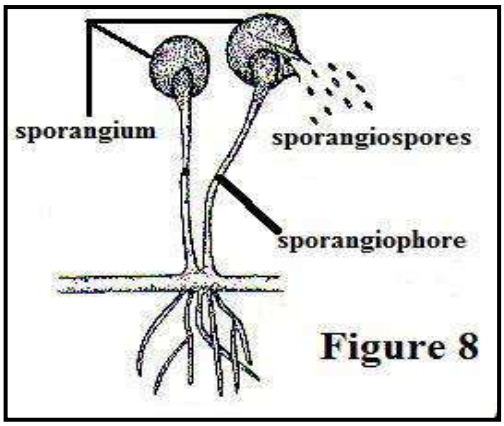


Figure 8

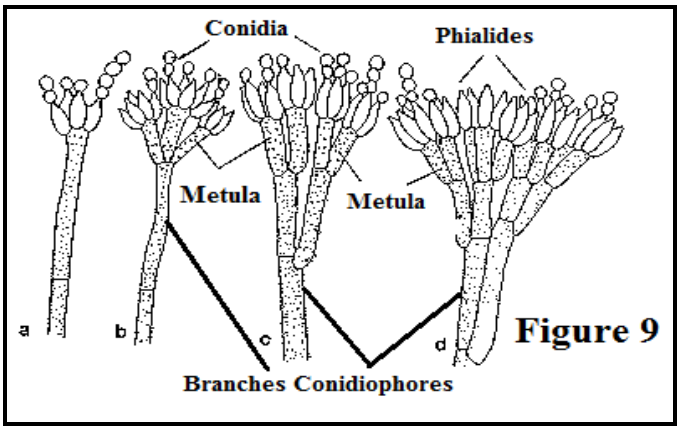


Figure 9

Sporangiospores may be motile or non- motile. In simpler fungi the sporangiospores are usually motile and are called (zoospores), if non- motile are called aplanospores. Fungal zoospores are equipped with one or two flagella (flagellum). There are at least two types of flagella in the fungi: The whiplash and tinsel. The flagella in fungi are differing in position, types, and number Figure 10.

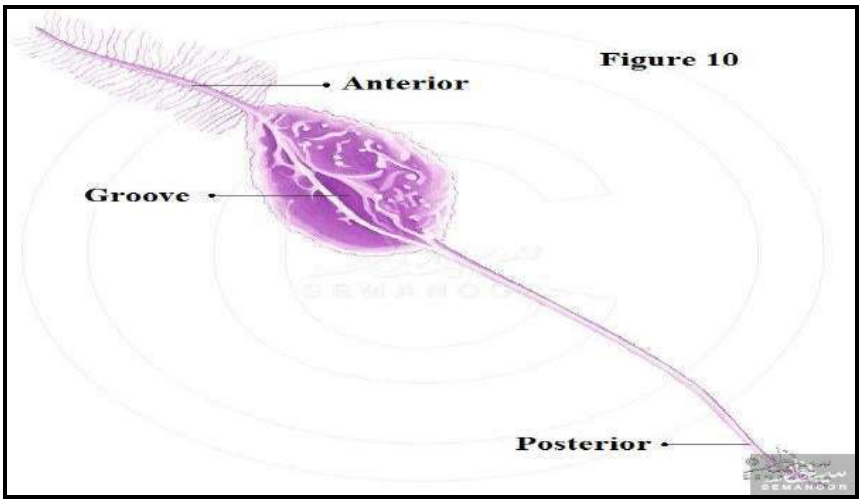


Figure 10

Sexual Reproduction:

Sexual reproduction in fungi as in other living organisms involves the union of two compatible nuclei. The process of sexual reproduction typically consist of three distinct phases:

1) Plasmogamy: a union of two protoplasts brings the nuclei close together within the same cell.

2) Karyogamy: The fusion of the two nuclei brought together by plasmogamy.

3) Mieosis: The reduction of chromosomes number to the half.

Karyogamy follows plasmogamy almost immediately in many of the simpler fungi. In the more complex fungi, however, those two processes are separated in time and space, with plasmogamy resulting in a binucleate cell containing one nucleus from each parent. Such pair of nuclei we call a **(Dikaryon)**.

The sex organs of fungi are called gametangia (gametangium), these may form differentiated sex cell called gametes or may contain instead one or more gamete nuclei. We use the terms **(isogametangia and isogametes)** to designated gametangia and gametes that are morphologically indistinguishable; we use **(heterogametangia and heterogametes)** to designate male and female gametangium and gamete that are morphologically different, in the latter case, the male gametangium is called the (**antheridium**) and the female is called the (**Oogonium**). What is the third phase of sexual reproduction?

We now list the various methods by which compatible nuclei are brought together in the process of plasmogamy. These methods are often referred to as methods of sexual reproduction. Fungi employ five general methods to bring compatible nuclei together for fusion. These methods are:

1- Planogametic copulation.
2- Gametangial contact.
3- Gametangial copulation.
4- Spermatization.
5- Somatogamy.

Sexual compatibility : Those in which every thallus is sexually self-fertile and, can therefore, reproduce sexually by itself without the aid of anther thallus, these type of fungi we called **(Homothallic fungi).** Those in which every thallus is sexually self-sterile, and requires the aid of anther compatible thallus or a different mating type for sexual reproduction, these types of fungi called (Heterothallic fungi).

Classification of Fungi:

Fungi are a specific and large kingdom and it is difficult to classified them. So we must collect alot of informations starting with cultural characters reaching to the size, color, shape, number of cell, type of spores. The classification system in fungi started with kingdom and end with species as follows:

Kingdom : Mycetae -Fungi-
Division : Mycota
Subdivision : Mycotina
Class : Mycetes
Subclass : Mycetidae
Order : ales
Family : aceae
Genus and Species: -There is no special ends-

Kingdom: Mycetae

Division 1: Myxomycota

General chracteristics:

1- No cell wall
2- Swarm cells contain two unequal anterior whiplash flagella.
This division consists of two classes:
Class 1: Myxomycetes (Free - living plasmodium)
Class 2: Plasmodiophoromycetes (Endoparasite plasmodium)

Division 2: Eumycota

This division consists of five subdivisions:

Subdivision 1: Mastigomycotina:

The main characteristics of this class are:

1. Swarm cells contain (posterior or anterior or both) whiplash flagellum.
2. No mycelium (in most individuals) or Mycelium is presence but coenocytic.

Subdivision 2: Zygomycotina:

1. Fungi with aseptate mycelium.
2. Asexual reproduction by aplanospores.
3. Sexual reproduction – gametangial contact- resulting in the formation of zygospores.

Subdivision 3: Ascomycotina:

1. Fungi with septate mycelium.
2. Producing ascospores in sac-like cells –asci-, usually eight ascospores.

Subdivision 4: Basidiomycotina:

1. Fungi with septate mycelium and forming -clamp connections- .
2. Basidium bearing usually four basidiospores.

Subdivision 5: Deutrromycotina:

1. Fungi with septate mycelium.
2. Usually producing conidia.
3. Sexual reproduction unknown.

Division 1: Myxomycota

Class 1: Myxomycetes

One founders of mycology considered the slime molds animals and called them –Mycotozoa-; because the vegetative phase is like-plasmodium. They have a free- living, a cellular, multinucleate somatic plasmodium. Produce flagellated swarm cells inside a fructification-sporophore- that usually develops a –peridium- enclosing the spores.

What is plasmodium?

It is a mass of protoplasm, delimited only by a thin plasma membrane and a gelatinous sheath. The plasmodium does not have a definite size or shape. The protoplast is fluid in some portions and gelatinous in others (veins), the fluid portion of protoplast is usually in the form of an intricately branched network streaming through the gelatinous portion.

There are three types of(sporophore)reproductive organs in class Myxomycetes:

1- Sporangium:

This sporangium either bearing on stalk or stalkless (sessile), each sporangium has a peridium of its own. There may also a thin, cellophane-like base, the hypothallus, and there are spores and capilitium inside sporangium Fig: 11 Ex: *Physarum*.

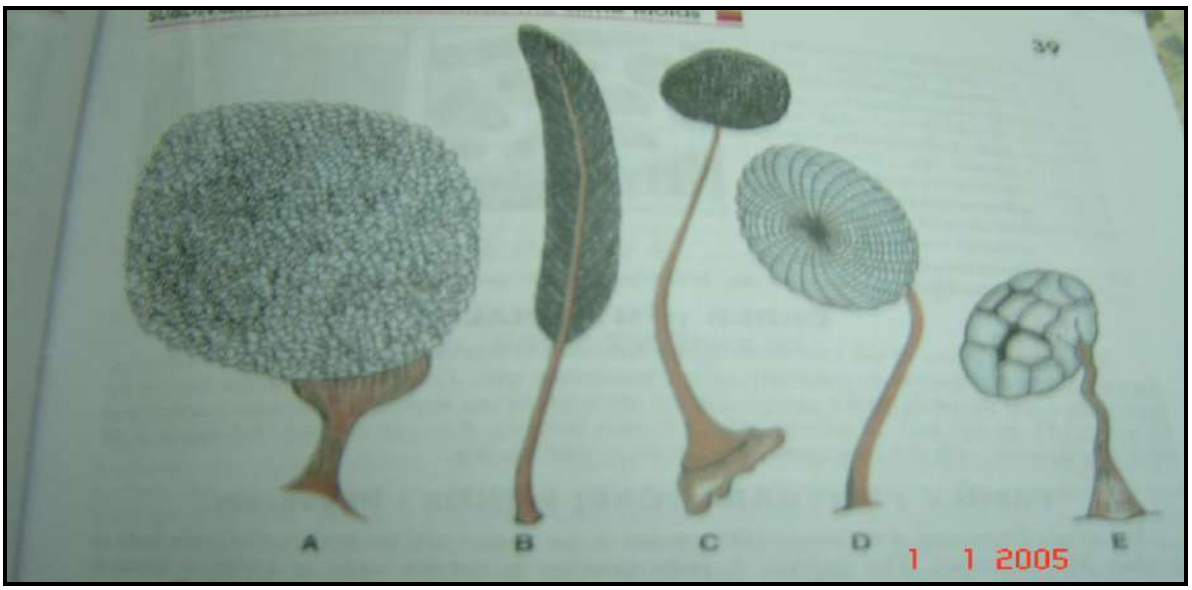


Figure 11: Types of Sporangium in Myxomycetes

2- Plasmodiocarp:

Is similar to a stalk less sporangium. In the formation of plasmodiocarp, the protoplasm concentrates around some of the main veins of the plasmodium and secreting a membrane around itself Ex: *Trichia*.

3- Aethalia:

A group of sporangia that have not separated into individual units. In some aethalia the wall of the individual sporangia are quite evident, in other they are difficult to see Ex: *Lycogala*.

Plasmodiocarp *Trichia*

Aethalia *Lycogala*

Life cycle of a typical Myxomycetes:

The sequence of events in the life history of the endosporous species is usually as follows:

The spores germinate under favorable conditions and release one to four rarely more myxamoebae or flagellate cells (swarm cells) that feed an bacteria.* Myxamoebae divide repeatedly until a considerable population has been formed, and then copulate in pairs.* In the presence of free water, myxamoebae may develop flagella and converted into swarm cells.*If so, they eventually lose their flagella forming myxamoebae.* The two forms- myxamoebae and swarm cells are thus inter-convertible, with the presence of water favoring the flagellate form and drier conditions inducing the amoeboid form.* Swarm cells as such do not divide, wherease myxamoebae do so regularly. Both stages are typically uninucleate and haploid-.*

After copulation, karyogamy occurs with formation of zygote. * The resulting zygotes are either flagellate at first, later becoming amoeboid, or amoeboid from the start depending on the nature of the gametes.*Growth of the zygote is accompanied by a series of mitotic nuclear divisions resulting in a multinucleate plasmodium with diploid nuclei.* The plasmodium grows by nuclear division and enlarge.* At maturity , the plasmodium thickens and converts itself into one or more sporophore.* Its protoplasm then cleaves into numerous spores.* Meiosis now take place in young spores Fig 12.

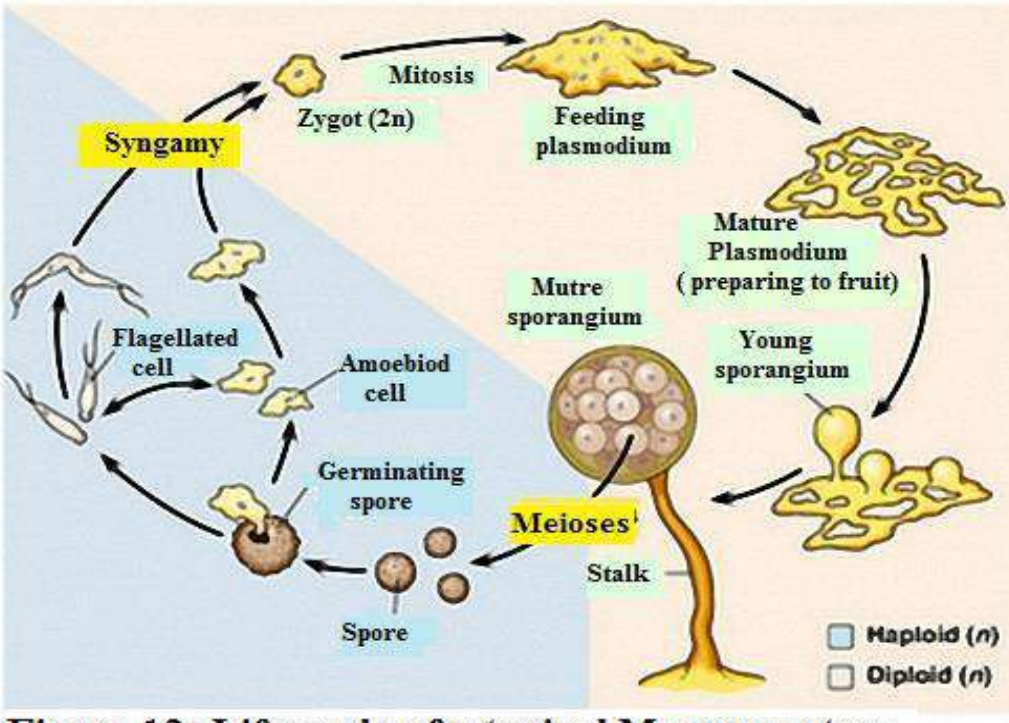


Figure 12: Life cycle of a typical Myxomycetes:

Classification of Class 1: Myxomycetes:

This class classified into two subclasses according to the position of the spores in relation to the fruiting body.

Subclass 1: Ceratiomyxomycetidae

In this subclass spores born outside (No fruiting body)
Order: Ceratiomyxales ex : **Genus:** *Ceratiomyxa :*

This genus called exospores, there is no sporangium, we can found them in root, leave, as white columns, under microscope we can see the spine bearing the spores.

Subclass 2: Myxogastromycetidae:
In this subclass spores born inside sporangia (fruiting body) (Endospores).
This subclass classified into 4 orders according to:

1. The color of sopres.
2. Presences or absence of capilitium.
3. Presence or absences of lime.

Order 1: Liceales:

1. Spores in mass are pallid or brightly colored.
2. The capilitium and columella are lacking but Pseudocapilitium is often present.
3. The lime is absences
   Ex: *Lycogala*

Order 2: Trichiales

1. Spores in sporangium are yellow to orange colored.
2. The capilitium is presences and the columella is lacking.
3. The lime is absences.
   Ex: *Arcyria.*

Order 3: Stemonitales:

1. Spores are dark or black in color**.**
2. The capilitium and columella is presence.
3. Lime is absences.
   Ex: *Stemonitis.*

Order 4: Physarales : Ex: *Physarum*

1. Spores are dark or black in color.
2. The capilitium and columella is presence.
3. Lime is presence. .

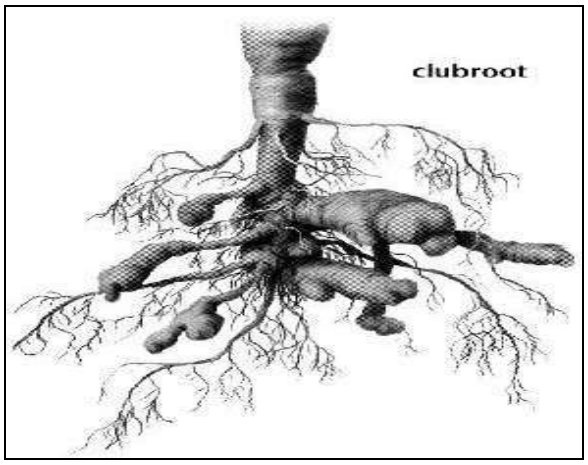
Class 2: Plasmodiophoromycetes:

General characteristics:

1. The somatic phase is a plasmodium that develops within the host cells (Endo) parasite.
2. Produce two types of spores –zoospores and resting spores.
3. When the resting spores are germinated give zoospores.

Family: Plasmodiophoraceae /// Ex:- *Plasmodiophora brassicae*
Causes: Club-root disease in *Cruciferae* Figure 13.

Figure 13:
Club-root disease in *Cruciferae*



Life cycle of *Plasmodiophora brassicae*:-

The life cycle is initiated when RESTING SPORES-cysts- germinate. * Each giving rise to a zoospore capable of infecting the host plant.* Zoospore attaches to the wall of a root hair and then penetration occur and converted to the myxoamoeba.* Following penetration of a host small sporangiogenous plasmodia appear within the host cells.* It is possible that, these plasmodia develop directly from individual amoebae .* Plasmodia increase in size with some fusion with one anthers, nuclear division during this phase is happened, and after the plasmodium reaches a certain size, it cleaves into segments that develop into zoosporangia.* Zoospores are then formed and released from the zoosporangium either directly into host tissue or to the outside of the host. – Asexual cycle-.

In the sexual cycle , the zoospores behave as gametes and couple in pairs forming – binucleate amoeboid cells-.* Then karyogamy occur to give zygote-2n- , also the cells of host increase in size – Hypertrophy- .* The young plasmodium then converted to old one and Meiosis take place and each nucleus converted to resting spore. Figure 14.

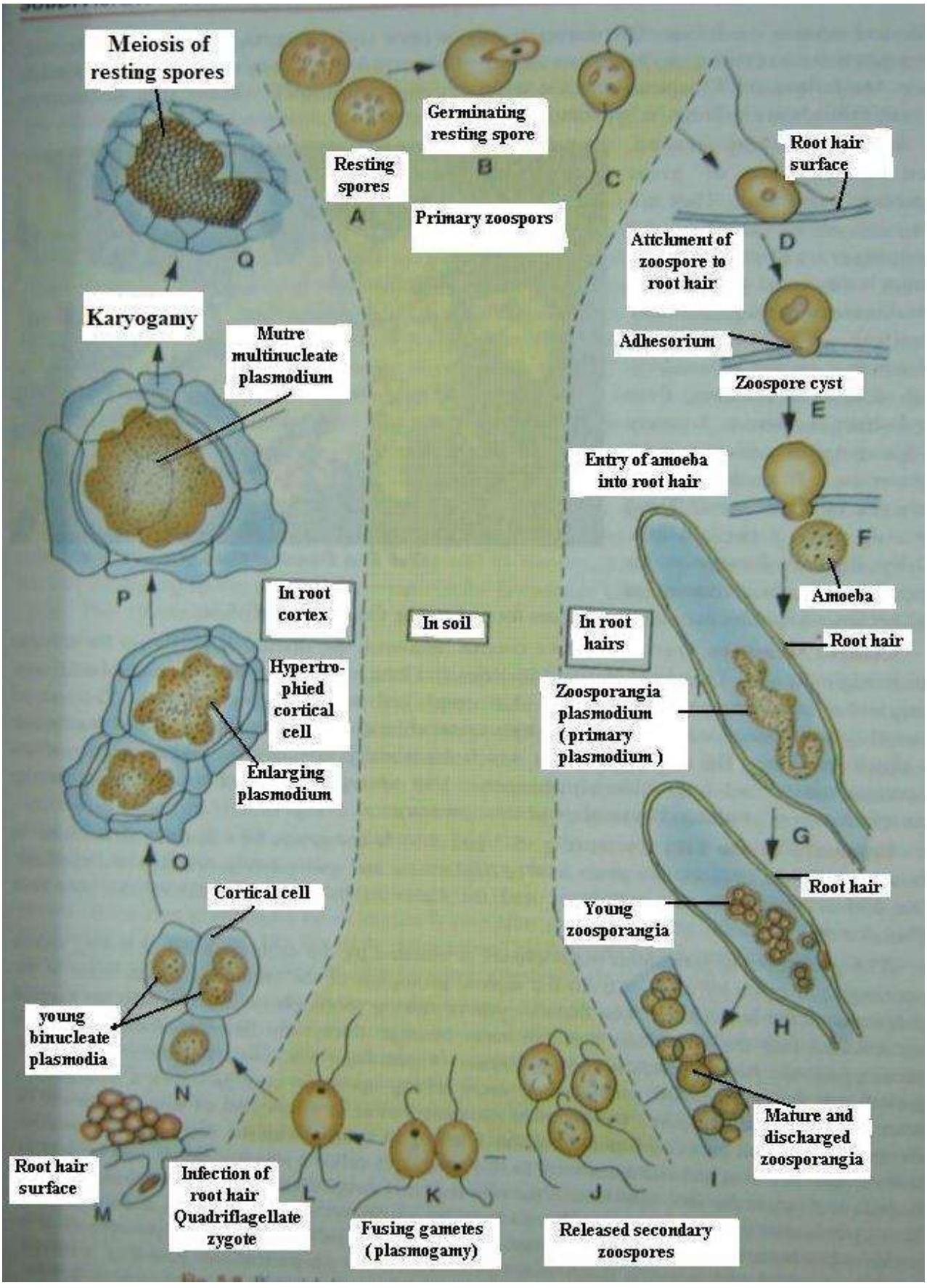


Figure 13: Life cycle of *Plasmodiophora brassicae*

Division 2: Eumycota

Sub division 1: Mastigomycotina:

This sub division classified to three classes depending on number, type and location of flagella

Class 1: Chytridiomycetes

General characteristics:-

1. Production motile cell – zoospores and planogametes - each with a single, posterior, whiplash flagellum.
2. The chytridiomycetes are more prevalent in aquatic habitats, many of them, however, also inhabit the soil, some of them are parasites.
3. Somatic structures are:
   a. Coenocytes structure.
   b. Multinucleate, globose or oval with or without rhizoid
   c. Well- develops mycelium.

This class was classified into three orders:

Order 1: Chytridiales:

General characteristics:-

1. The organisms which included in this order are unicellular, globose, with or without rhizoid and holocarpic.
2. Water or soil inhabiting species, many of them former parasitic on algae and water mold, many of the later on vascular plants.
3. There are only a few economically important parasites in the entire order. *Synchytrium endibioticum* causes the disease known as Potato wart. (Black wart disease on Potato).

Life cycle of *Synchytrium endobioticum:*

Asexual cycle

The fungus causes hypertrophy and hyperplasia of the surface cell layers of the infected Potato tubers; which contain **resting sporangia**.* When the warts lyses, the resting sporangia are release in soil, and then the **zoospores** are released when the conditions are suitable*. The zoospores are penetrating into the host through the root hairs, then the zoospore increase in size and produce two layers chitinous wall around itself to form **prosorus**.* The fungus- parasite- increase in size, and mitosis is started to give 32 nuclei, then cytoplasmic septa are formed to form 4-9 sporangia in one sac

–**Sorus**.* The mitosis is continuous to give 100-300 nuclei in each sac, each nuclei will be converting to zoospore in the presence of water. * The zoospore can penetrating the host again.*

Sexual cycle will be started in:???

Lacking the water at a certain period in the development of the fungus affords a maturation of gametes.*These gametes are union in pairs to form zygote, which can penetrating the host cell.* The parasite will increase in size and converting to resting sporangium, then the nucleus is undergo division to give zoospores. Figure 15.

Note: It is considered that, meiosis is occurring during zoospore formation.

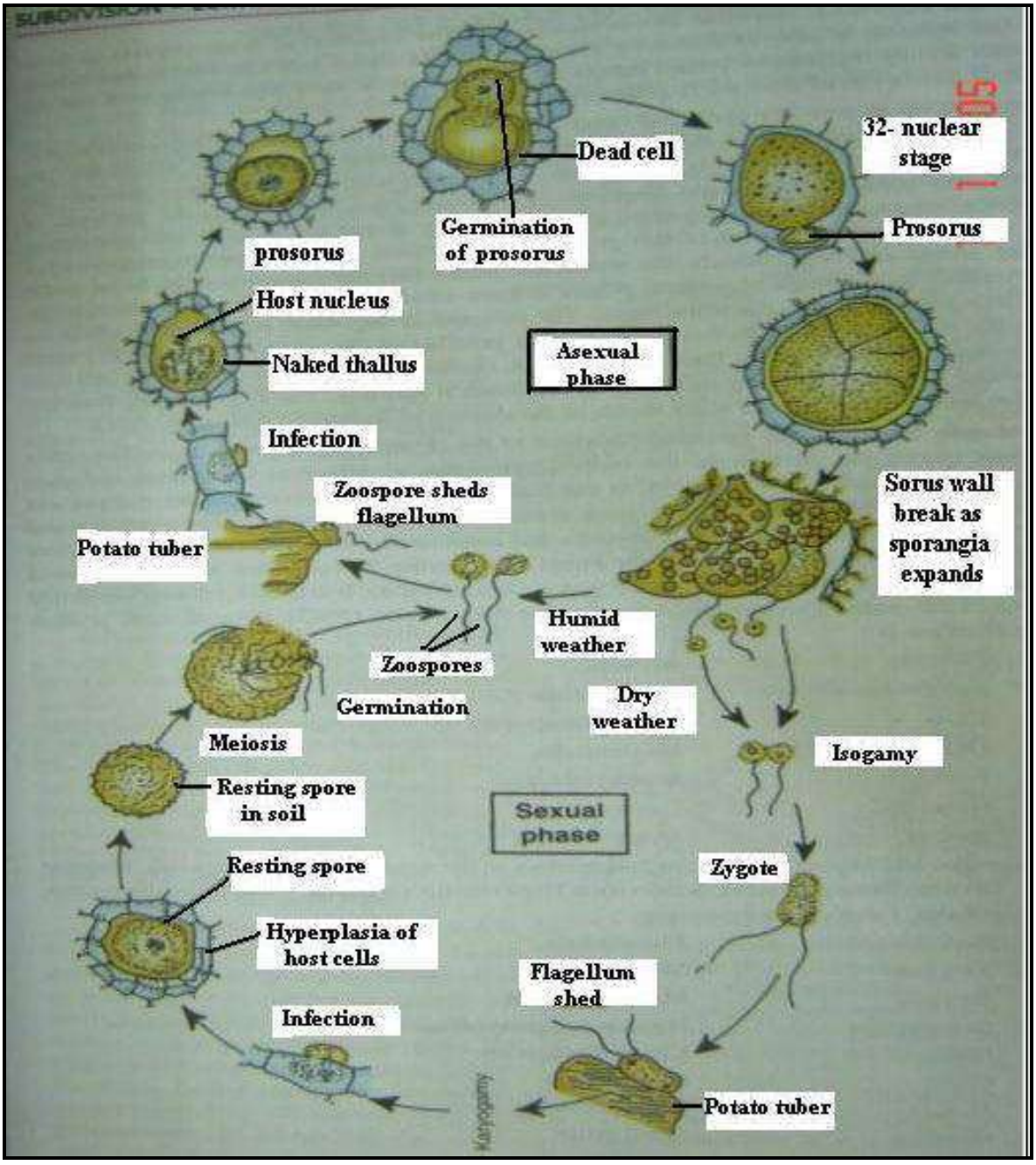


Figure 15: Life cycle of *Synchytrium endobioticum*

Order 2: Blastocladiales

General characteristics:-

1. Most of them are saprobes on animals and plants debris.
2. Vegetative structure is Eucarpic.
3. Somatic structure consists of basal cell with rhizoid and bearing one sporangium or more.

Family: Blastocladiaceae ex : **Genus: *Allomyces***

Life cycle of *Allomyces*:

Species of the genus *Allomyces* exhibit a definite alternation of generations, haploid gametothallus alternating with diploid sporothallus. The gametothalli produce colorless female gametangia and orange male gametangia usually in a 1:1 ratio.

The male gametangia are smaller than female and borne on the later such as in *A. macrogynus* or below them such as in *A. arbuscula*. Both types of gametangia release motile gametes, the gametes are posterior uniflagellate, copulation then occurs to give zygote. Zygote enlarges and gives rise to the first hyphal tube, which elongates, branched dichotomously, and develops into a diploid sporothallus.

At maturity, the sporothalli form two types of sporangia; thin walled, elongated, colorless zoosporangia (Mitosporangia), and thick-walled, pitted, resistant sporangia (Meiosporangi) resting sporangia that contain melanin pigments and appear reddish brown. The zoosporngia germinate soon after their formation, releasing diploid zoospores (mitospores) that swim about for a time, encysted and give rise to sporothalli, thus repeating the diploid generation. The resistant sporangia (Meiosporangia) require a rest of 2-8 weeks or more before they germinate.

Meiosis in the resistant sporangia takes place at the time of germination to form haploid zoospores; that are slightly smaller than the diploid. Then meiospores being haploid give rise to gametothalli, which produce gametangia instead of sporangia Figure 16.

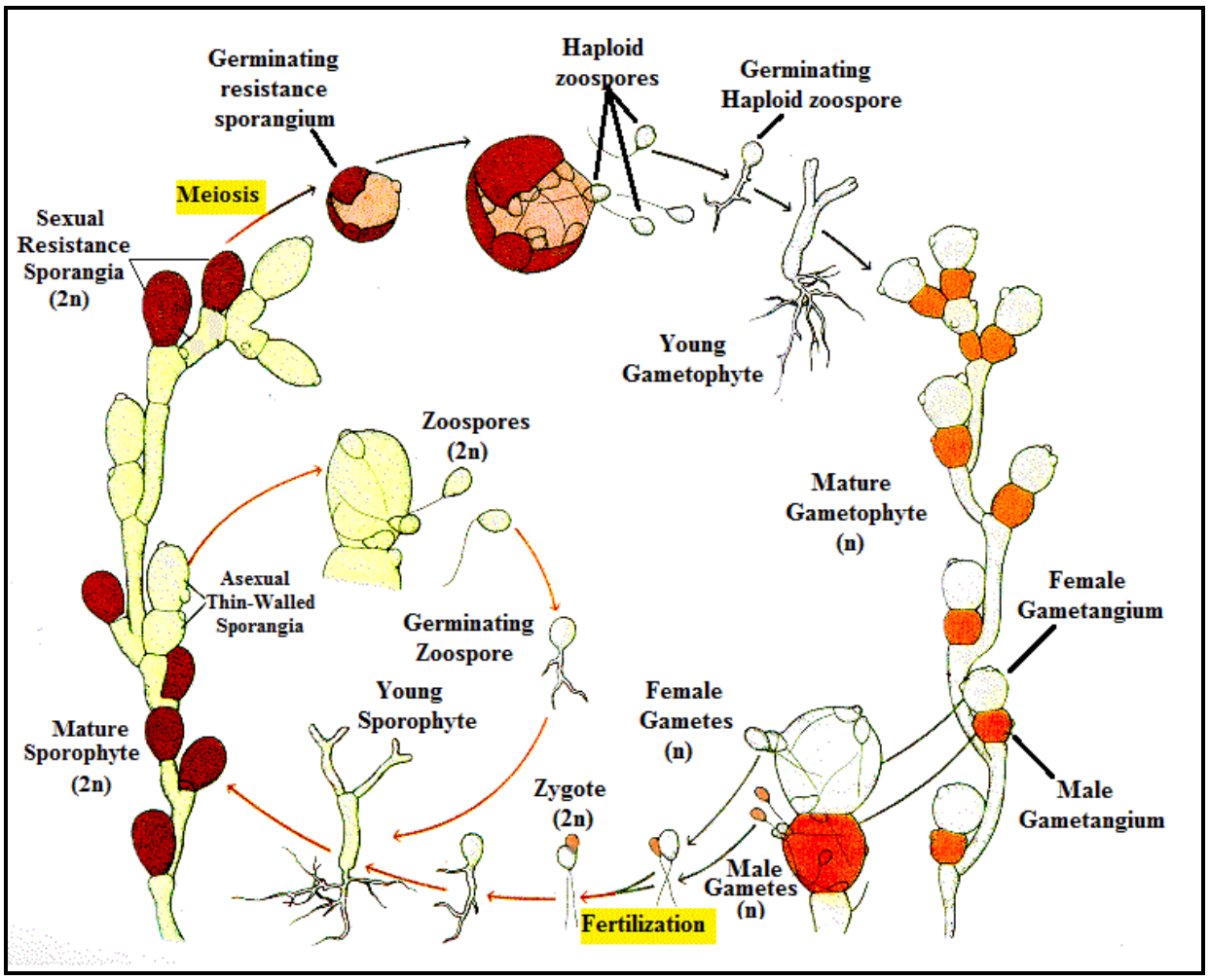


Figure 16: Life cycle of *Allomyces macrogynus*

Order 3: Monoblepharidales

Family: Monoblepharidaceae

Genus: *Monoblepharis*

Class 2: Hypochytridiomycetes:

1. The hypochytridiomycetes, are aquatic, fresh-water or marine chytrid like fungi whose motile cells are anterior uniflagellate, with a tinsel type flagellum.
2. They are parasitic on algae and fungi or saprobic on plant and insect debris in the water in which they live.
3. All are included in the single order hypochytridiales.
   Ex: *Rhizidiomyes*

Class 3: Oomycetes:

General characteristics:-

1. They produce biflagellate zoospores, one is tinsel and the second is whiplash.
2. Most of them are living in water so they called as water mold.
3. Some of them are obligate parasites on higher plant caused downy mildew diseases. Others are parasites on algae or small animals such as fishes.
4. Sexual reproduction is gametangial contact produce oospore.
5. Their cell walls consist of mainly glucan, but also contain cellulose. In most species there is no chitin.

Order 1: Saprolegniales

General characteristics:-

1. Some species such as *Saprolegnia parasitica* causes diseases of fish .
2. Mycelium is coenocytic, we can see septum only in the bases of reproductive organs-sporangia or gametangia.
3. Asexual reproduction by biflagellated zoospores. There are two types of zoospores:
   - **A.** Pyriform zoospores, they called also primary zoospores.
   - **B.** Reniform zoospores: they called also secondary zoospores.

Species that produce only one type of zoospore are monomorphic , while these which producing two types are dimorphic.

According to the swarming period, fungi in this order divided into:

1- **Monoplanetic fungi**: Those that have only one swarming period and only one type of zoospore ex: *Pythiopsis*.

Pyriform zoospore →Swarming→ encystment → germination →new thallus

2- **Diplanetic fungi**: Those that have two swarming period and two types of zoospores ex: *Saprolegnia*.

Pyriform zoospore →Swarming→ encystment → reniform zoospore→Swarming→ encystment → germination →new thallus

3- **Polyplanetic fungi**: Those that have more than two swarming period, the zoospore which is repeated is secondary zoospore ex: *Dictyuchus*.

Pyriform zoospore →Swarming→ encystment → reniform zoospore→ Swarming→ encystment → reniform zoospore→ Swarming→ encystment → germination → new thallus

4- **Aplanetic fungi**: Those that have no swarming period and so there is no motile spores ex: *Geolegnia*.

Family: Saprolegniaceae Ex: *Saprolegnia parasitica*:-

Life cycle of *Saprolegnia parasitica*:

The sporangia are elongated, tapering structures borne at the tips of somatic hyphae and separated from them by a septum.* An opening develops at the tip of the sporangium, and the primary zoospores escape into surrounding water, they swim about for some time, come to rest and encyst.* After a short resting period, a thin papilla develops on the cyst, its tip dissolves, and a reniform zoospore with two lateral flagella creeps out.* The encysted spore now germinates that develops into a new thallus.* By internal proliferation; sporangia continue to be formed, with several a sexual generations following one anther -Asexual cycle-. *When conditions favorable to sexual reproduction, the somatic hyphae give rise to oogonia and antheridia.*Meiosis now takes place in gametangia, producing haploid oospheres in oogonia and haploid gamete nuclei in antheridia.* The antheridia are much smaller than the oogonia, and they are often borne on the same hyphae that bears the oogonia.*Fertilization tubes originating in the antheridium penetrate the oogonial wall and reach the oospheres.* One male nucleus enters each oosphere through the fertilization tubes forms a diploid zygote nucleus.*Then a thick wall develops around each oosphere, converting it into oospore.* After rest period, the oospores are liberated from oogonial wall and germinated to give rise a new thallus. Figure 18.

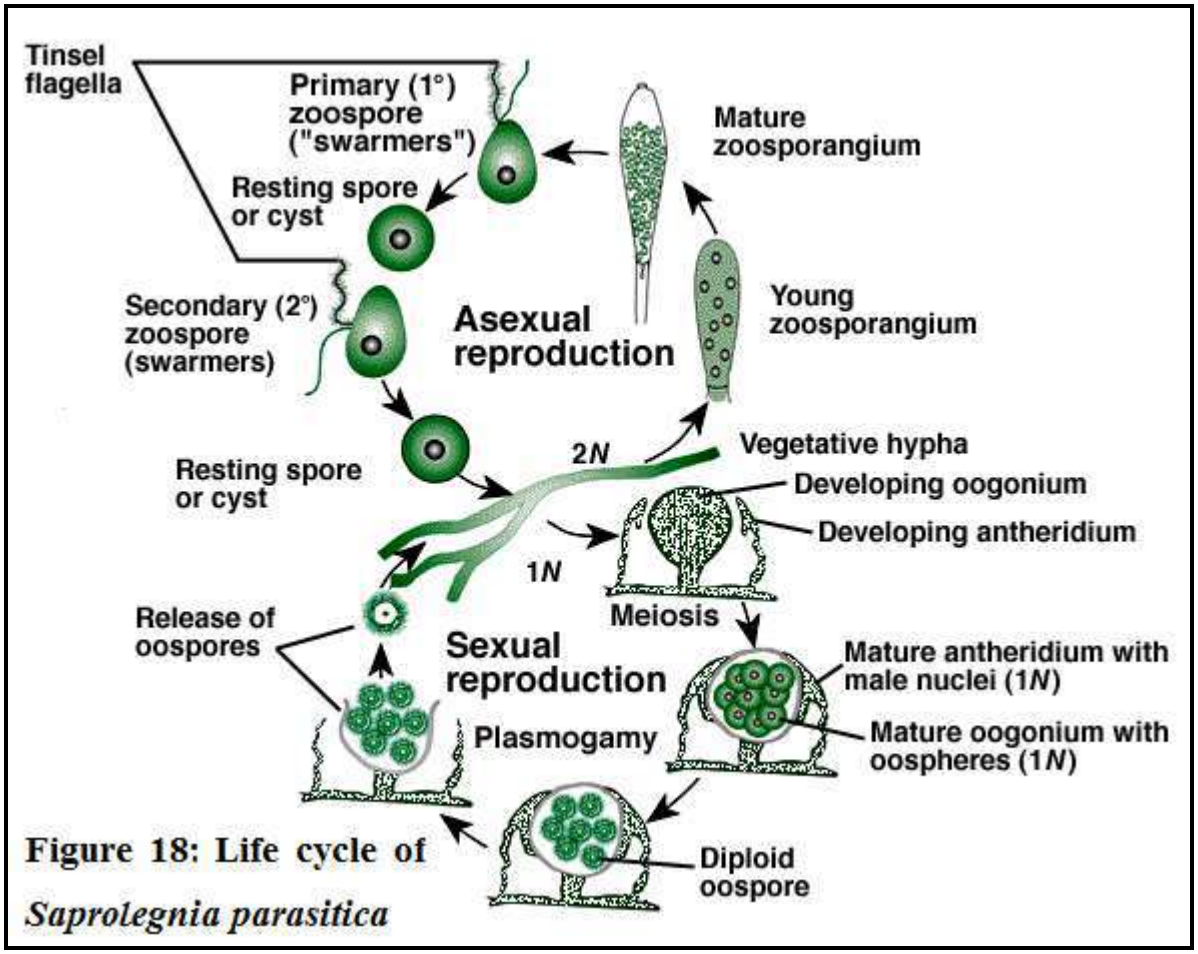


Figure 18: Life cycle of *Saprolegnia parasitica*

Order 2: Peronosporales

The peronosporales are the most specialized of the oomycetes. This large order of fungi includes aquatic, amphibious, and terrestrial species as a group of highly specialized obligate parasites that cause:

1-Witting or Damping off diseases **2-** White rust diseases **3-**Downy mildew diseases

General characteristics:-

1. The mycelium is branched and coenocytic, the hypha of parasitic species are intercellular or intracellular. Those of the most parasites growing between host cells and producing haustoria.
2. Sporangia are separated from mycelium after maturation – Spores are released after the separation of sporangia.
3. In some species, sporangia act as conidia and germinated into a new thallus.
4. Asexual reproduction occurs by reniform zoospores with only one swarming period.
5. Sexual reproduction occurs by gametangial contact.

This order was classified into three families according to the type of sprangiophores:

Family 1: Pythiaceae : Sporangia on somatic hyphae or on sporangiophores of indeterminate growth, periplasm a thin layer or absent; facultative, or saprobes.

Family2: Peronosporaceae: Sporangia borne on sporangiophpres of determinate growth; periplasm is conspicuous; obligate parasites of plants; sporangia are wind-borne.

Family 3: Albuginaceae: Sporangia borne in chain; periplasm is conspicuous; obligate parasites of plants.

Family 1: Pythiaceae

Genus 1: *Pythium*:

General characteristics:-

1. This fungus causes damping off seedling. Some species are saprobes, other are parasites.
2. Mycelia are coenocytic, sporangia are globose to oval and either terminal or intercalary on somatic hyphae.
3. Production of zoospores is preceded by the formation of a bubble-like vesicle.
4. Zoospores are biflagellated- reniform.
5. This fungus does not form haustorium.

Genus 2: *Phytophthra*

General characteristics:-

1- This fungus causes Late blight disease on Potato.
2- Mycelia are coenocytic but more brnching than the mycelia in *Pythium*.
3- Sporangia are smaller and lemon-shaped with terminal papillae.
4- It does not form vesicle.
5- Producing haustorium.
Notice Figure 19 and 20--

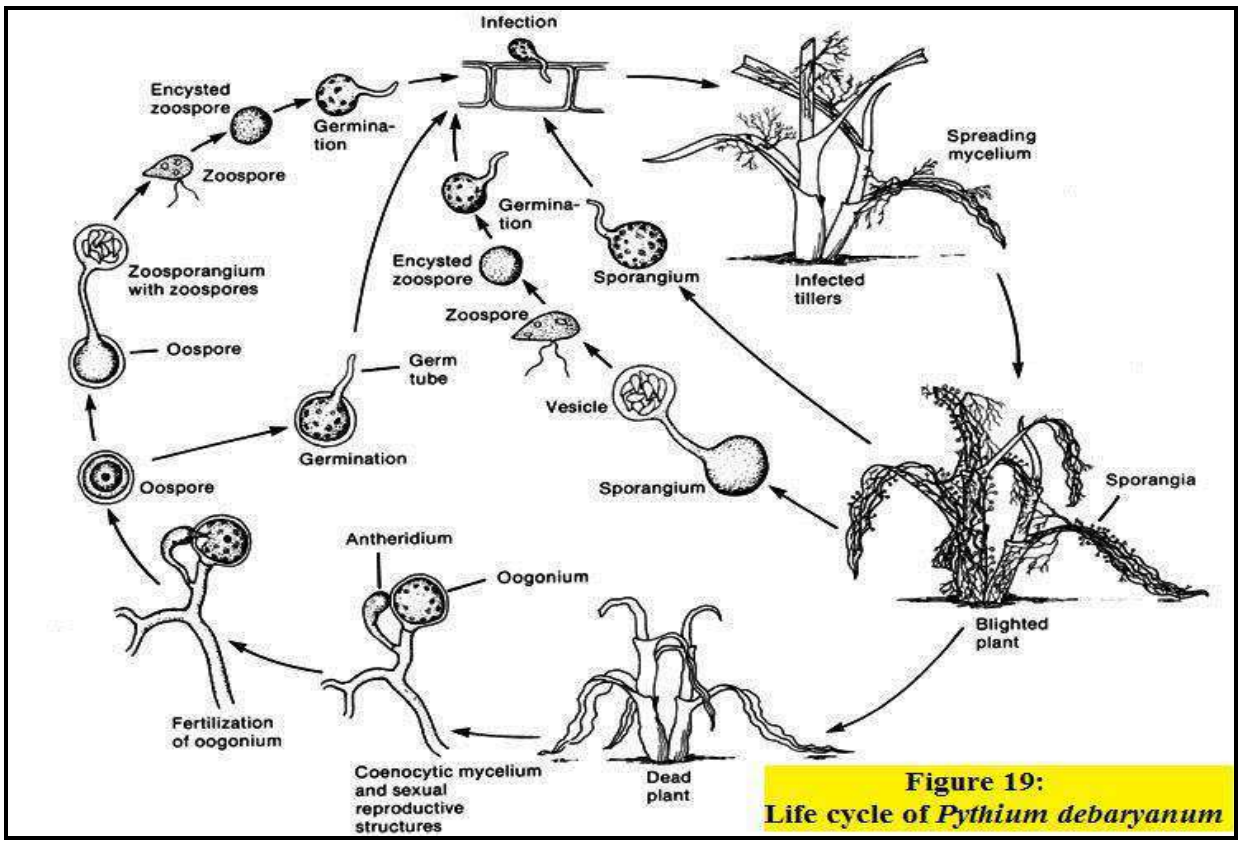


Figure 19:
Life cycle of *Pythium debaryanum*

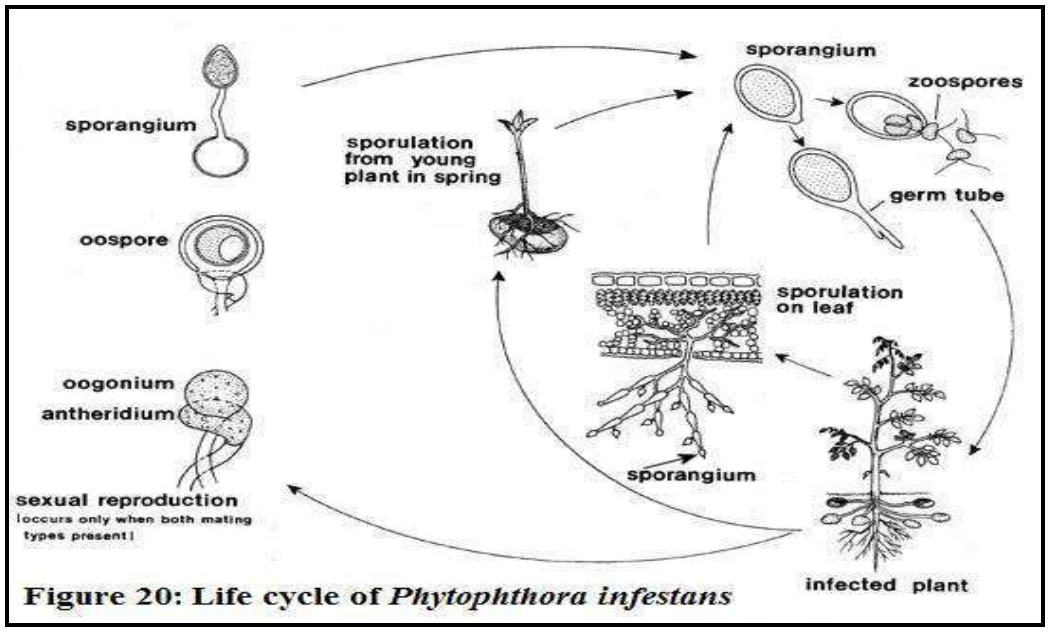


Figure 20: Life cycle of *Phytophthora infestans*

Family 2: Peronosporacea This is most highly specialized family in the order peronosporales. All species are obligate parasites of vascular plants causing diseases called downy mildew. The family includes a number of common genera differentiated chiefly by the branching of their sporangiophores as follows:

Genus 1:- ***Peronospora:*** The sporangiophores are dichotomously branched at acute angles with curved pointed tips on which sporangia are borne. This genus causes D.M. on Radish.

Genus 2:- ***Plasmopara:*** The branches and their subdivision occur at right angles. This genus causes D.M. on Grape.

Genus 3:- ***Bremia:-*** Is similar to *peronospora* except that the tips of branches are expanded into cup-shaped apophyses with four sterigmata each bearing the sporangia. This genus causes D.M. on Lettuce.

Genus 4:- ***Basidiophora*****:** The sporangiophore is club-shaped with swallen head over which the sporangia are borne in minute sterigmata. This genus causes D.M. on Onion.

Genus 5:- ***Sclerospora:*** The sporangiophore is a long-stout hypha, with many upright branches near the end, bearing sporangia at the tips. This genus causes D.M. on Mongra. **Notice Figure 21…**

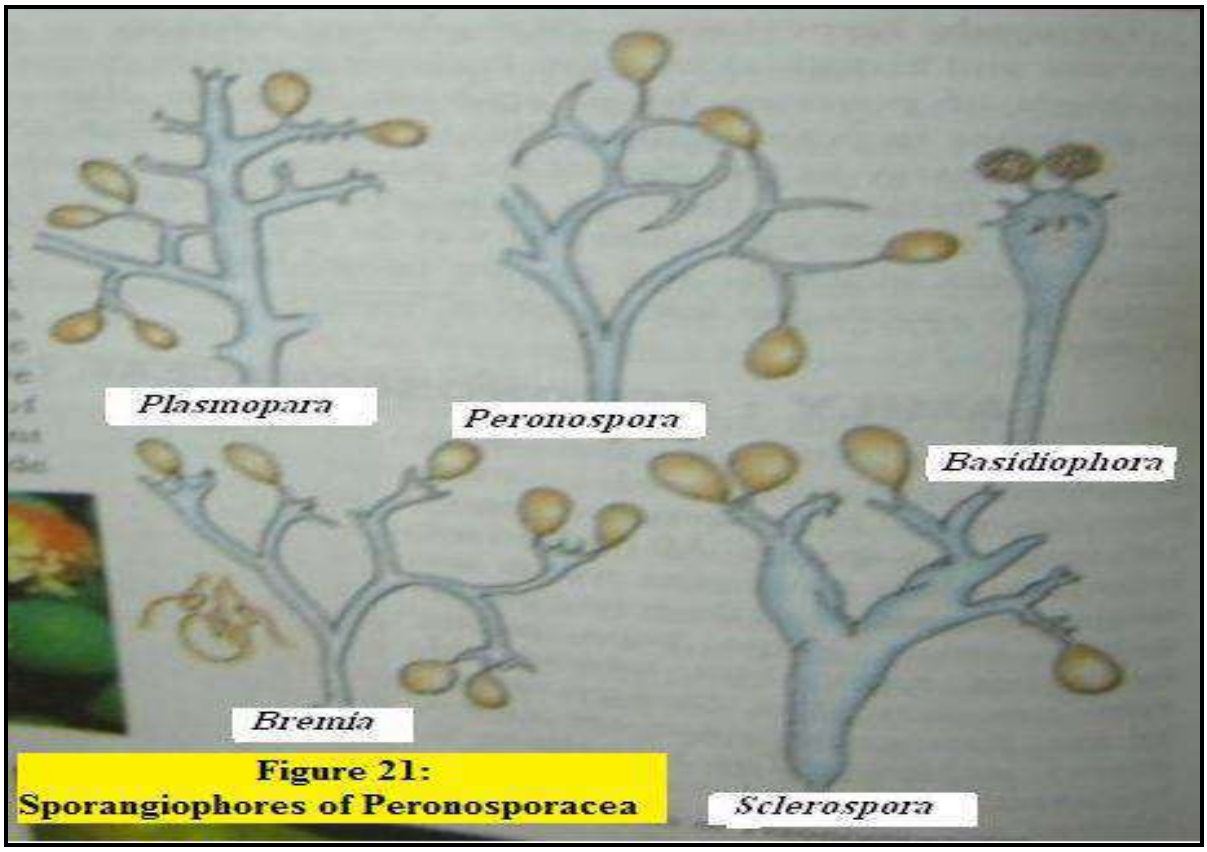


Figure 21:
Sporangiophores of Peronosporacea

Family 3:- Albuginaceae:-

This family includes the fungi known as white rusts. All are obligate parasites causing diseases of vascular plants.

Genus: ***Albugo***:- There are several species of *Albugo*, the only one genus in this family. The more important species is *A. candida* which attack Crucifers.

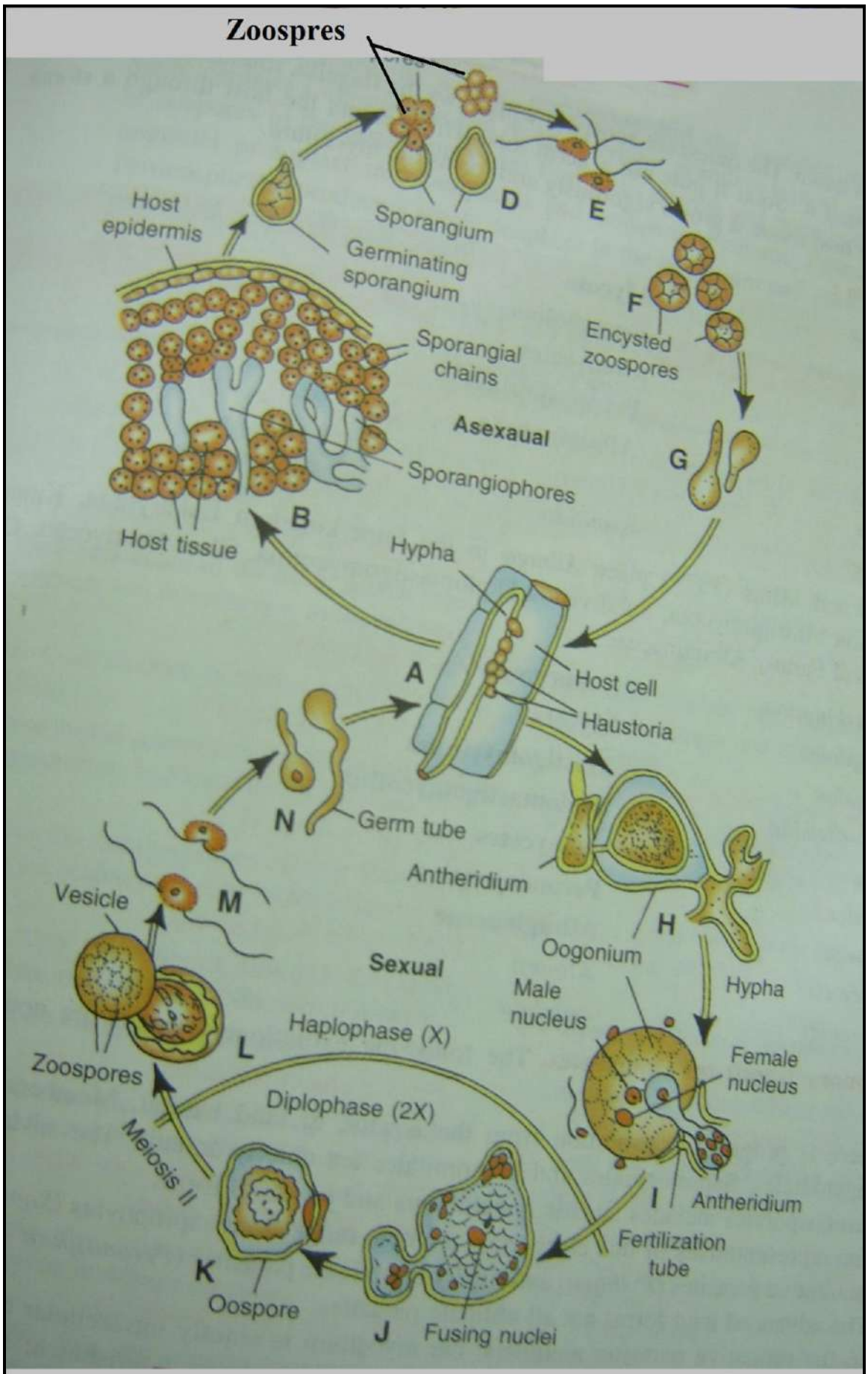
Life cycle of *Albugo candida*:

The mycelium is intercellular and feeds by means of hausturia. * The maturity mycelium produces short, club-shaped sporangiophores from the tips of a large number of hyphal branches below the epidermis of the host.* Each sporangiophore give rise to several sporangia that it produces in succession, one below the other, so that a chain of sporangia is formed with oldest at the tip of the chain.* Both the growth of the mycelium and the production of numerous sporangia exert a pressure from below on the host epidermis, causing rupture. *So the sporangia are released and form a white rust on the surface of the host.*Zoospores are released from sporangia, Encystment, and then germinated and infects the host.

-Asexual cycle-

Oogonia and antheridia are formed within the tissues of the host, both organs are mulltinucleate at the start, but only one nucleus in each is finally functional. They are formed near each other and borne terminally on somatic hyphae.* They soon contact, the antheridium then forms a fertilization tube, a single male nucleus passes through it together with some cytoplasm, and fuses with the egg nucleus.

The resulting zygote nucleus divides several times mitotically as the oospore develops a thick ornamented wall. The oospore germinates to form zoospores that encyst and germinate by germ tubes to complete the life cycle. Figure 22.



Life cycle of Albugo candida

Division 2: Eumycota

Sub division 2: Zygomycotina

Class 1: Zygomycetes

General characteristics:-

1. Most zygomycetes produce a well - developed mycelium consisting of coenocytic hyphae.
2. Producing a thick- wall resting spore called a zygospore, that develops within a zygosporangium formed as a result of complete fusion of two equal or unequal gametangia.
3. Asexual reproduction by production sporangiospores or aplanospores.
4. Most of zygomycetes are saprobes, such as bread-mold, others are parasites such as Fly fungi, and some are obligate parasites in other Zygomycetes or facultative parasites in plants.

Classification of class zygomycetes:

Traditionally, most authors have divided this class into three orders:

Order 1: Mucorales Order 2: Entomophthorales Order 3: Zoopagales

Order 1: Mucorales:-

General characteristics:-

1. Most of Mucorales are saprobes, living on decaying plant or animal matter.
2. Some of zygomycetes produce organic acids such as oxalic, lactic, and succinic acids.
3. Few of zygomycetes are parasites such as *Rhizopus stolonifer* in fruits during the storage. Figure 22.

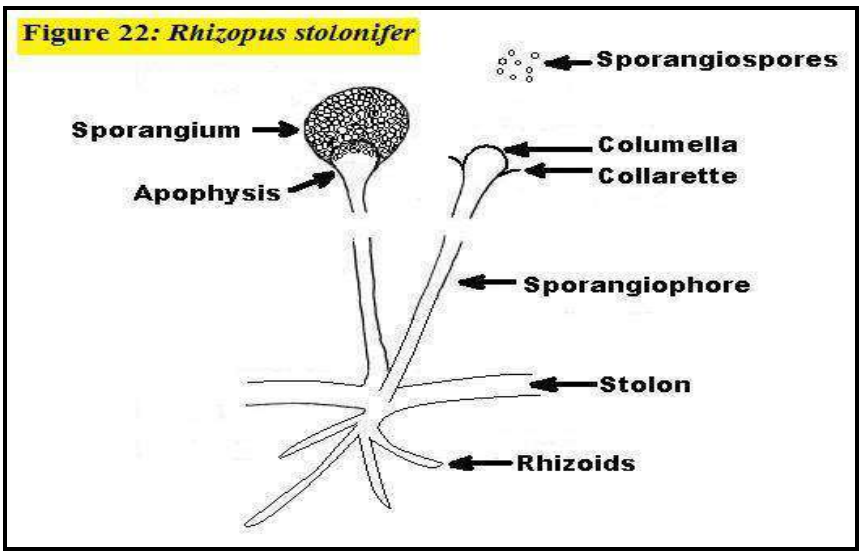


Figure 22: *Rhizopus stolonifer*

A sexual Reproduction:-

The Mucorales reproduce asexually by aplanospors that are produced in sporangia. The sporangia are borne on simple or branched sporangiophores. Such sporangium is formed at the tip of a sporangiophore as globose swelling into which nuclei and cytoplasm have moved from the somatic hyphae below. The part of sporangiophore within sporangium is called columella. Sporangium contains many thousands of sporangiospores. Figure 23

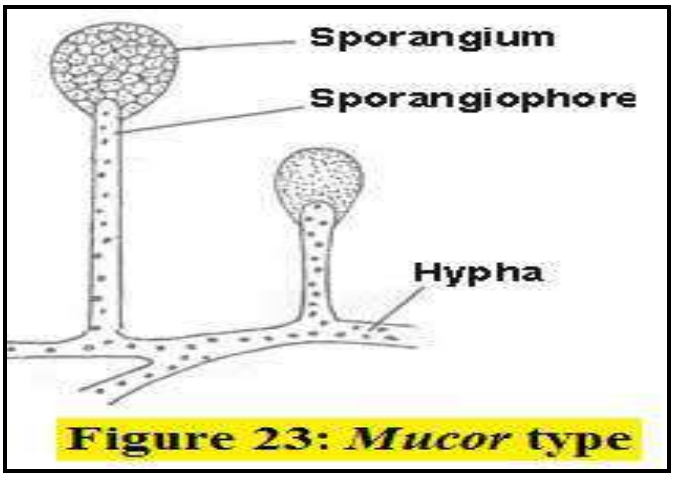


Figure 23: *Mucor* type

Sexual reproduction:

Sexual reproduction in the Mucorales takes place by the copulation of two multinucleate gametangia that are mainly similar in structure, but that may differ in size. The first step leading to the formation and fusion of these gametangia involves the formation of special hyphae called zygophores. The tips of the two zygophores swell to from progametangia. A septum termed the gametangial septum then forms near the tip of each progametangium, separating it into two cells, a terminal gametangium and a suspensor cell.The fusion septum then dissolves; plasmogamey and Karyogamey are take place forming prozygosporangium. It enlarges, develops a thick multilayered wall, and becomes the zygosporangium in which single zygospore develops. Figure25.

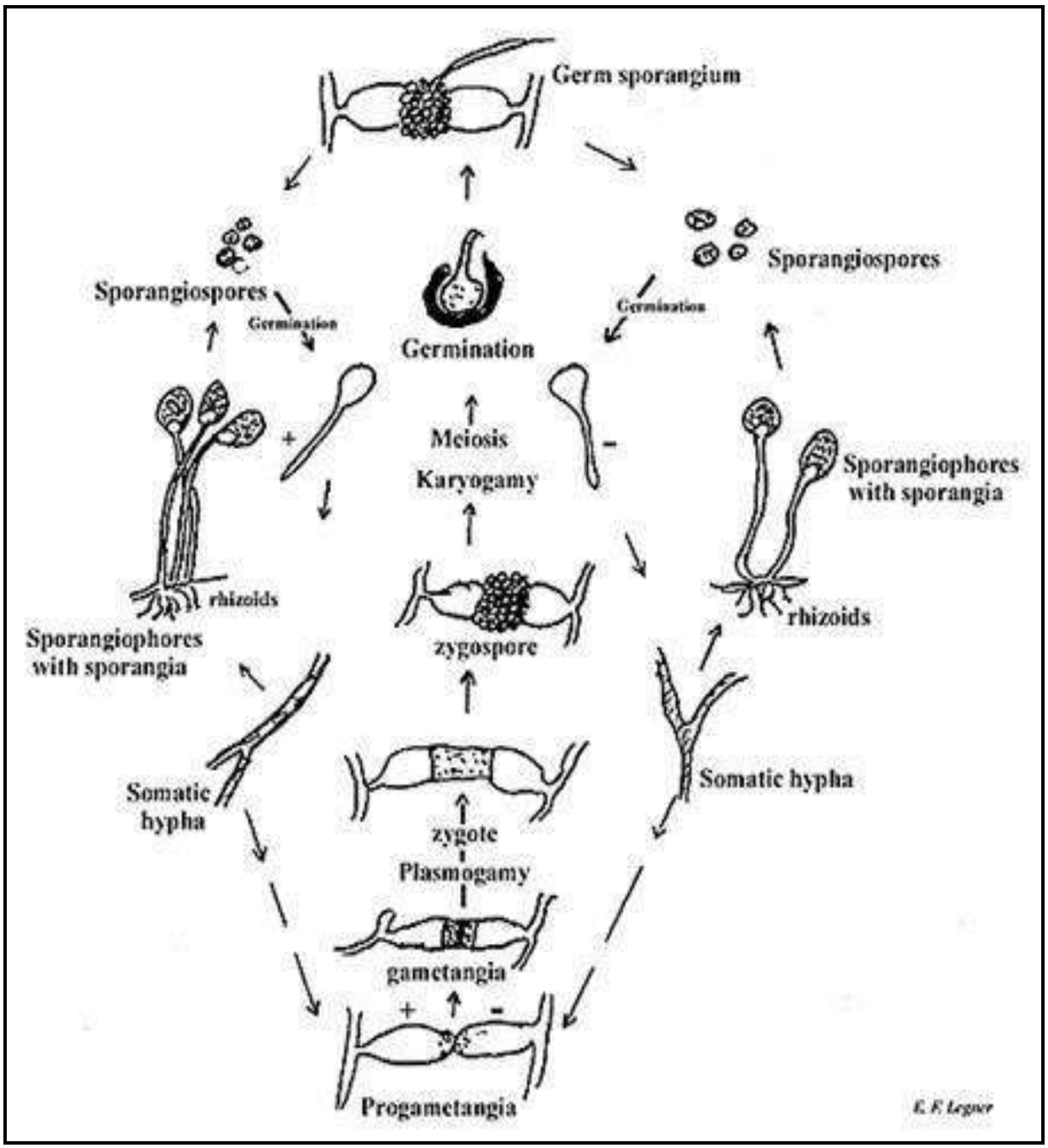


Figure 25: Life cycle of *Rhizopus stolonifer*

Order 2: Entomophthorales: -

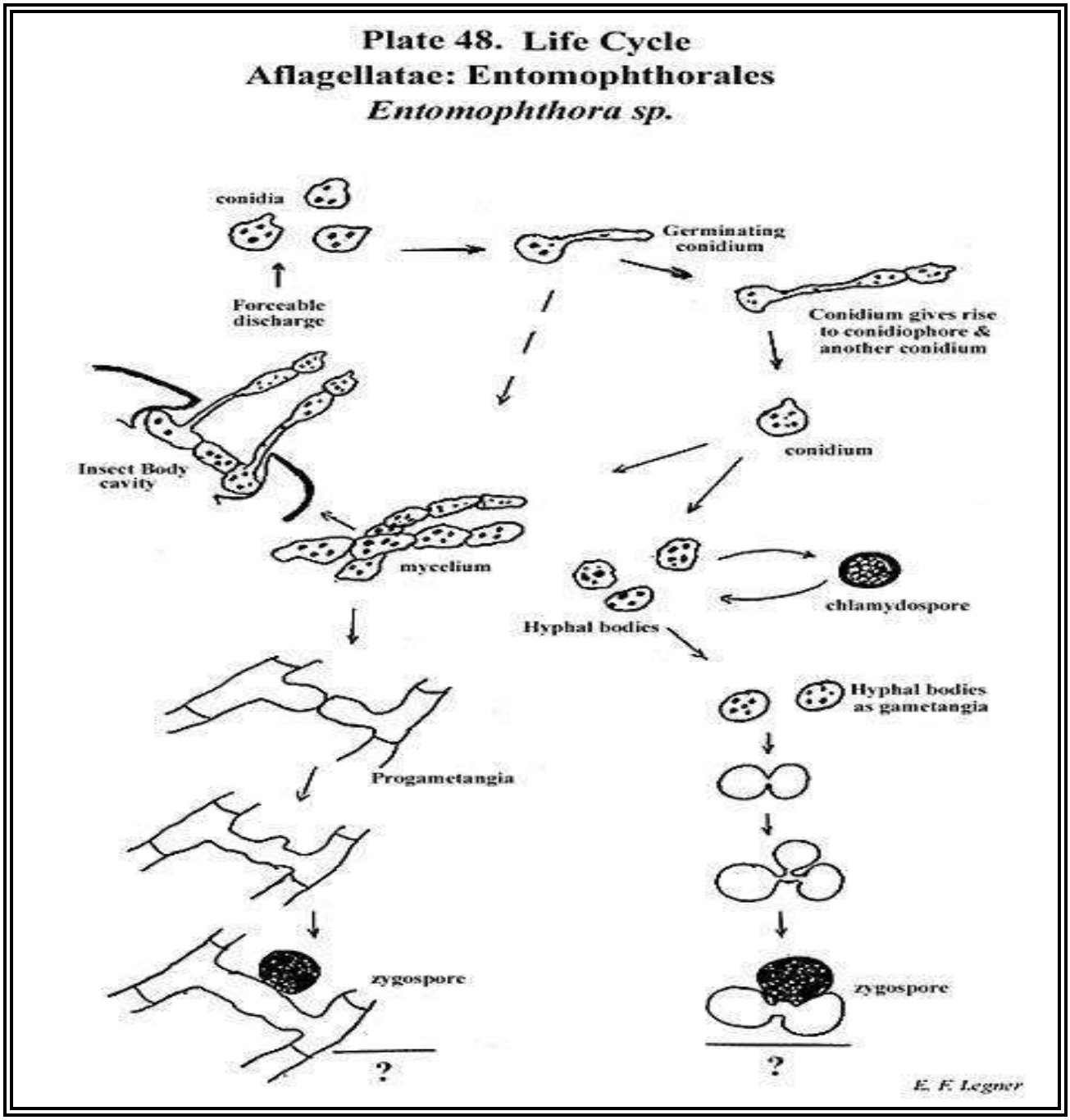
Family: Entomophthoraceae

Ex: *Entomophthora muscae*

Many of these fungi are parasites in insects. The most familiar species is *Entomophthora muscae* commonly called the fly fungus, which is often found on the dead bodies of house flies clinging to long unwashed window panes in attics, garages, and university classrooms. If you examine such a fly you will find a wide, white, halo

–like zone on the glass surrounding the dead fly. The white zone consists of spores that have been shot off the sporogenous cells growing out of the body of the fly.

The spores, which are produced singly at the tips of un-branched sporogenous cells, are covered by a mucilaginous substance and adhere to any object. If this spore contacts another fly, it quickly germinates and penetrates the cuticle of the body. Infected fly usually die within a week or so after infection and the sporulation process is repeated. Sexual reproduction in *Entomophthora* takes place when hyphal bodies acting as gametangia, copulate and develop a zygosporangium containing a zygospores.



Division 2: Eumycota

Sub-division 3: Ascomycotina:-

General characteristics:-

1. The one character distinguishing the ascomycotina from all other fungi is ascus, a sac-like cell containing usually definite number of ascospores formed by free cell formation after karyogamy and meiosis. Eight spores are typically formed within the ascus, but this number may vary from one to over thousand according to the species.
2. Mycelia are septate.
3. The absence of any type of flagellate cells.
4. Ascomycotina has two reproductive phases: the ascus or sexual stage, often called perfect stage, and the conidial or asexual stage (imperfect stage).
5. Fungi somatic structure either unicellular such as yeast or multicellular like other ascomycotina.
6. Sexual reproduction by gametangial contact, gametangial copulation, somatogamy and spermatization. The female gametangia called ascogonium and the male are antheridia. Male nucleus passes from the antheridium into the ascogonium through a pore developed at the point of contact between the two gametangia. The ascogonium is often provided with a trichogyne that receives the male nucleus. Some times the male and female nuclei do not fusion directly, resulting a binucleate cell which called dikaryon.
7. There are two types of asci: unitunicate and bitunicate. In the so called unitunicate ascus the two layers are closely adherent and the spores are released through a terminal pore -operculum-. In the bitunicate ascus the endotunica (endoascus) separating from the exotunica (exoascus) at the time of spore release, while the exotunica remains as originally formed. Sterile, elongated hairs, arising between the asci often form a part of the hymenium, those hairs are called paraphysis.
8. With few exceptions, ascomycotina produce their asci in fruiting bodies called ascocarps. In general there are five major categories of ascomycotina, separated according to the way they bear their asci:-

A. Those that bear naked asci without any fruiting bodies.

B. Those that produce their asci inside a completely closed ascocarp called a cleistothecium.

C. Those whose ascocarp, the perithecium, is more or less closed, but at maturity is provided with a pore (ostiole) through which the ascospores escape.

D. Those that produce their asci in an open ascocarp, called apothecium.

E. Those that form their asci directly in a cavity (locule) within stroma.

The stroma itself thus forms the wall of the ascocarp in such species. We call such a structure an ascostroma. Figure 26.

Classification of Ascomycotina:

According to the type of ascocarps, Ascomycotina can be classified into five classes:-

Class 1: Hemiascomycetes: Asci arising naked, no ascogenous hyphae or ascocarp produced.

Class 2: Plectomycetes: Asci produced within ascocarp (Cleistothecium)

Class 3: Pyrenomycetes: Asci produced within ascocarp (Perithecium)

Class 4: Discomycetes: Asci produced within ascocarp (Apothecium)

Class 5: Loculoascomycetes: Asci produced within ascocarp (Pseudothecium)

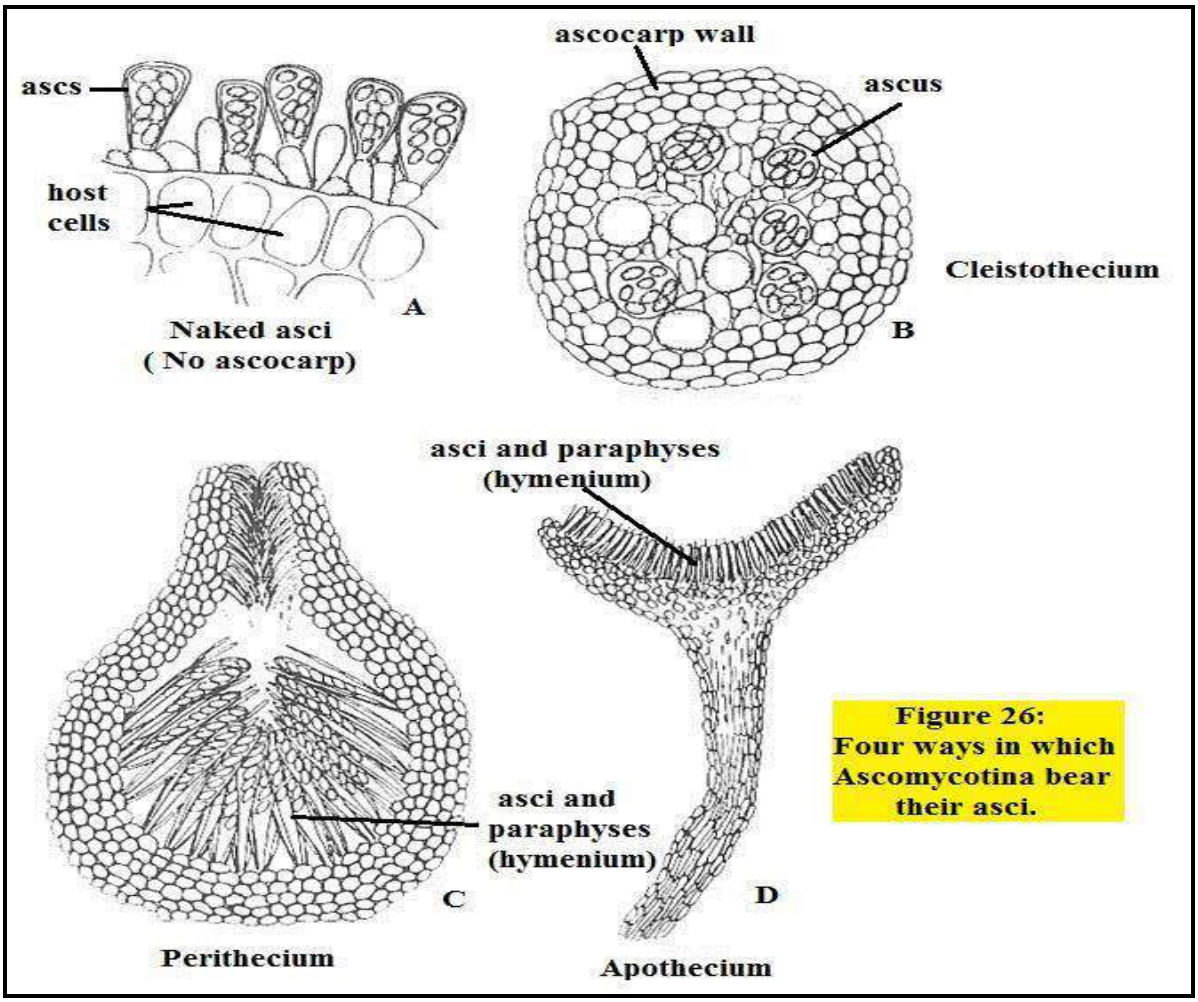


Figure 26: Four ways in which Ascomycotina bear their asci.

Class 1: Hemiascomycetes:-

This class involves fungi do not form ascocarp, so there is no ascogonium and antheridium. This class consists of two orders:

Order 1: Endomycetales Order 2: Taphrinales

Order 1: Endomycetales:-

The asci in this order formed directly from zygote such as in Yeast which is very important in alcoholic fermentation, bread preparation, and production of vitamin B complex. This order involves two families:-

Family 1:- Endomycetaceae:

This family involves many genera and many species, but the most important one is ***Schizosaccharomyces octosporus***, this species growing well on honey and others materials and on solid and liquid media forming mature asci during three days. The single cell is globose or cylinder in shape, uninucleus, (1N) chromosome. During asexual reproduction, the nucleus divides and a septum is formed between the two nuclei. Cleavage at the septum results in two uninucleate cells. So this yeast called (Cleavage yeast).

Sexual reproduction occurs by union of two daughter cells, the fertilization tube is formed in adhering region between two cells, then plasmogamy and karyogamy happened to produce zygote, which undergo meiosis resulting a young ascus with four nuclei., then mitosis occurs to give rise eight nuclei, each nucleus will converting to the ascospore which gives somatic cell (Homothalic). Figure 27a.

Family 2: Saccharomycetaceae:-

Ex; ***Saccharomyces cerevisiae*** which it is heterothallic. The single cell is oval. Asexual reproduction occurs by budding. Sexual reproduction need two mating type (a and ά).* It has been shown that, when (a) cells are near, but not in contact, with (ά), they elongate and enlarge toward the cells of opposite mating type in response to a sex hormone.* After cell fusion, the zygotes being to bud and several generations of diploid cells are formed which undergo meiosis to form young ascus with four nuclei, two are (a) and two are (ά),* then mature ascus is formed with four ascospore. Figure 27b.

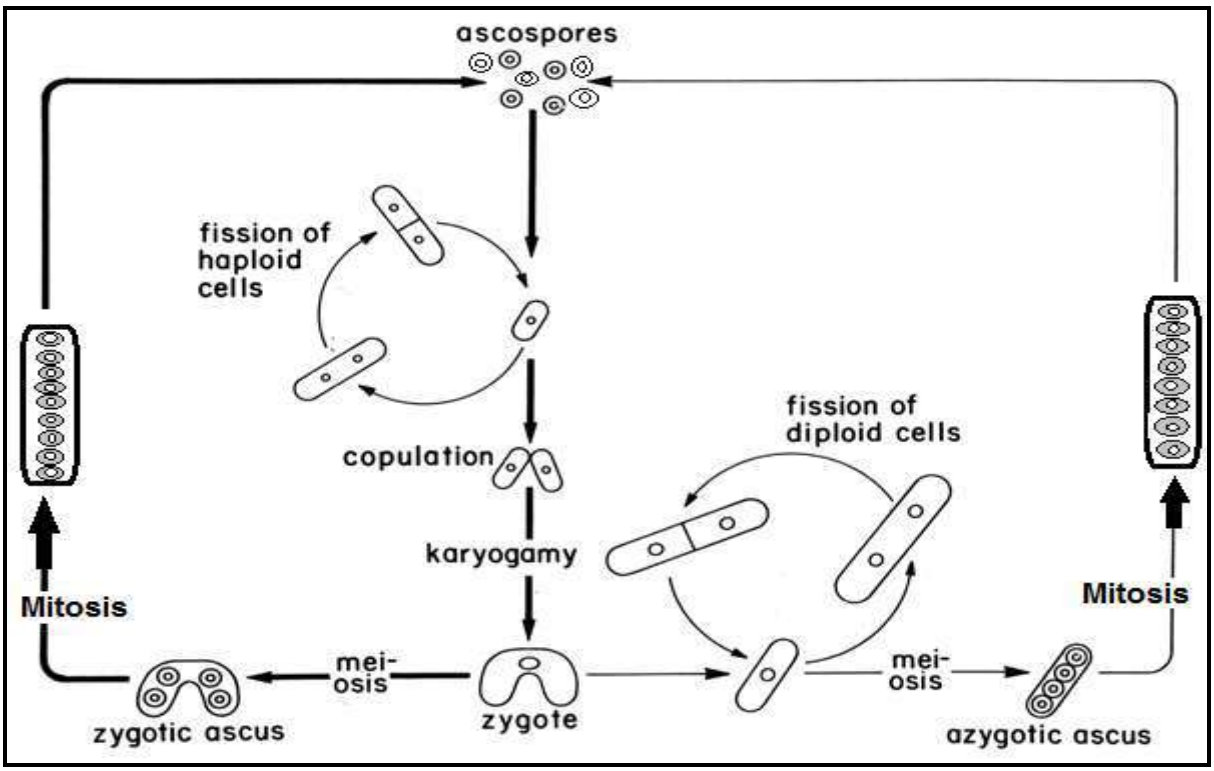


Figure 27a: Life cycle of *Schizosaccharomyces octosporu*

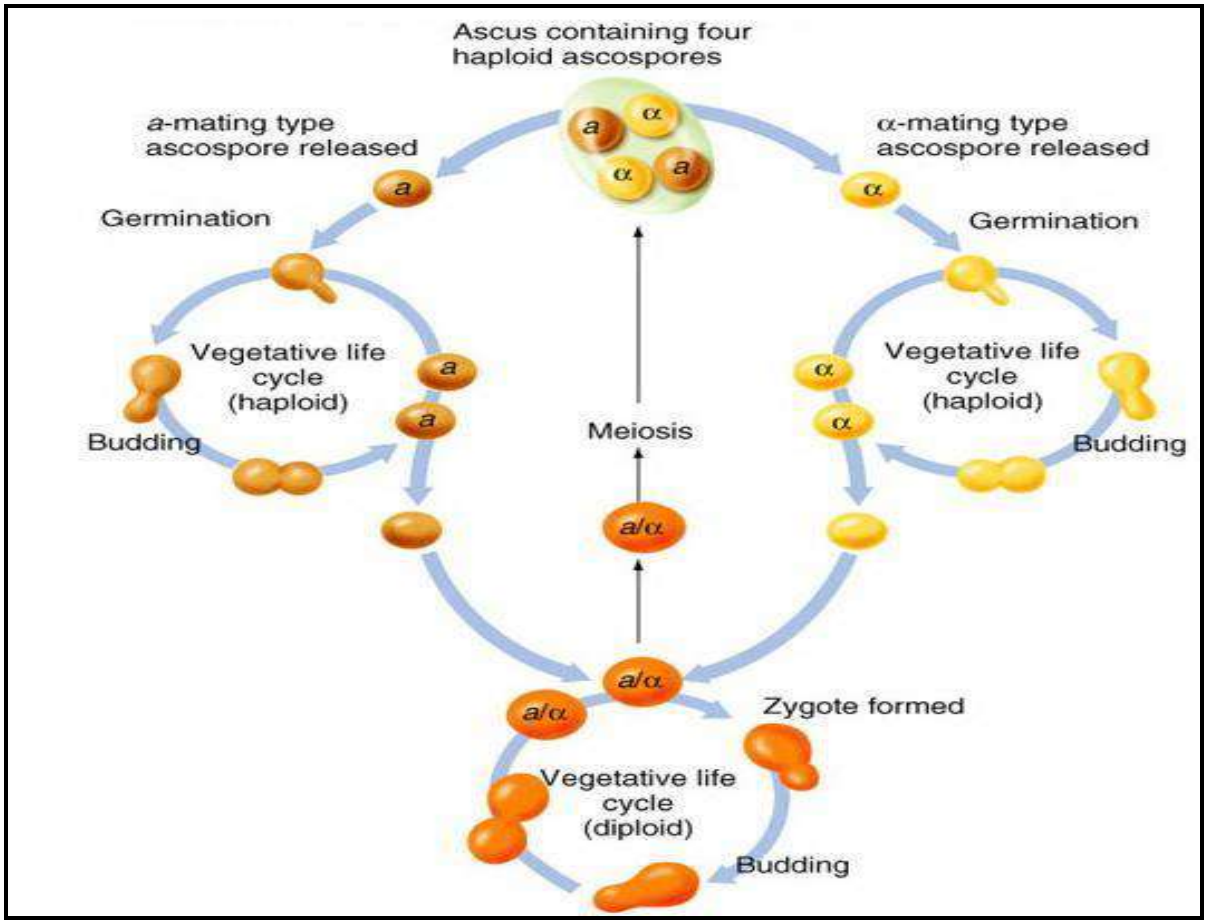


Figure 27b: Life cycle of *Saccharomyces cerevisiae*

Order 2: Taphrinales

General characteristics:-

1. The fungi in this order are obligate parasite. Ex: *Taphrina deformans* causes Leaf curl disease.
2. Asci are arising naked, no ascocarp.
3. Asexual reproduction occurs by budding from the ascospore within ascus or out of it.

Ex : *Taphrina deformans* : Causing leaf curl on leaves and twigs on peach and almond, especially after a cool and moist spring.

Life cycle of *Taphrina deformans*:-

The ascospores, soon after they are formed, produce small, round or ovoid blastospores by budding (1). * The blastospores, like the ascospores, are uninucleate, and haploid (A).* On the surface of host, the blastospores may continue to bud, producing secondary blastospores or may germinate by germ tubes that infect the host and produce the mycelium(2).* At the time of germination, the conidial nucleus divides, and resulting pair of nuclei migrate into germ tube.* The mycelium grows and branches, spreading between the cells and penetrating the tissues of the host.* Hyphal strands become more or less massed in the subcuticular region, and here break up into their component binucleate cells- ascogenous cells- or called – chlamydospores- (3). * Karyogamy occrs within each ascogenous cell, and about this time the cell begins to elongate(4).*While this elongation is proceeding, the diploid nucleus divides mitotically, and one daughter nucleus remains near the base of the cell while the other moves towards the growing tip. * A septum then develops between these two nuclei, separating the cells into a basal stalk cell and an upper ascus mother cell. * The protoplast of the basal cell soon disintegrates, leaving the cell empty, while the upper cell is being converted into ascus.* Meiosis and a subseqent mitotic division result in the formation of eight nuclei (H&J)* Each nucleus is source of ascospore 6,7,8). Figure 28.

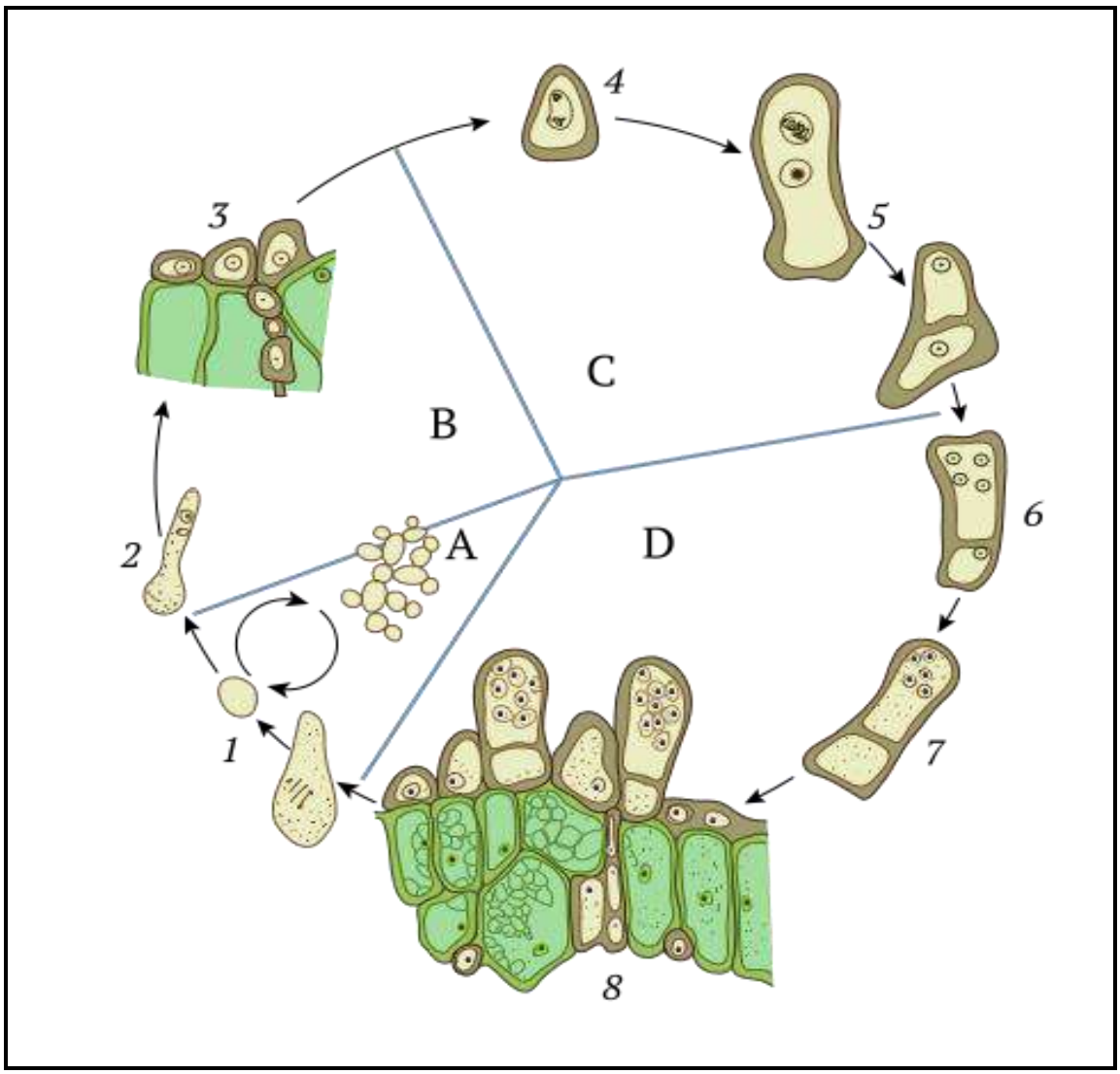


Figure 28: Life cycle of *Taphrina deformans*

A. Haploid stage (yeast)
B. Dikaryon stage (mycelium)
C. Diploid stage (proasci)
D. Developing of asci and sporogenesis}

1. ascospores and blastospores (conidia) budding
2. Dikaryotization
3. Dikaryotic micelium on plant cells, ascogenous layer forming
4. Karyogamy
5. Mitosis of diploid nucleus, proascus and basal cell forming
6. Developing ascus after meiosis
7. Mitosis of haploid nuclei, ascospores forming
8. Sporogenous layer forming on plant cells

Class 2: Plectomycetes

General characteristics:-

1. Asci are unitunicate. 2- Producing cleistothecium ascocarp.the

Order 1: Eurotiales

Some individual are saprobes, others are parasites on animals, plant and human causing many diseases, some causing food spoilage.

Family: Eurotiaceae

Genus 1: *Aspergillus*

The air everywhere seems to contain the conidia of these organisms. The genus *Aspergillus* contains 200 species . These organisms causing the spoilage of food, texture, and leathers, and some species causing diseases in human such as Aspergillosis which causes by *A. fumigatus*. symptoms closely resemble those of tuberculosis and it is probable that some doctors mistakenly diagnosed the disease as tuberculosis. Because of their great enzymatic activities, Aspergilli are employed in several industrial processes. Such as production of citric acid and gluconic acid by *A.niger*, production of some enzymes by *A. oryzae* and some species are used to produce antibiotics, while *A. nidulans* causes nail infection and *A. flavus* is aflatoxin producer.

Somatic structure: The mycelium produces an abundance of conidiophores arise singly from the somatic hyphae, the hyphal foot cell. The conidiophores are long, erect hyphae, each terminating in a bulbous head, the vesicle. As the multinucleate vesicle develops, a large numbers of conidiogenous cells are produced over its entire surface completely covering it. One or two layers of conidiogenous cells (some times termed sterigmata) may be produced, according to the species. The conidium-bearing cells whether primary or secondary are typical phialides. The phialides reach maturity; they begin to form conidia at their tips, one below other in chains Figure 29.

Sexual reproduction:- The perfect stages of most species of *Aspergillus* have not discovered. And it is likely that such species have lost their ability to reproduce sexually. Sexual reproduction takes place in several ways and results in at least five different types of ascocarps. The sexual or perfect stage of *Aspergillus* called *Eurotium* or *Emericella*. In *Eurotium* the sex organs, antheridia and ascogonia are produced close to each other on somatic hyphae. Both are multinucleate, elongate structures, often helical, they coil around each other Figure 30.

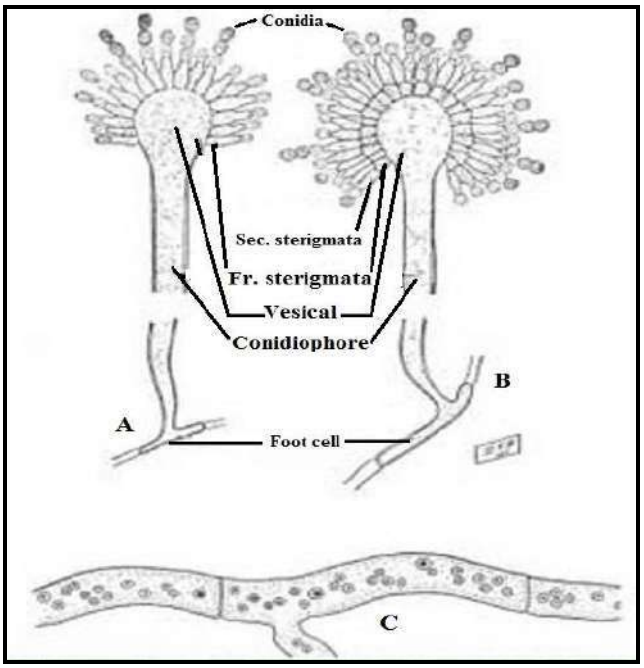


Figure 29
Somatic structure of *Aspergillus*

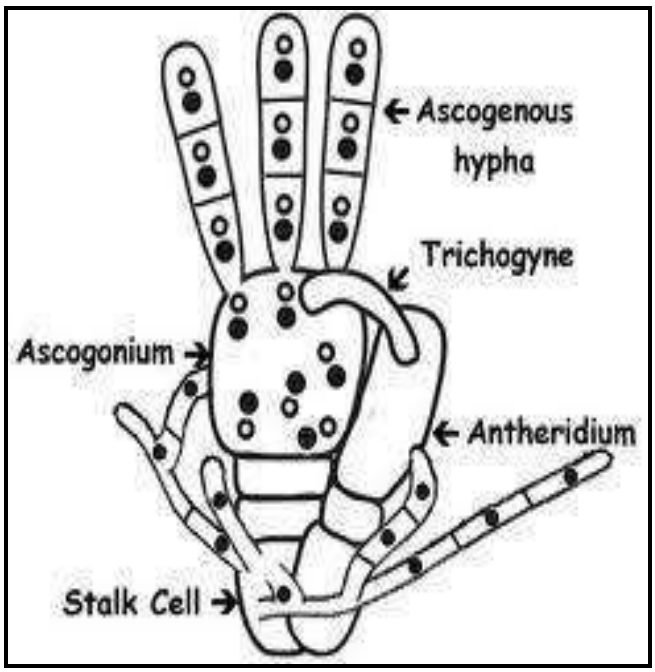


Figure 30
Sexual stage of *Aspergillus* (Ascogonium & Antheridium)

Genus 2: *Penicillium:*-

So called green molds and blue molds. We so frequently find on citrus and other fruits, on cheeses in the refrigerator, and other food stuffs. The conidia of *Penicillium*, like those of *Aspergillus*, are everywhere in the air and in the soil. In the biological Lab, they are as frequent contaminants as *Aspergillus* and *Rhiozpus*.

Various species of *Penicillium* attack and destroy fruits*; P. italicum* and *P. digitatum* are common pathogens of citrus and fruits causing blue mold and green mold respectively. *P. expansum* causes a decay of apples in storage. *P. roqueforti* is responsible highly priced flavor of Roqueforti cheese and *P. camemberti* for of Camembert cheese. *P. notatum* or *P. chrysogenum* was used for penicillin production, and *P. griseofulvum* was used for griseofulvin production, which is the best antibiotic effective in control of fungal skin diseases (Dermatomycoses), such as athletes foot. The sexual stage of *Penicillium* is called *Talaromyces*.

Morphology of *Penicillium*:-

The mycelium produces simple, long, erect conidiophores that branch about two-thirds of the way to the tip, broom-like fashion. The conidiophore, commonly referred to as the brush. The multiple branching of the conidiophore ends in a group of phailides that bear the long conidial chain Figure 31.

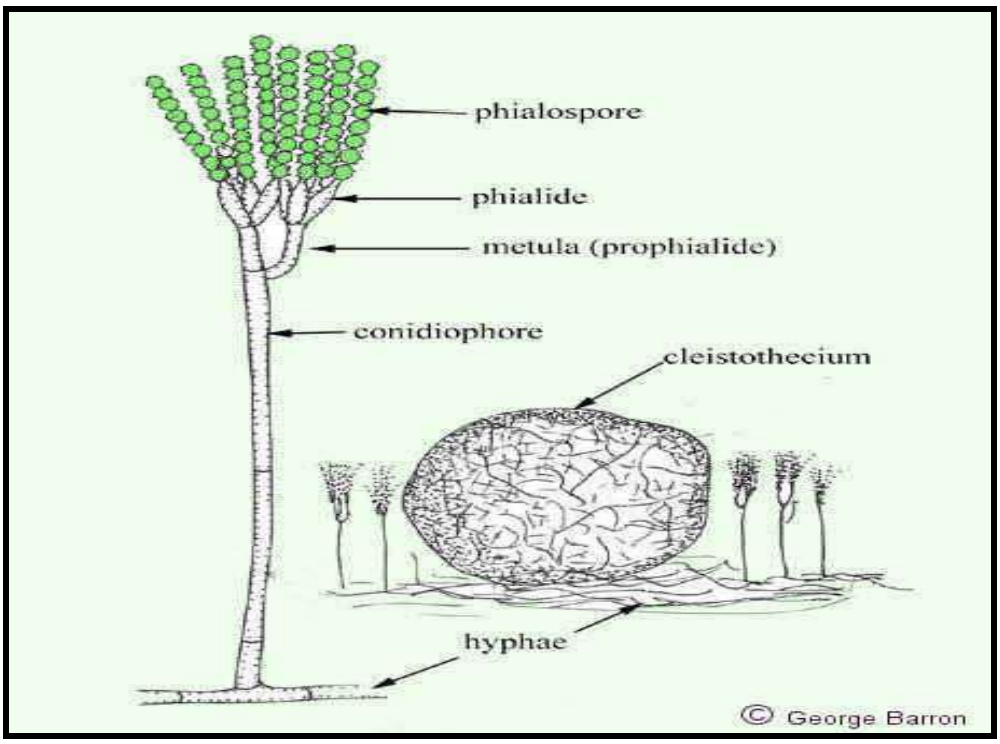


Figure 31: Asexual stage of *Penicillium* (conidial stage)

Order 2: Erysiphales

These fungi have a completely closed ascocarp (Cleistothecia). And they are obligate parasites causing Powdery mildews. These appear to the unaided eye as a white, powdery coating on the infectious parts.

Asexual Reproduction:

A few days after the fungus has infected the host, its somatic hyphae produce great numbers of long, hyaline, erect conidiophores. A generative cell at the apex of each conidiophore now begins producing conidia.

Sexual Reproduction:

sexual reproduction occurs by antheridium and ascogonium. The result of sexual reproduction is forming the ascocarps which appear white in color at the first time then converted to orange or red.

The classification of this order depend on the number of asci inside the ascocarp and the type of appendages as follows:

Genus 1: *Erysiphe*:

- The are many asci in ascocarp Figure 32.
- The appendages are similar to the hyphae, (mycelioid appendages) Figure 32.
- Causes P.M. on Graminae.

Genus 2: *Sphaerotheca*:

- There is only one ascus in ascocarp Figure 32.
- Mycelioid appendages.
- Causes P. M. on Rose

Genus 3: *Uncinulla:*

- Many asci.
- Hook-shaped appendages Figure 32.
- Causes P.M. on Grape.

Genus 4: *Microsphaera*:

- Many asci.
- Dichotomously branched appendages tips Figure 32.
- Causes P.M. on Lilac.

Genus 5*: Podosphaera*:

- One ascus.
- Dichotomously branched appendages tips Figure 32.
- Causes P.M. on Apple.
-

Genus 6*: Phyllactinia*

- Many asci.
- Bulbous appendages bases Figure 32.
- Cause P.M. on Morus.

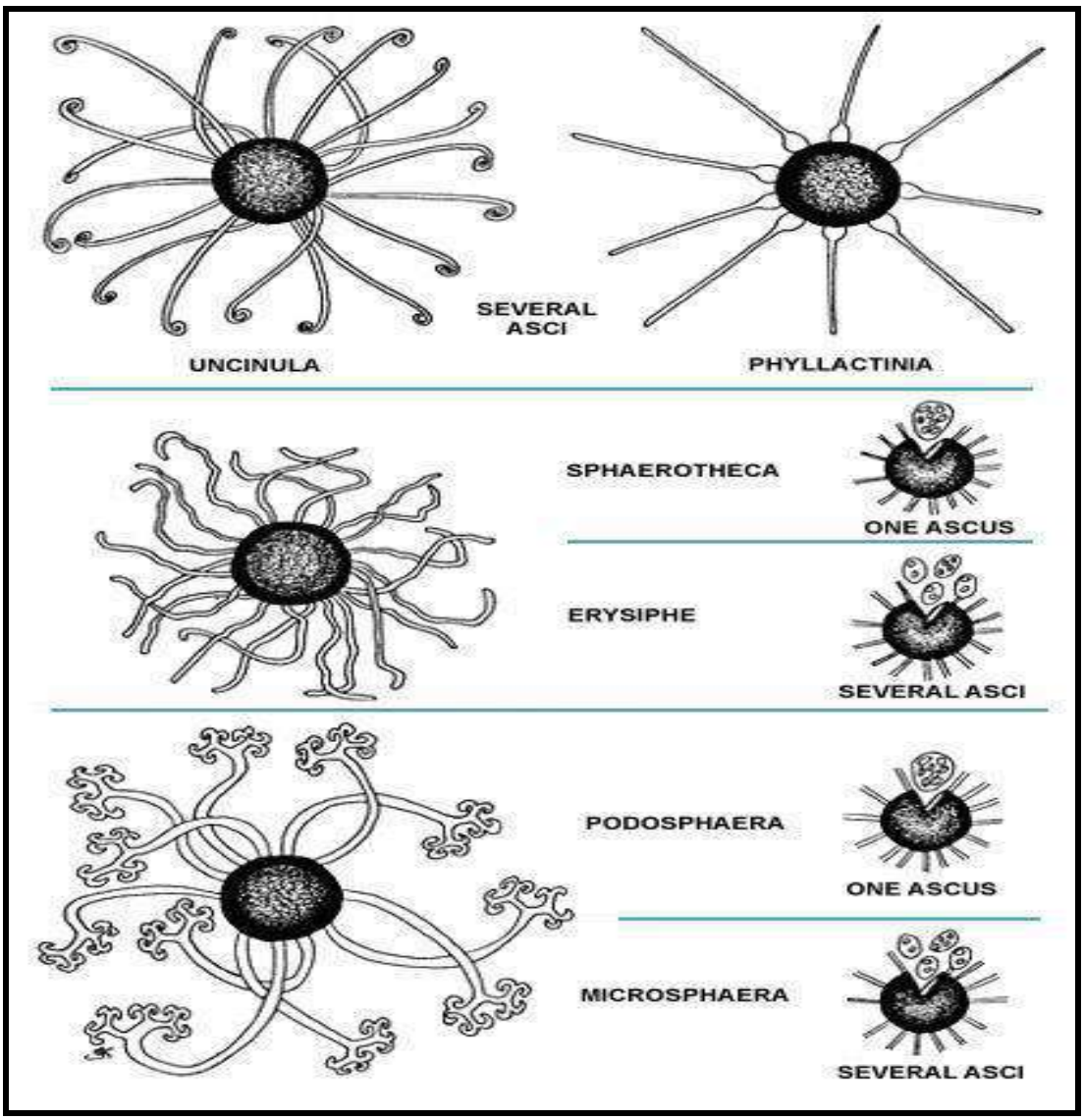


Figure 32: Types of appendages of Erysiphaceae

Class 3: Pyrenomycetes:- The ascocarp is perithecium.

Order 1: Shpaeriales: Perithecium is dark-black in color.

Order 2: Hypocreales: Perithecium is colored.

Family1: Claviceptaceae: These produce their perithecia with a well- developed, stroma composed entirely of fungal tissue.

Genus : *Claviceps purpurea :* causing ergot disease of Rye

The Life cycle:-

The thread-like ascospores are discharged from the perithecia in the spring about the time that certain susceptible grasses such as rye are in bloom. If the ascospores, which are wind disseminated, happen to reach the flowers of the rye plant or other susceptible host, they germinate by sending germ tubes into ovary, and cause infection. As the mycelium developed, it destroys the ovary tissues and replaces them in the flower by a soft, white, cottony mycelial mat that soon becomes covered by acervulus- like layers of short conidiophores bearing minute, oval conidia at their tips. These conidia are mixed with a sticky, sweet, nectar-like secretion, the origin of which is obscure. Attracted by this nectar, insects visit the infected ovaries and distribute the conidia to uninfected flowers, spreading the fungus in this way. In the meantime, the mycelium mat, which has produced the conidiophores, continues to develop, and eventually transformed into a hard pink or purplish pseudoparenchymatous sclerotium (is a very dense, heavy-packed group of hyphae surrounded by a thick wall. The color is mostly brown or blackish even though the rest of the mycelium may be white. Sclerotia may store food and serve as resistant vegetative resting structures when they occur). During the harvesting operations, many sclerotia are knocked off the spikletes, and fall to the ground where they pass the winter. The following spring, the sclerotia germinate and form several long-stalked, mushroom-like, dark purple stromata with globose head. The stromata, which are about three-eights of an inch tall, are easily visible. Within these stromatal heads and just below their surfaces, arise a number of minute cavities surrounded by the pseudoparanchymatous stromatic tissue. Each cavity contains a single, multinucleate ascogonium at the base of which one or more multinucleate antheridia form. Plasmogamy takes place between one of the antheridia and the ascogonium, with the male nuclei migrating into female organ. While the asci are forming, thin perithecial walls develop around these sexual apparatus within the stromatal heads, producing definite perithecia that open out on the surface of the stroma through a long-neck-like ostiole. Each mature perithecium bears several elongated, cylindrical asci, each containing eight thread-like ascospores. The sclerotia contain a number of poisoning alkaloids are responsible for poisoning animals, including humans. Cattle are often poisoned by grazing on grasses that carry the sclerotia of the fungus or in fields where the sclerotia are lying, having fallen off the plants during harvesting operations. Their legs, hoofs, and tail become gangrenous and cows may abort their calves. This disease of animals is known as ergotism. The sclerotia contain a number of powerful alkaloids such as ergotamine, ergometrin, and ergonovin, which are medically to induce labor and prevent post partum hemorrhage during childbirth.

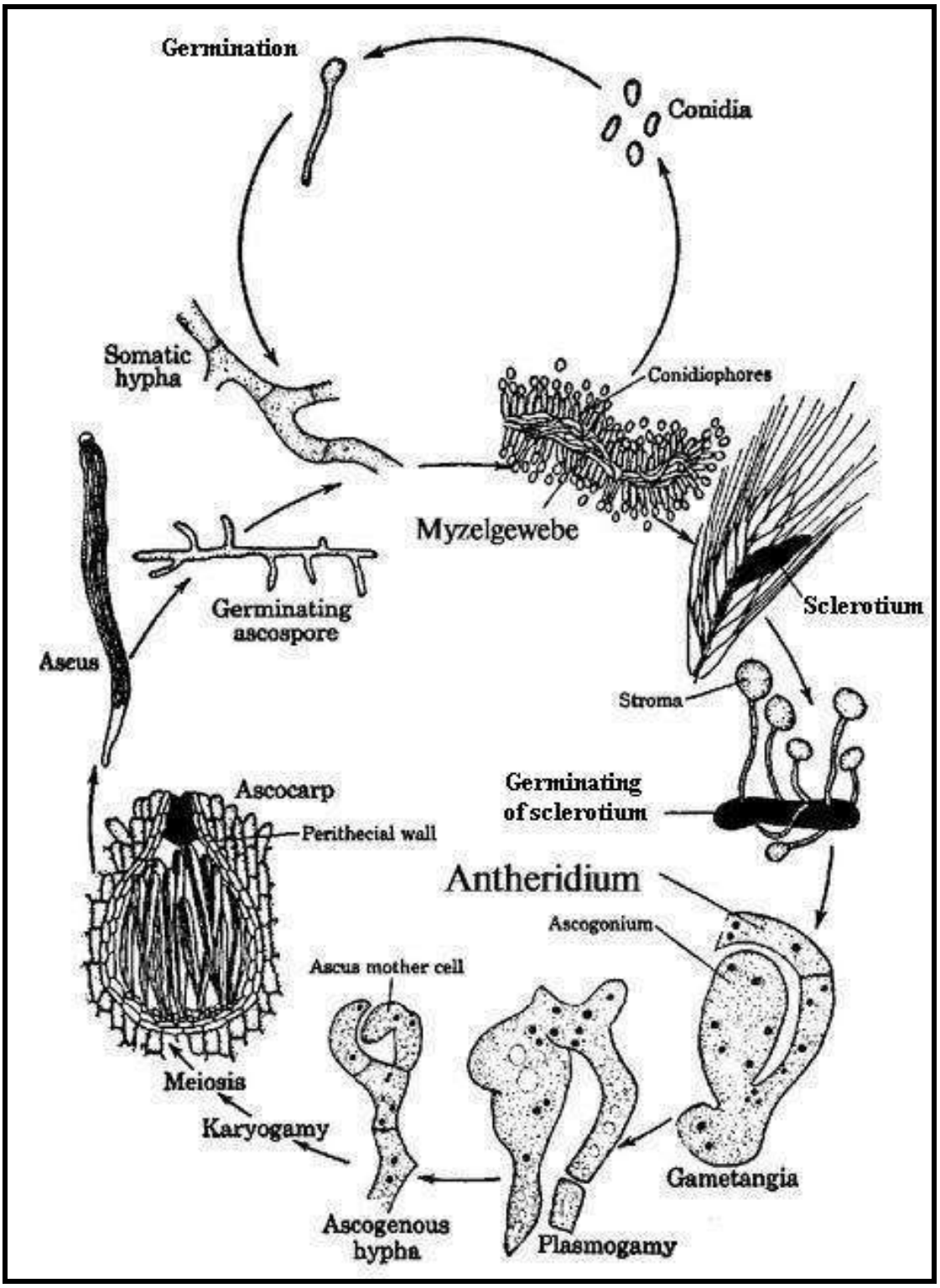


Figure 33: Life cycle of *Claviceps purpurea*

Class 4: Discomycetes

General characteristics:

1. Produce their asci in apothecia; we define apothecium as an open ascocarp.
2. Discomycetes contain fungi included, Morels, Traffle and Spongiofungi.
3. The asexual stage is unknown in most of these fungi.
4. Discomycetes classify into two groups according to its habitat.

Group 1: Epigean: which presence on the surface of soil, and they involved operculate and inoperculate.

Group 2: Hypogean: which presence under the surface of soil.

Epigean inoperculate discomycetes:

Most of them are parasites and causes plant diseases.

Order1: Helotiales

Family: Sclerotinaceae

Genus*: Sclerotinia*

Species: *S. fructicola*, or *Monilinia fracticola* or *M. laxa*, which causes the brown rot of peach and other stone fruits.

Life cycle of *Monilinia fracticola* or *Sclerotinia fracticola*

(Asexual cycle): The mycelium of *M. fracticola* which begins as a germ tube emerging from the ascospore or conidium (A). In the spring, invades a susceptible host, causing twig blight or leaf blight. Soon after the mycelium reaches a certain stage in its growth, it produces long, branched conidiophore (B). That rapidly breaks up into chains of oval or lemon-shaped conidia (C). The conidia break off easily from the chain and are scattered by the wind. If they reach a susceptible host, they germinate in the presence of water, each conidia produces a germ tube, invades the host, and thus spreads the disease (D). **Note:- young peach fruits are resistant to the invasion of fungus, but as they approach maturity their resistance decrease and the fungus invades through hair sockets, insect punctures and other wounds and cause the familiar brown rot.**

The mycelium of the fungus spreads rapidly, secreting a head of powerful enzyme that dissolves the middle lamella of the host cells and renders tissues soft. Invasion of the soften tissues by the hyphae penetrate the entire fruit, which shrivels and mummifies (E). *Monilinia fructicola* commonly produces spermatia (F&H). The function of which no one has yet discovered? Apothecial fundaments are formed in large numbers on

peach mummies on the ground (G&I). **Note: The production of apothecia on the grounded mummies and their absence from the aerial mummies that cling to the tree branches have not been explained.** The long-stalked apothecia are produced in great numbers in the spring on peach mummies that have passed the winter on the ground and develop asci an ascospores (J&M). Air currents carry the spores to the blossoms, twigs, and young leaves of the trees and, if the weather conditions are favorable, the ascospores initiate infection and start a new life cycle Figure (34).

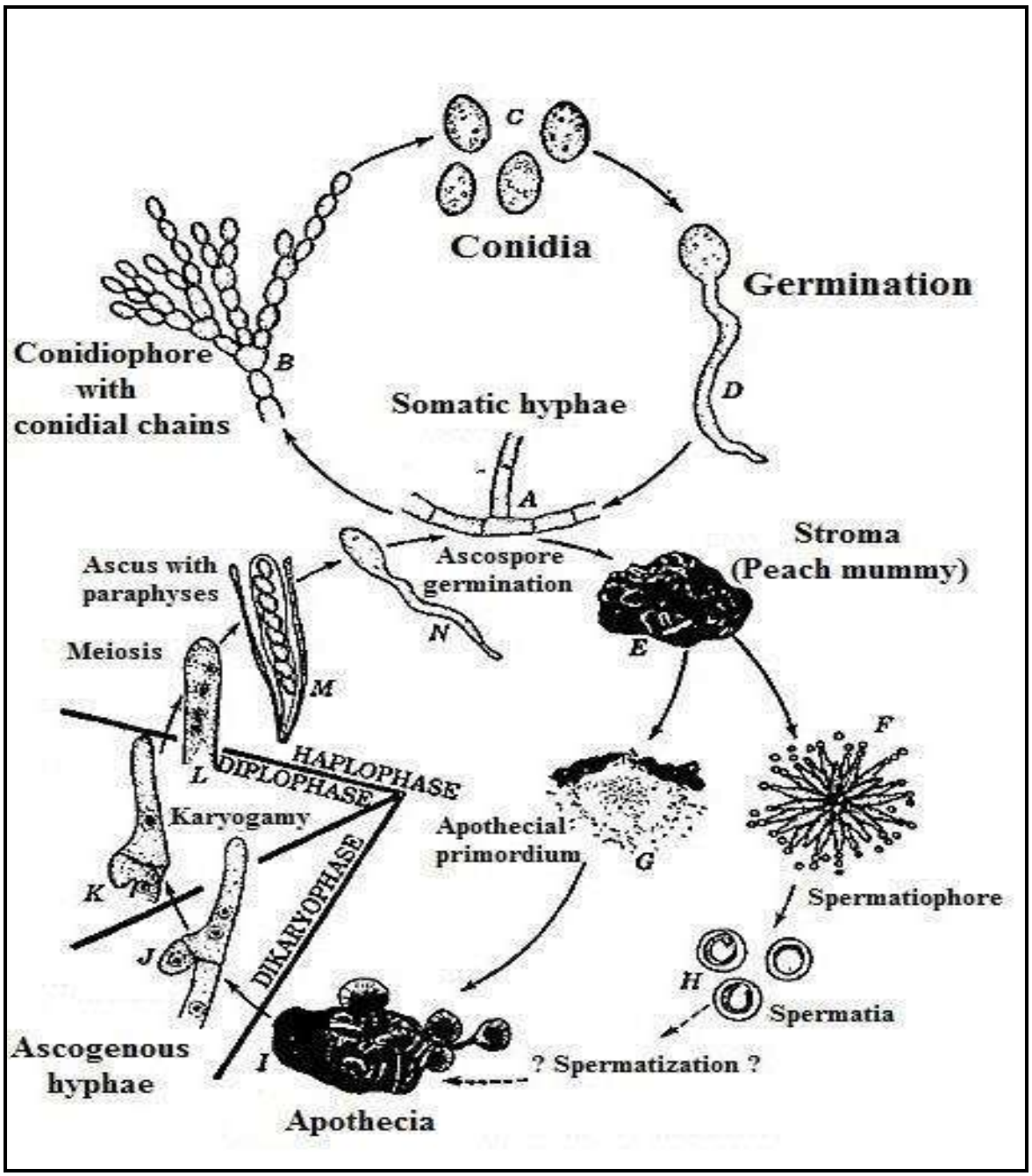


Figure 34: Life cycle of *Monilinia fracticola*

Epigean operculate discomycetes:

General characteristics:

1- Involve the fungi that apothecia on the surface of the soil, and their asci with operculum.
2- Most of them are saprobes.
3- Asexual reproduction is unknown.

Ordre 2: Pezizales involve two families:

Family 1: Pezizaceae:

1. Pezizaceae are mostly cup- disc, or sessile to stalked; minute to very Large; bright-colored to dark-brown; smooth, velvety, hairy.
2. Apothecia reach to 5cm or more.
3. Ex: *Peziza aurantia*; Orange in color, edible (spongefungus), sessile apothecium.

Family 2: Morchellaceae: Figure 35

1- Morchellaceae is characterized by large, stalked apothecia.
2- Apothecia reach to 14cm.
3- Grayish white to a dark-brown in color.

Figure 35 : ***Morchella spp.***

Hypogean discomycetes :

The ascocarps are hypogean and remain closed in most species, liberating the ascospores only when the ascocarp decays or broken by animals.

Order 3: Tuberales

Fungi in this order are mycorrhizal fungi living in association with the roots of Oak and beech-trees. The ascocarp surrounding by a thick-wall cells called peridium. There is a veins which contain the hymenial layer (ascospores).

There are two families,

1. **Tuberaceae: ex: *Trimania*** : the wall is spiny and there are only four ascospores
2. **Terfeziaceae: ex: *Terfezia*** : The acospores are globose and eight in number, and the wall is smooth.

Class 5: Loculoascomycetes

General characteristics:

1. The asci are bitunicate.
2. The ascocarps are ascostroma in which the asci are borne in locules.

Order: Pleosporales

Family: Venturiaceae

Genus: *Venturia*

Species: *V. inaequalis*

Venturia inaequalis attacks apple fruits and causes apple scab.

In the spring, at the time the apple buds are bursting, the fungus begins its life cycle by forcibly ejecting its ascospores, through the openings of ascocarps buried in the tissues of dead apple leaves lying on the ground.

The ascospores are two-celled, yellowish with the upper cell shorter and somewhat wider than the lower (H). The unequal size of the two cells of the ascospores gives the species its name. Air currents lift the ascospores to the apple leaves on the trees, and germination occurs in the presence of moisture (I). The germ tubes issuing from the ascospores penetrate the cuticle, and the mycelium begins to grow forming a

thin, subcuticular stroma. A few days after infection, numerous short conidiphores (B) break through the cuticle and each produces a flame-shaped conidium at the tip, so that conidiophore and conidium resemble a short burning candle. Conidia are spread by rain to other leaves or to young fruits in various stages of development; the fungus propagates it self asexually throughout the spring and summer, producing several conidial generations. Late in the season when the leaf cells begin to die, the mycelium penetrates deep into the leaf tissues and proceeds to form ascocarps as follows:-

When coil in a hypha consisting of uninucleate cells initiates the formation of the stroma. As this develops, a coil of multinucleate cells representing the ascogonium differentiates inside the young stroma, and a trichogyne pushes through and protrudes from the stromatal wall (E). In the same time, an antheridium is formed from a hypha of the opposite strain and contact is soon established between the antheridium and the trichogyne. The antheridium nuclei pass into the ascogonium through the trichogyne (F). The nuclear pairs pass into the ascogenous hypha, which now develop from the lower portion of the ascogonium (G). Ascus formation takes place, and the stroma continues to develop and form the ascocarp (H). The ascospores mature in April or May depending on the locality Figure(38).

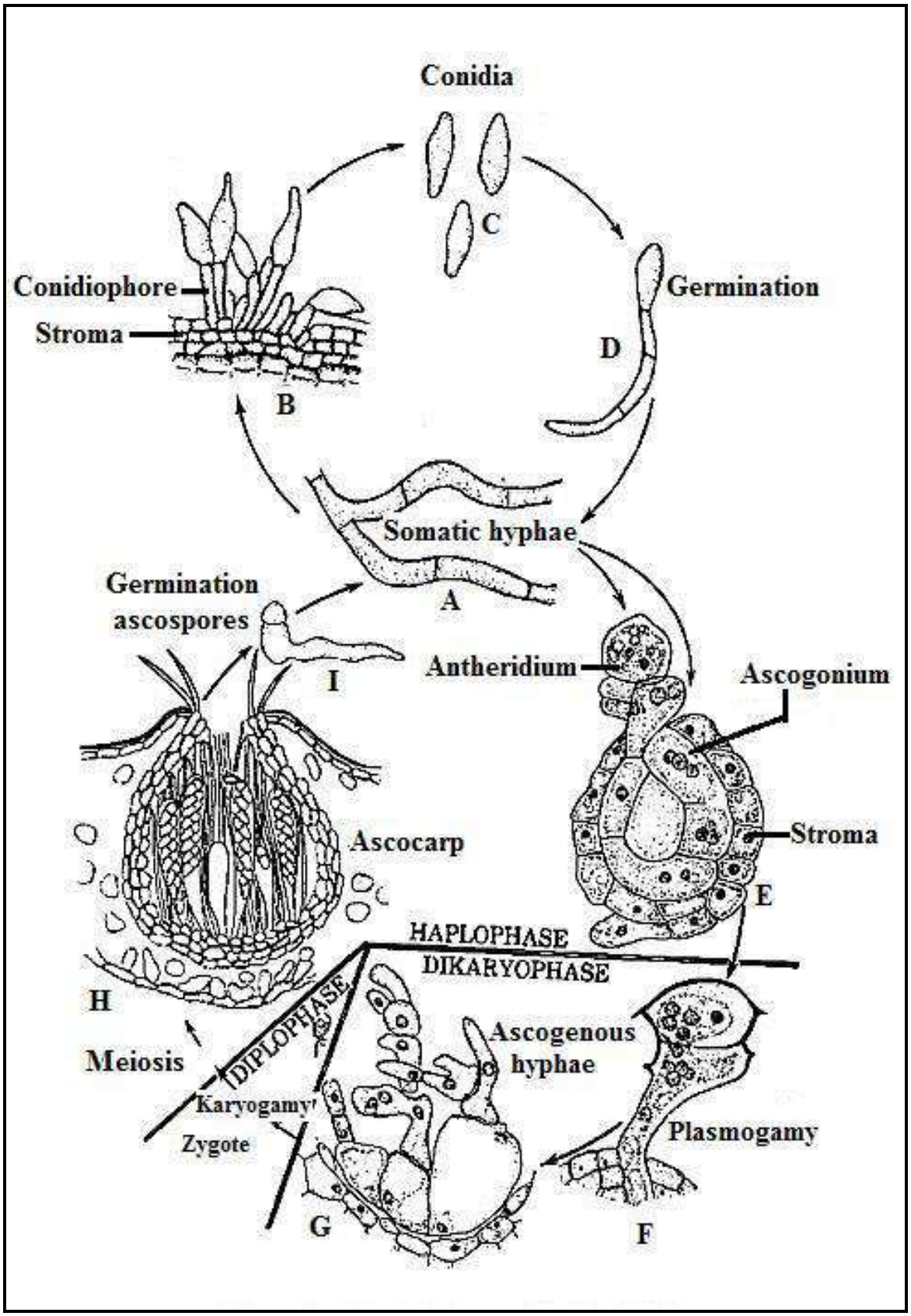


Figure 38:- Life cycle of *Venturia inaequalis*

Division 2: Eumycota

Sub-division 4: Basidiomycotina

General characteristics

1. Some basidiomycotina are saprobes such as mushroom, other are parasites which causes smut and rust diseases.
2. They produce their spores, called basidiospores on the outside of a specialized, spore-produced structure, the basidium.
3. The mycelium of most basidiomycotina passes through three distinct stages before the fungus completes its life cycle:

   - The primary mycelium (1n):- Usually develops from the germination of a basidiospore. It is septate and uninucleate from the beginning. It gives rise to;-
   - Secondary mycelium: Usually involves an interaction between two compatible mycelia (n+n) (Dikaryon).

There are no sexual organs in subdivision basidiomycotina, so the sexual reproduction occurs by spermatization or somatogami.

Basidiomycotina characterized by presence of clamp connections, that are formed during nuclear division when the binucleate cell is ready to divide, a short-branch arises between the two nuclei (a) and (b) and begins to form a hook. The nuclei now divide. One division becomes oriented obliquely, so that one daughter nucleus (b) forms in the clamp connection and the other (b′) forms in the dividing cell. The second division orients itself along the long axis of the dividing cell, so that one daughter nucleus (a) forms near one end of the cell and the other (a′) approaches the nucleus (b′) of the first division near the other end of the cell. In the meantime, the clamp has bent over, and its free end has fused with the cell, so that the clamp forms a bridge through which one of the daughter nuclei (b) passes to other end of the cell and approaches one of the daughter nuclei (a) of the other division. A septum forms to close the clamp at the point of its origin and another septum forms vertically under the bridge to divide the parent cell into two daughter cells with (a) and (b) nuclei in one daughter cell and (a′) and (b′) in the other as shown in the diagrams below Figure 39.

   - Tertiary mycelium: is represented by organized specialized tissues that compose the basidiocarps of the more complex basidiomycotina.

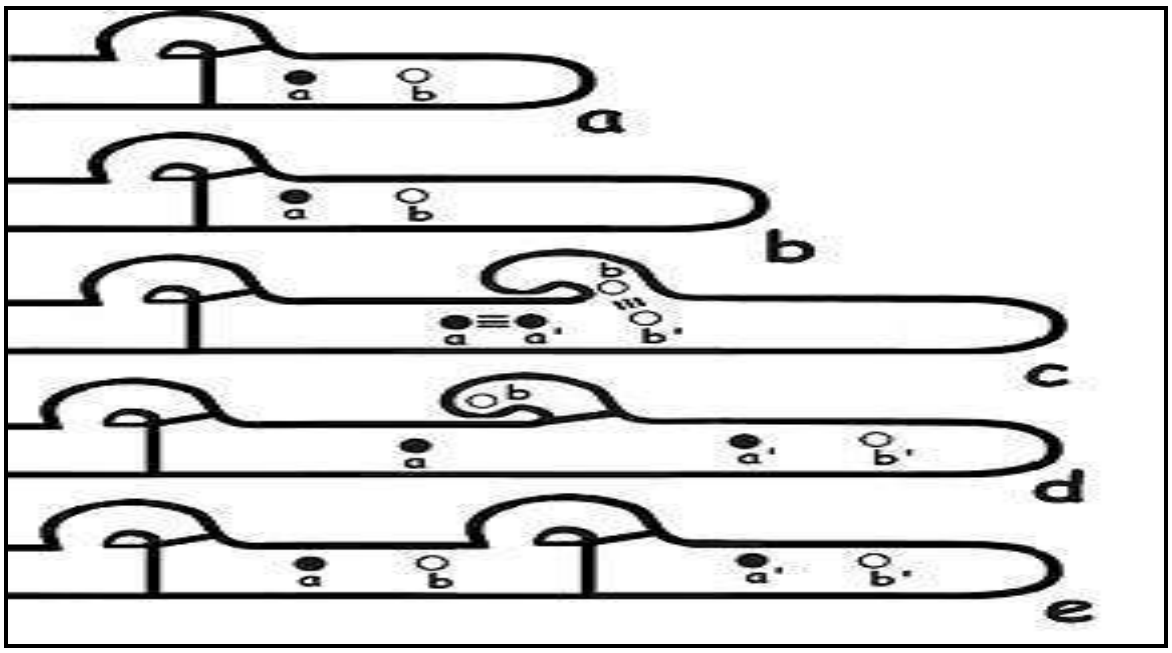


Figure 39: Diagram shows the formation of clamp connection in basidiomycotina.

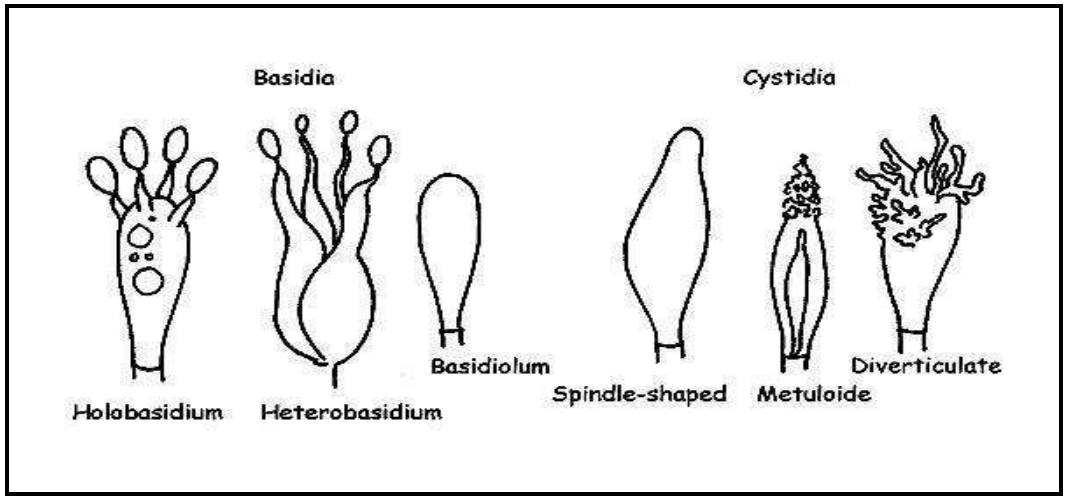


Figure 40: Hymenium of basidiomycotina and Types of basidium

The basidium:

The basidium may be defined as a structure bearing on its surface a definite number of basidiospores (usually four) that are typically formed as a result of karyogamy and meiosis. There are two types of basidium:

1. A simple club-shaped basidium originated as a terminal cell of a binucleate hypha and is separated from the rest of the hypha by a septum over which a clamp connection is generally found (Holobasidium) Figure 40.
2. Heterobasidium: Divided into four cells by transverse or longitudinal primary septa Figure 40.

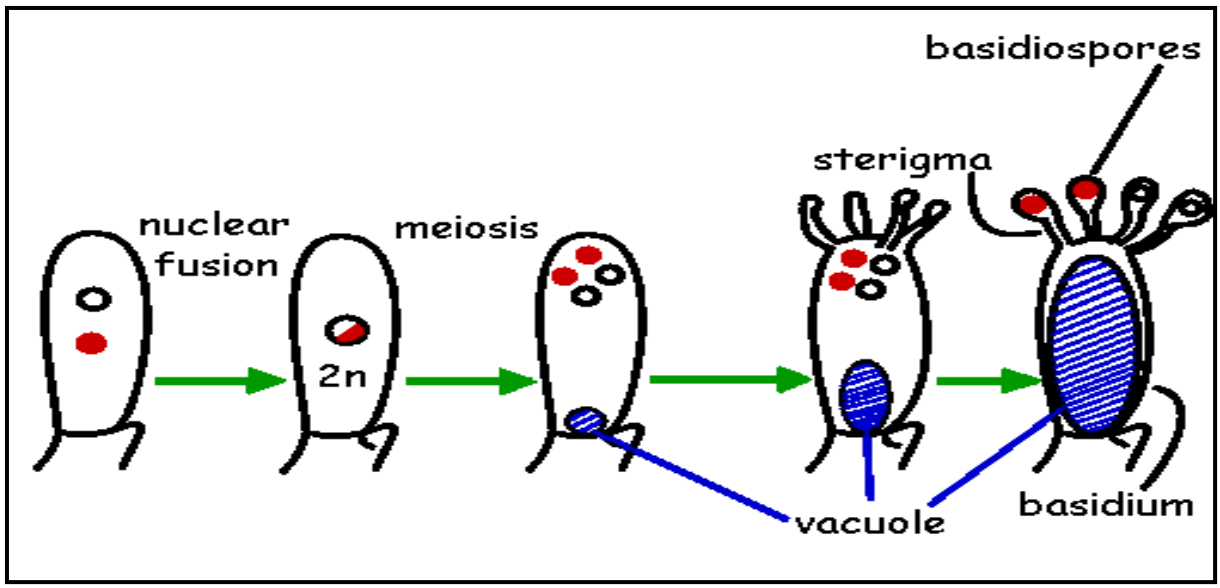


Figure 41 (Formation of basidium and Basidiospores)

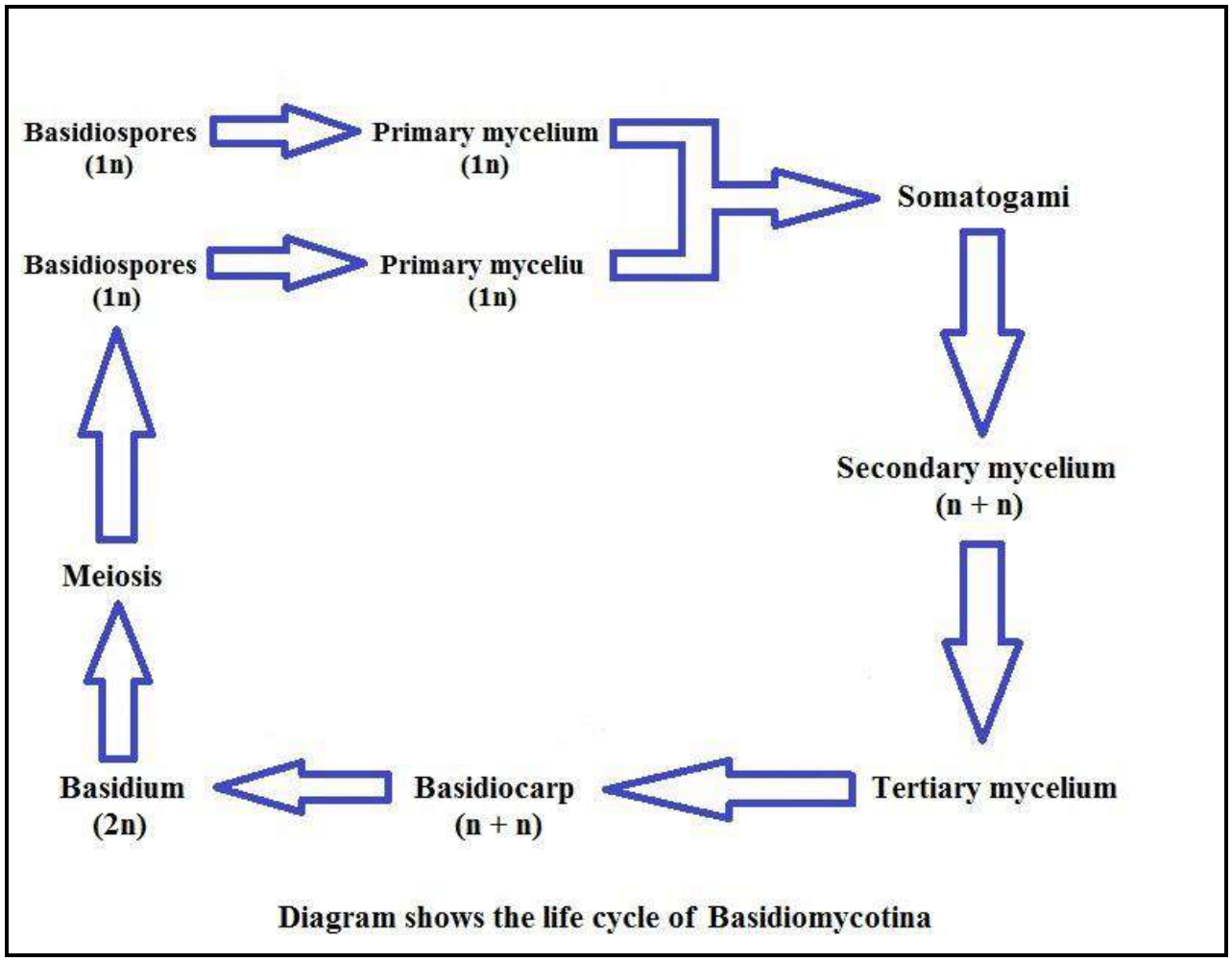


Diagram shows the life cycle of Basidiomycotina

Classification of Subdivision Basidiomycotina:

Class 1: Teliomycetes:

General characteristics:

1- There is no basidiocarp but produces teliospores instead of that.

2- Basidium septate by transverse septa.

3- Parasitic fungi.

It involves two orders:-

Order 1: Uredinales (Rust fungi).

Order 2: Ustilaginales (Smut fungi).

Order 1: Uredinales (Rust fungi):-

This order involves fungi which economically important causes rust diseases. These fungi are obligate parasites on cereals crops causing black stem-rust. There are no basidiocarps but these fungi contain many spore stages which forming within pustules. The mycelium presence between host cells and send haustorium. The fungi which have five types of spore stages called macrocyclic rust which needed either one host (autoecious rust) or two hosts that called (heteroecious rust), the life cycle of these fungi is long. Those which have short life cycle are called (microcyclic rust). The example of macrocyclic but autoecious is *Melampsora lini* which causes flax rust. And macrocyclic heteroecious rust is *Puccinia graminis* which causes black rust on gramineae.

Stages of life cycle :

1. Pycnia stage ---------- pycniospore (1N) one cell

Or Spermagonium ---------- spermatia (1N) one cell

2. Acial stage ---------- Aciospore (N + N) one cell

3. Uredinial stage ---------- Urediniospore (N + N) one cell

4. Telial stage ---------- Teliospore (2N) two cells

5. Basidial stage ---------- Basidiospre (1N) one cell

Life cycle of *Puccinia graminis* :-

In the spring, infection of the alternate host, the barberry, occurs when a basidiospore lands on the surface of the leaf. The basidiospore germinates, and a monokaryotic hypha invades the leaf. A flask shaped pycnium that is immersed in the surface leaf tissue is formed. Pycniospores are produced within the pycnium and are exuded in a drop of nectar. These pycniospores act as function as spermatia and fuse with the flexuous hyphae (the receptive hyphae) of a pycnium of another mating type. The nucleus of the pycniospore migrates into the flexuous hyphae, and its progeny make their way down through the haploid hyphae to the aecial primordium, establishing the dikaryon. The aecial primordium, now dikaryotic, forms the copulate aecium which bears binucleate, thin-walled aeciospores in chains. The aecia are formed on the underneath surface of the barberry plant.

The aeciospores are dispersed by air currents and may land on the primary host, a cereal plant. The aeciospores germinate, and the dikaryotic hyphae penetrate the host. The hyphae within the cereal plant eventually form pustules on the surface of the host. These pustules are uredinia and are reddish in appearance owing to the formation of a thick-walled red urediniospores, each bourne on a short stalk, within them. Each uredinospore is binucleate, preserving the dikaryotic condition. The uredinospores are capable of initiating new infections on the cereal plants, and this particular stage may repeat numerous times during the summer. This stage is responsible for the huge buildup of spores that is a major factor in making this fungus a devastating parasite. As autumn approaches, a new type of sorus appears on the wheat plant. This is the telium which bears teliospores. The teliospores are composed of two binucleate cells and have thick, dark walls making the telium appear black to the naked eye. The teliospores overwinter and, in the spring, each of its cells functions as a probasidium. Karyogamy takes place in each cell of the teliospore, and a metabasidium is produced from each cell. Meiosis occurs in the metabasidium, which is then divided by transverse septa into four cells, each containing a single nucleus. Each cell of the metabasidium forms a sterigma and the nucleus is included in the basidiospore that is then formed. This basidiospore is capable of initiating infection again on the barberry plant. **Figure 42.**

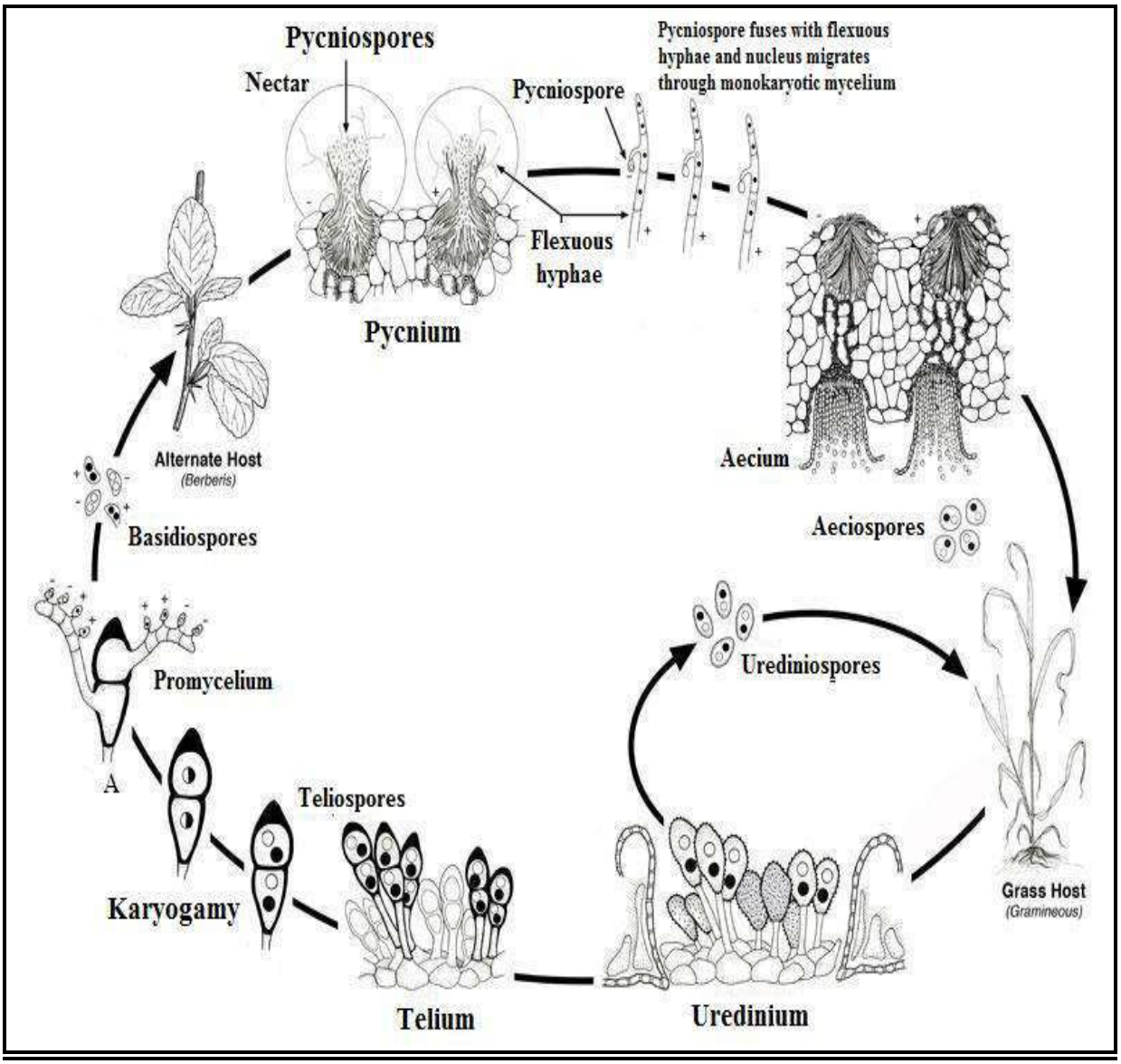


Figure 42: Life cycle of *Puccinia graminis*

Order 2: Ustilaginales (Smut fungi)

Ustilaginales are obligate parasites fungi on Angiosperms such as wheat. The smuts are so called because they form black, dusty spores masses that resemble soot or smut. The teliospores (chlamydospores) are binucleate which have external wall (exine) and internal wall (intine) and dikaryon. When teliospore germinates it give rise promycelium which bearing basidiospores (sessile). Basidiospores can be budding in asexual reproduction, and some of smut fungi do not obligate parasites so we can cultivate it in laboratory. The sexual reproduction occurs by somatogami.

This order is divided into two families:

Family 1: Ustilaginaceae:

The promycelium is transversely septate, with lateral and terminal basidiospores Figure 43A.

Ustilago nuda causes loss smut on wheat.
Ustilago hordei causes covered smut on wheat
Tolyposporium eherenbergi causes long smut on sorghum.

Family 2: Tilletiaceae:

The promycelium is aseptate and only terminal basidiospores are produced Figure 43B.

Tilletia caries causes stinking smut on wheat.
Tilletia foetidae causes stinking smut on wheat.
Urocystis agropyri causes flag smut on wheat.

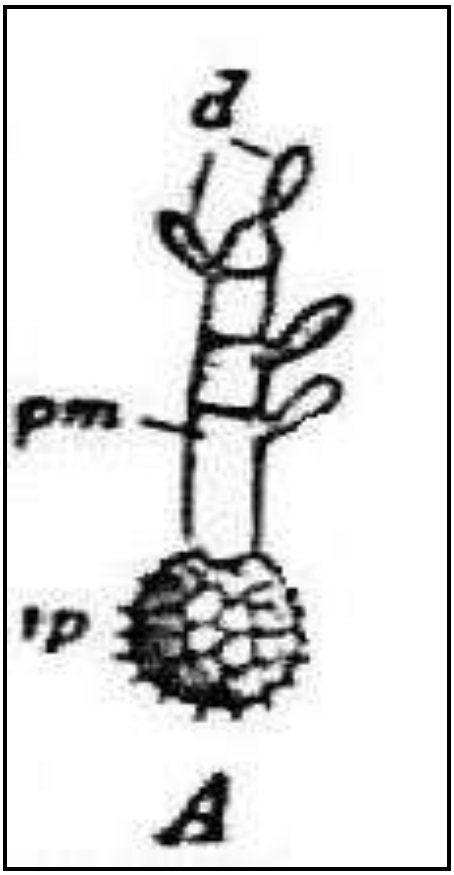


Figure 43A

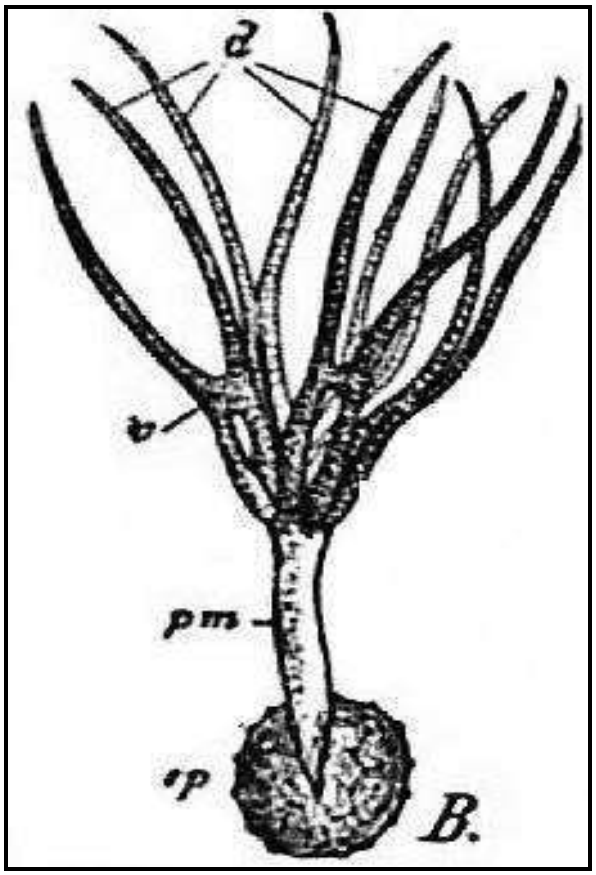


Figure 43 B

Sub-division 4: Basidiomycotina

Class 2: Hymenomycetes

This class involves edible mushroom and other saprophytic fungi. The main characteristic of these fungi is the club-shaped basidium which bears four basidiospores on sterigmata. The basidium in this class was bearing in hymenial layer which open before spore maturation.

Class 3: Gasteromycetes:

The spore remains inside fruiting body and do not release before maturation.

Class 2: Hymenomycetes : This class involves two orders:-

Order 1: Agaricales

The fruiting bodies are fleshy; the hymenial layers are bearing on gills (Mushroom).

Order 2: Polyporales:

The fruiting bodies are not fleshy; the spores are bearing in different ways.

Order 1: Agaricales:

This order involves mushroom which is saprophyte, such as ***Agaricus bisporus***. Its basidium bears only two basidiospores. The other examples of edible mushroom are: ***Agaricus campestris*** which is growing well on animal wastes and it is brown in color. This order also involves poisoning mushroom which we can distinguished it by:

1- Presence of scales on the cap.
2- Presence of annulus.
3- And presence of volva Figure 43.

There are many examples of poisoning mushroom as follows:
Agaricus xanthodermus (Yellow staining fungus).
Inocybe: (Red staining fungus)
Coprinus: Some species are edible; others are poisoning (Black liquid like ink).
Amanita which produces amanita toxins such as:
Amanita phalloides: Produces α-amanitine, β-amanitin and phalloid which are high toxic materials. ***A. muscaria*** which contains muscarine, causes nerve system damage. Its scales are red in color and called fly fungus.

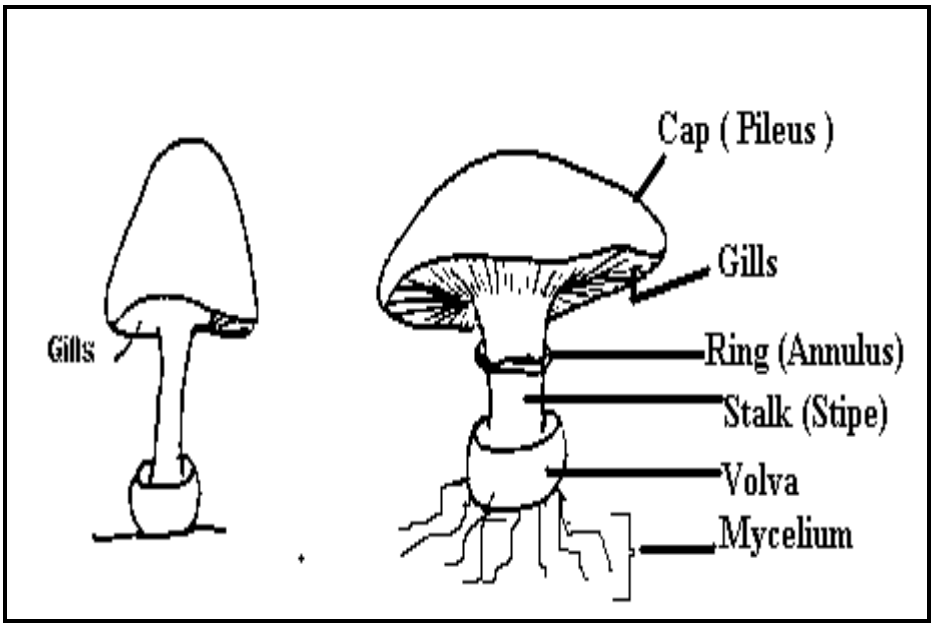


Figure 43: Poisoning mushroom

Order 2: Polyporales: This order is classified into three families:

Family 1: Polyporaceae (Pore fungi): ex: ***Polyporus.***

The fruiting bodies contain pores which coated with hymenial layer Figure 44.

Family 2: Clavariaceae (Coral fungi): ex: ***Clavaria***.

This family involves color fungi, white or yellow Figure 45

Family 3: Telephoraceae (Shelf fungi): ex: ***Sternum*** :

They are growing on the trees like shelf, and causes wood degradation Figure 46.

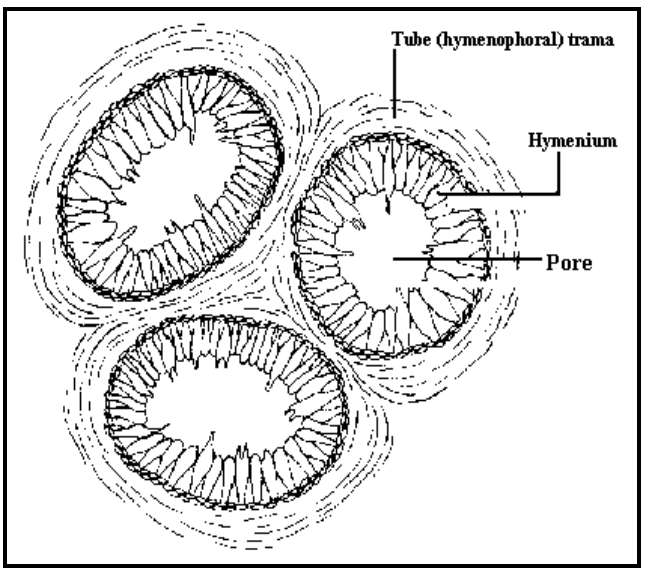


Figure 44: Hymenium of polypore **Figure 45: Coralloid basidiocarps of *Clavaria vermicularis***

Figure 46: Basidiocarps of two shelf or bracket fungi

Class 3: Gasteromycetes:

Gasteromycetes including organisms which are commonly known as puff balls, earthstars, stinkhorns, and bird's nest. The fruiting bodies are characterized by a distinct outer wall (peridium) that may open in various ways after the spores are mature or may remain closed permanently, with the spores liberated only after the disintegration of the peridium through the action of external agents. The peridium consists of one, two, or three layers: exoperidium, mesoperidium and endoperidium. The peridium contains ostiole which the spores are liberated through it.

This class is classified into two orders:

Order 1 : Lycoperdales

Family1: Lycoperdaceae	**Ex1 : *Lycoperdon***	**(Puff ball) Figure 47**
Family2: Gasteraceae	**Ex1 : *Geaster***	**(Earth star) Figure 48**
Order 2 : Nidulariales	**Ex1 : *Cyathus***	**(Bird's nest) Figure 49**

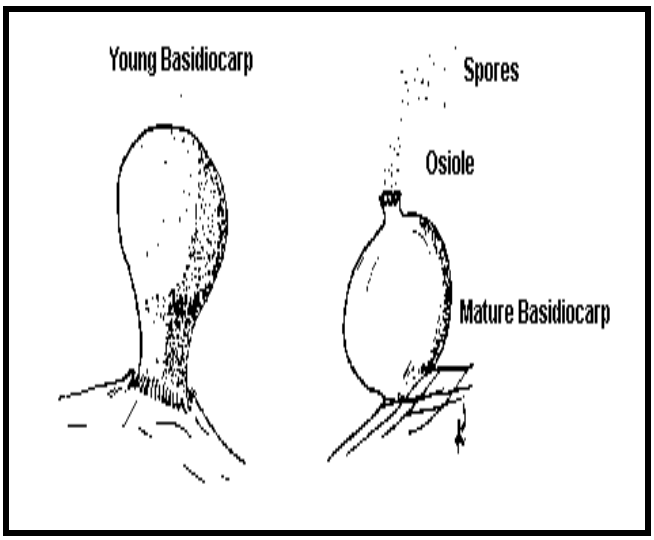


Figure 47:- *Lycoperdon* (Puff ball)

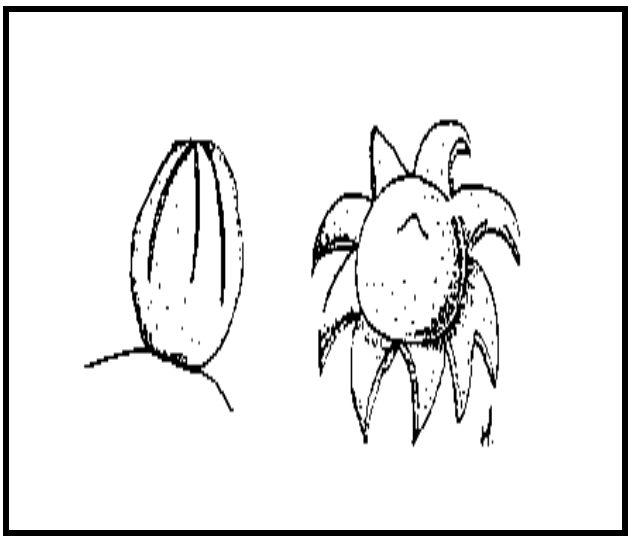


Figure 48: *Geaster* (Earth star)

Figure 49: *Cyathus* (Bird's nest)

Division 2: Eumycota

Sub division 5: Deutrromycotina:

Are known as imperfect fungi which characterized by:

1. They have septate hyphae.
2. Reproduce only by conidia.
3. The majority are either saprobes or parasites of plants. A few are parasitic on other fungi and some even trap and consume nematodes.
4. Some are used in commercial production of certain chemicals including some antibiotics.

The bases used in the classification of imperfect fungi:

1. Presence or absence of conidia
2. Shape, color and form of conidia
3. Type of asexual fruiting structures

Class 1: Hyphomycetes

Mycelium is sterile, or produce conidia bearing on conidiophores, these conidiophores arise either directly on mycelium or formed in the inside special structures called (sporodochium or synnema).

Order 1: Moniliales or Form- order: Moniliales:

It is a very large group of probably over 7000 species. The conidia either bearing on free and separated conidiophore (sporodochium) or collected conidiophores (synnemata) Figure 49. This order involves three families:

Family 1: Moniliaceae

It is the larger family which involves the fungi which their conidia bearing on conidiophore (colorless) and colorless hyphae such as*Verticillium*, *Botrytis*. The conidia of later genus are in cluster like grape clusters Figure 50A.

Genus 1: *Candida*: Cells are collected to form pseudomycelium which bearing arthrospores Figure 50.

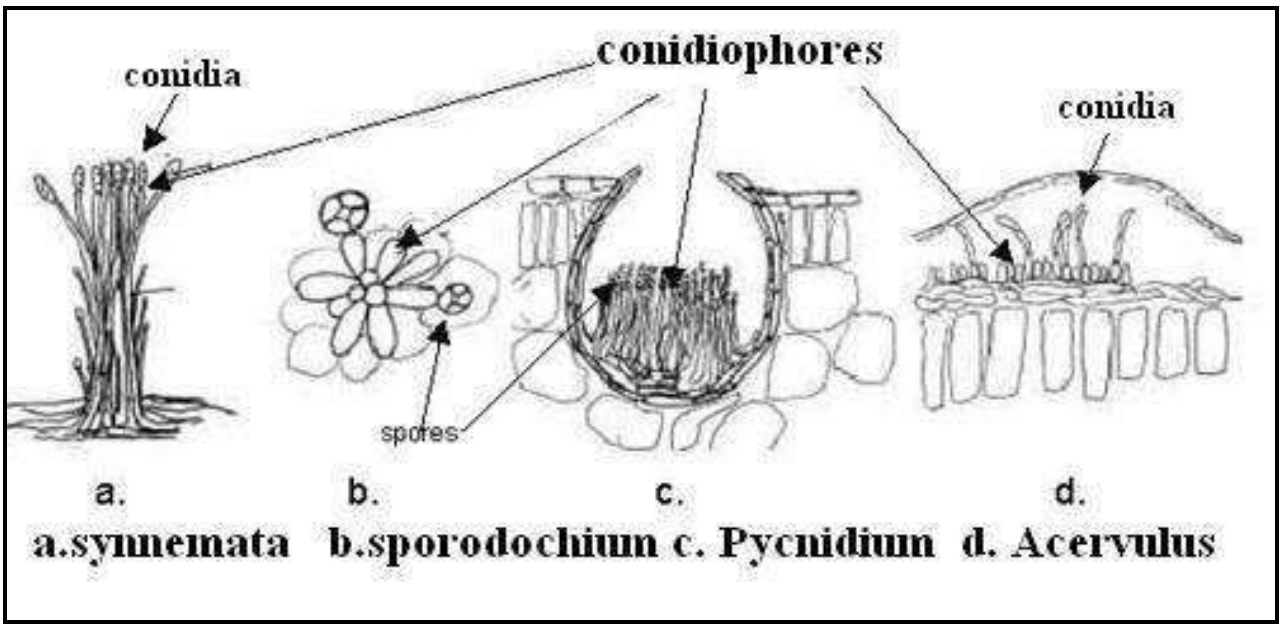


Figure 49: Types of asexual fruiting bodies in Deutrromycotina

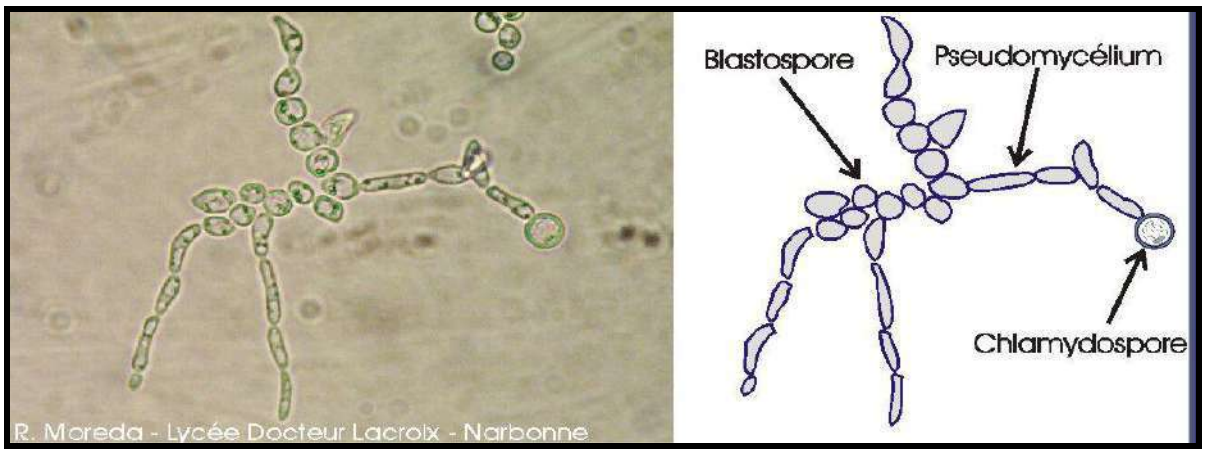


Figure 50: ***Candida albicans***

Family 2: Dematiaceae: It is characterized by dark-color or black conidia, conidiophore, and mycelium. Most of them are saprobes such as:

Genus 1: ***Alternaria***: Bottle-shaped conidia, and divided by longitudinal Septa Figur 51.

Genus 2: ***Helmenthosporium***: All produce rather large phragmospores, multicellular conidia possessing transverse septa (2,3 or 4) septa Figure 51.

Genus 3: ***Cladosporium***: All produce two types of conidia, the first is bicellular conidium and the second if unicellular small conidium, dark- green to black in color Figure 51.

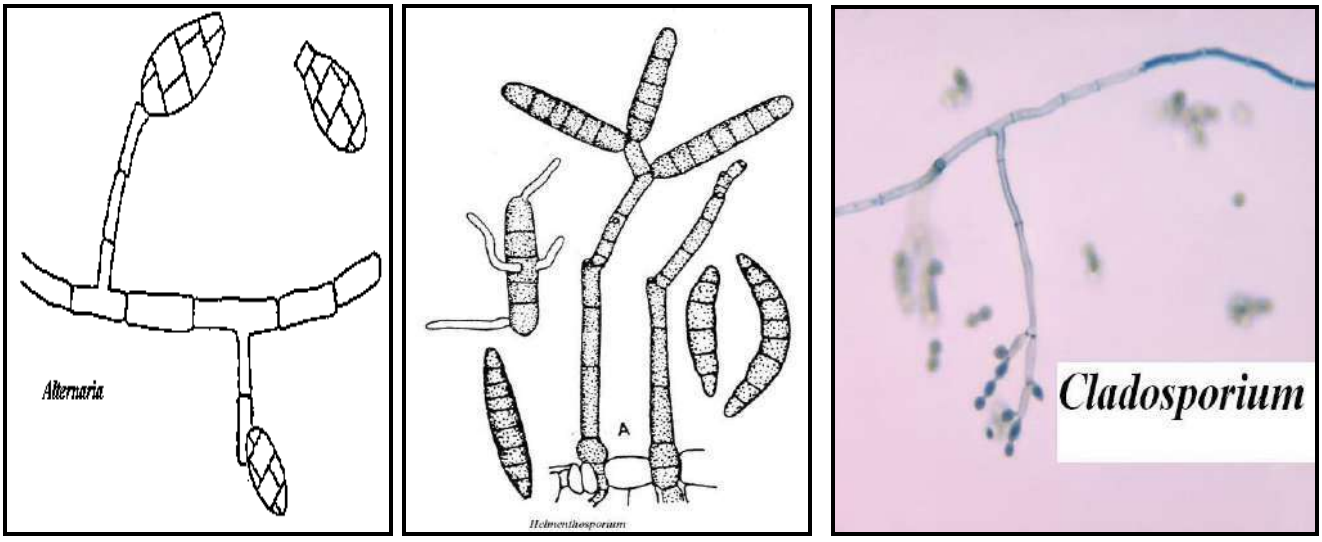


Figure 51: Conidia of some common form-genera of Moniliales

Family 3: Tuberculariaceae

The asexual fruiting bodies are bearing within a sporodochium.

Genus: *Fusarium*:

It is a member of the form-genus *Fusarium* produces two types of conidia that are termed macroconidia and microconidia. Both types are produced from phailides. Maroconidia are long, multiseptate, crescent or canoe-shaped structures that are generally born in sporodochia. Microconidia are small, one-celled, spherically or ovally shaped Figure 52. A number of *Fusarium* is parasites, generally causing a wilting of the host plant.

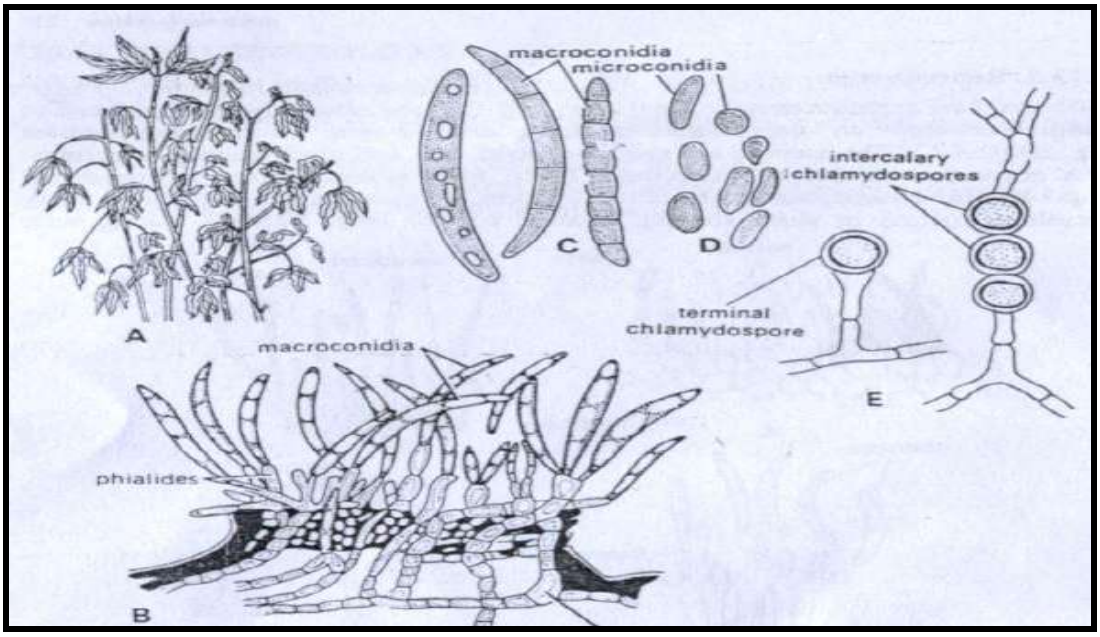


Figure 52: Sporodochium of *Fusarium*

Order 2: Agonomycetalas (Myceliasterile)

There are no conidia, conidiophores, and reproductive organs. There are a few families and genera in this order.

Genus*: Rhizoctonia*

It is commercially important. It is saprophyte in soil causing damping off seedling. It is distinguish by mycelium which form right angle when branched. The branches are narrow in branching regions and more thickness.

Class 2: Coelomycetes

Mycelium produce conidia bearing on conidiophores, these conidiophores arise either directly on mycelium or formed in the inside special structures called (Acervulus or Pycnidium).

Order 1: Sphaeropsidales

The distinctive structure of Spaeropsidales is of course the pycnidium.

Family1: Sphaeropsidaceae

Ex; *Septoria apii*

The asexual fruiting bodies are pycnidium which causes late blight disease on celery. The genera are characterized by small, ostiolate pycnidia sunken in the substratum, very short phialides and hyaline or greenish, long conidia (needle-shaped conidia).

Order 2: Melanconiales

Asexual fruiting bodies are acervuli.

Family: Melanconiaceae

Genus: *Colletotrichum*

The form-genus *Colletotrichum* produces typically elongated, hyaline conidia with round ends. Dark setae are often found in the acervulus. This genus causes Bean anthracnose.