University of Baghdad
College of Science
Biotechnology Department

Lectures in

Mycology

Third Stage

BY

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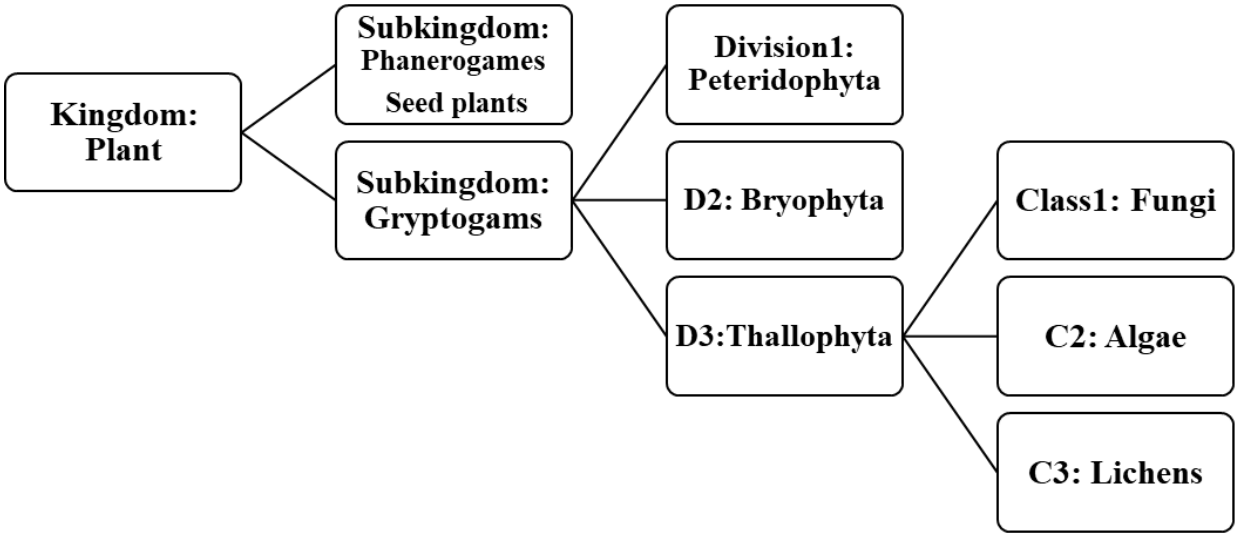
Lecture 1

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 needs 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 peptidoglycan. 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.

<u>Morphology of fungi:</u>

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.

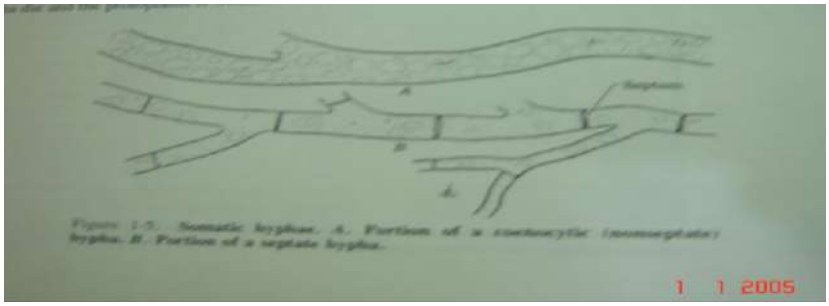


Figure 1

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 tends 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.

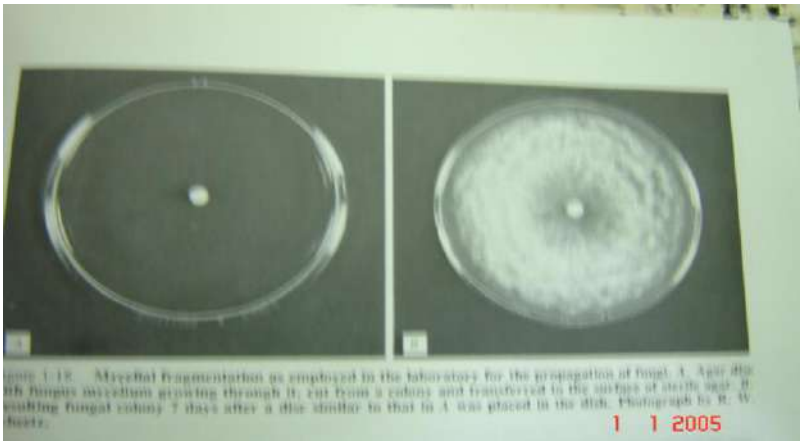


Figure 2

<u>Fungi can be classified into four groups according to their morphology:</u>

1- **Mold** (Mould): Which grow as branching filaments (hyphae) and produce the mycelium such as *Aspergillus*, *Mucor*.

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* Figure **<u>3</u>**

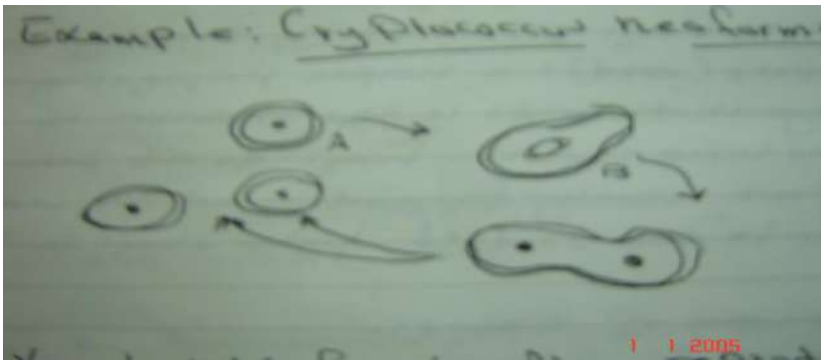


Figure 3

3- **Yeast-like fungi**: Also reproduce by budding and grow as non- branching filament- pseudohyphae- such as *Candida albicans*. Figure 4

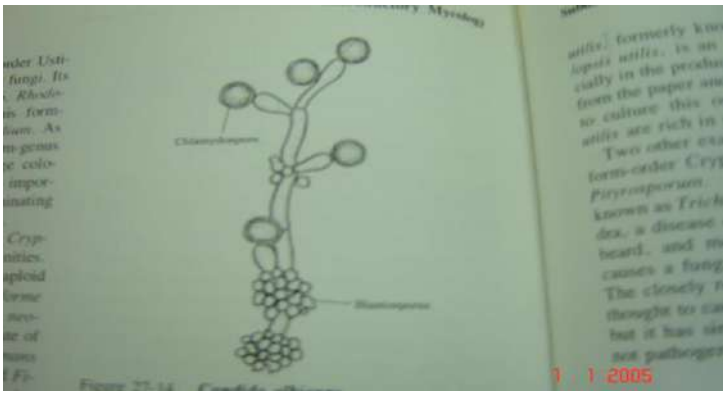


Figure 4

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.

<u>Reproduction:</u>

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 develops 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 a part 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 produces 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.

Lecture 2: 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 known 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 consumer such as *Agaricus bisporus*-**edible mushroom**-.
6. Use it as important **research tools** in cytologists, Geneticists, and Biochemists such as *Neurospora*.

Living mode of fungi

In nature fungi obtain their food either by infecting living organisms as **parasites** or by attacking dead organic matter as **saprobes**, many also form symbiotic relationships with plants as in Lichens and mycorrhiza (**Ecto and Endotrophic**).

Fungi that live on dead matter and incapable of infecting living organisms are called (**obligate saprobes**); those capable of causing disease or of living on dead organic matter (**facultative parasites** (or) **facultative saprobes**); and those that can't live except on living protoplasm, (**obligate parasites**). A living organism 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 multisugar such as starch.
2. **Nitrogen sources:**
   A. **Organic source**: such as amino acids and peptone.
   B. **In organic source**: such as nitrate and ammonia.
3. **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 – 40 ºC)** and the optimum is **(25 – 35º C)**

B. Psychrophilic fungi: The range is **(5 – 25ºC)** and the optimum is **(15 ºC)**

C. Thermophilic fungi: The range is **(20 – 50ºC)** and the optimum is **(40ºC)**

2- **Hydrogen Ion concentration (pH)** (as mention before).

4. **Aeration**: All fungi prefer living in aerobic condition.
5. **Light**: is not necessary for fungal growth but it is (some time) important to form sexual and asexual structures.
6. **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 typical characteristics 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 Reproduction

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 they separate from each other or from another hyphal cell, they are often called **chlamydospores** Figure 5.

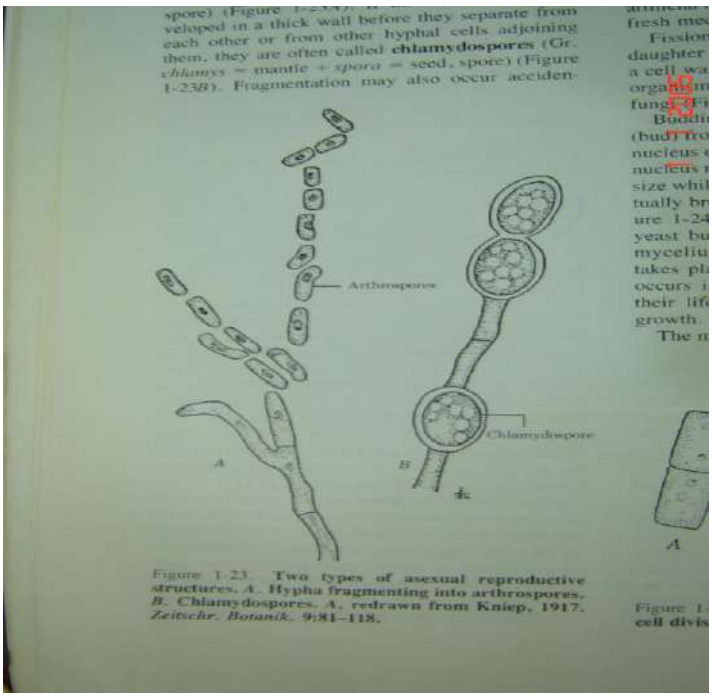


Figure 1-23. Two types of asexual reproductive structures. A. Hypha fragmenting into arthrospores. B. Chlamydospores. A, redrawn from Kniep, 1917. *Zeitschr. Botanik*, 9:81–118.

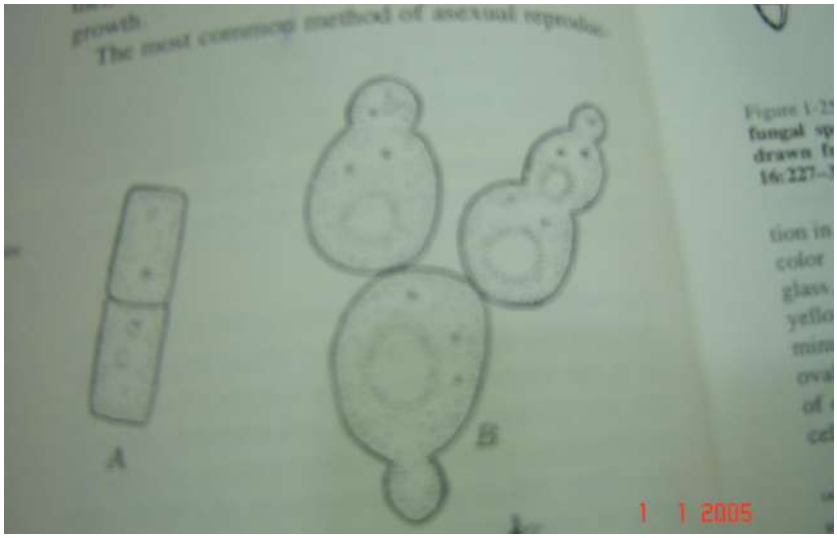
Fragmentation may also occur accidentally by the tearing off of parts of the mycelium through **external forces**. Such pits of mycelium under favorable conditions will start a new employ mycelia fragmentation to keep fungal cultures growing on artificial media by transferring a bit of mycelium to fresh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

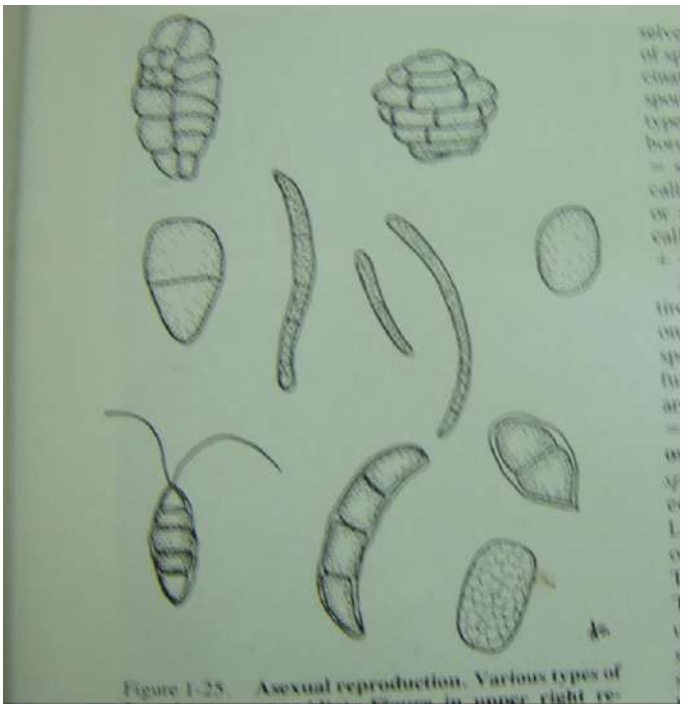
3. **Budding of somatic cell or spores**

   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.



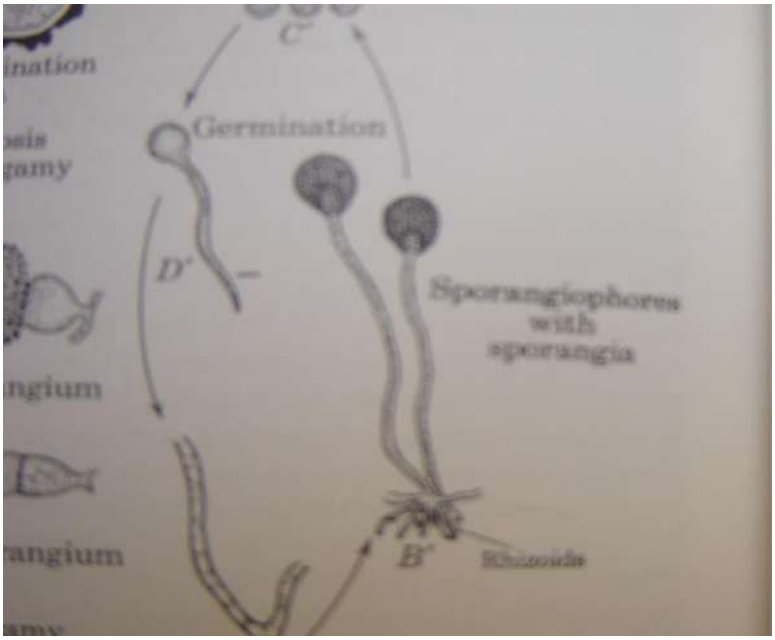
4. **Spore formation**

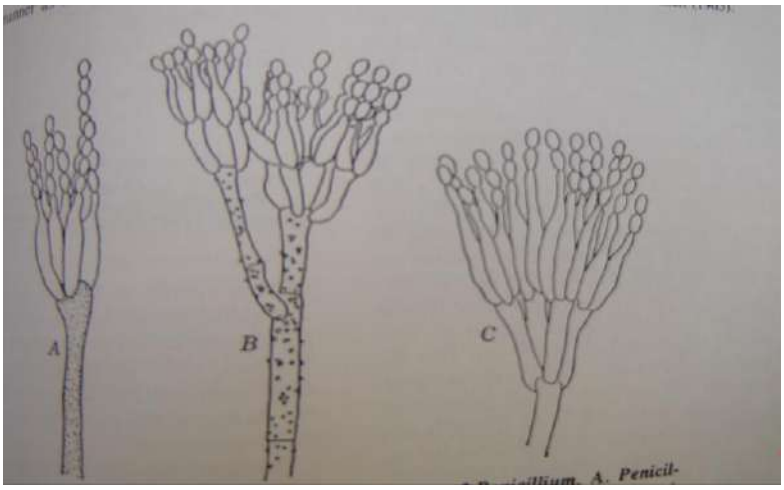
   The most common method of asexual reproduction in fungi is by means of spores. Spores vary in **color** from hyaline through green, yellow, orange, red, brown to black; in **size** from minute to large; in **shape** from globose through oval, oblong, needle-shape to helical; in **number of cells**, from one to many; in the **arrangement of cells**; and in **the way** in which the spores them-self is **borne** 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**, or are produced at the **tips or sides of hyphae** in various way and are then called **conidia** (conidium) Figure 8.





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 differ in position, types, and number Figure 9.

Sexual Reproduction

Sexual reproduction in fungi as in other living organisms involves the **union of two compatible nuclei**. The process of sexual reproduction typically consists 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) **Meiosis**: 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 later 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 it self without the aid of anther thallus, this 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**).

Lecture 3:

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 seven classes:

Class1: Chytridiomycetes: The main characteristics of this class are:

1- Swarm cells contain one posterior whiplash flagellum.

2- No mycelium (in most individuals).

Class 2: Hypochytridiomycetes:

1- Swarm cells contain one anterior whiplash flagellum.

2- No mycelium (in most individuals).

Class 3: Oomycetes:

1- Mycelium is presence but coenocytic.

2- Spore is motile with two flagella. One is whiplash and the second is tinsel.

3- Sexual reproduction is resulting in the formation of oospores.

Class4: Zygomycetes:

1- Fungi with aseptate mycelium.

2- Asexual reproduction by aplanospores.

3- Sexual reproduction – gametangial copulation - resulting in the formation of zygospores.

Class 5: Ascomycetes:

1- Fungi with septate mycelium.

2- Producing ascospores in sac-like cells –asci-, usually eight ascospores.

Class 6: Basidiomycetes:

1- Fungi with septate mycelium and forming -clamp connections-.

2- Basidium bearing usually four basidiospores.

Class 7: Deuteromycetes:

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, acellular, multinucleate somatic plasmodium. Produce flagellated swarm cells inside a fructification-sporophore- that usually develops a –peridium- enclosing the spores.

<u>What is plasmodium?</u>

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 capillitium inside sporangium Fig: 10 Ex: *Physarum*.

2- Plasmodiocarp: Is similar to a stalkless 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 is quite evident, in other they are difficult to see Ex: *Lycogala*.

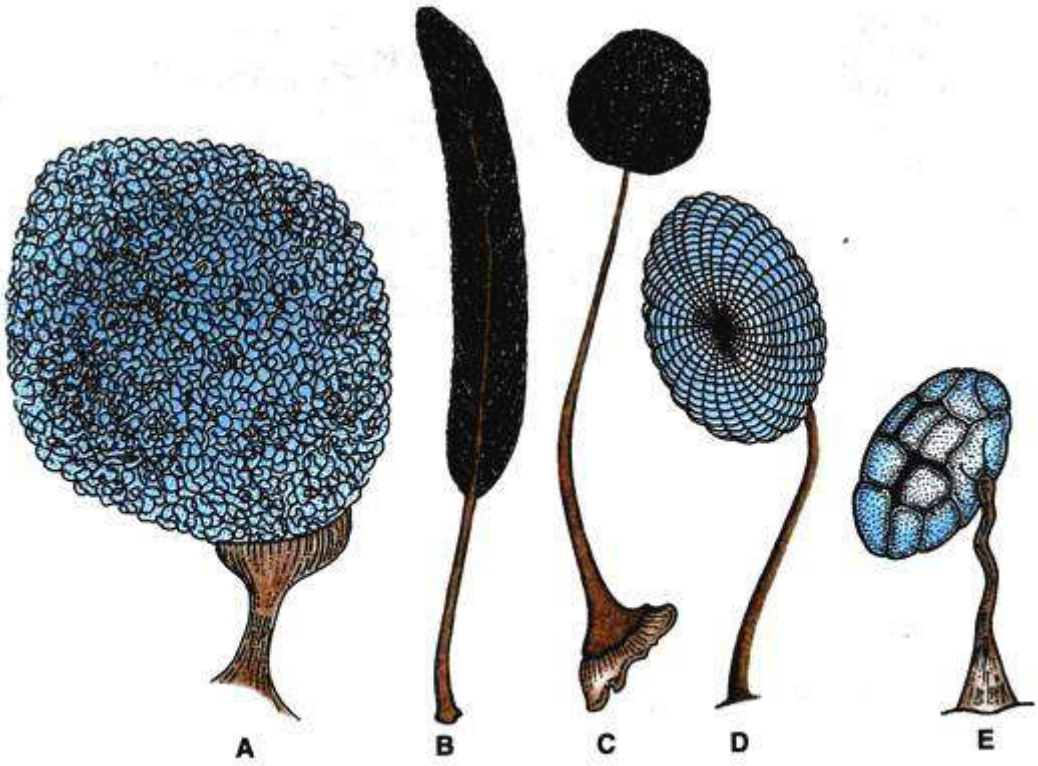


Fig.2.2. Different types of sporangia in slime molds : A, *Arcyria*; B, *Stemonitis*; C, *Comatricha*; D, *Didymium*; E, *Physarum*

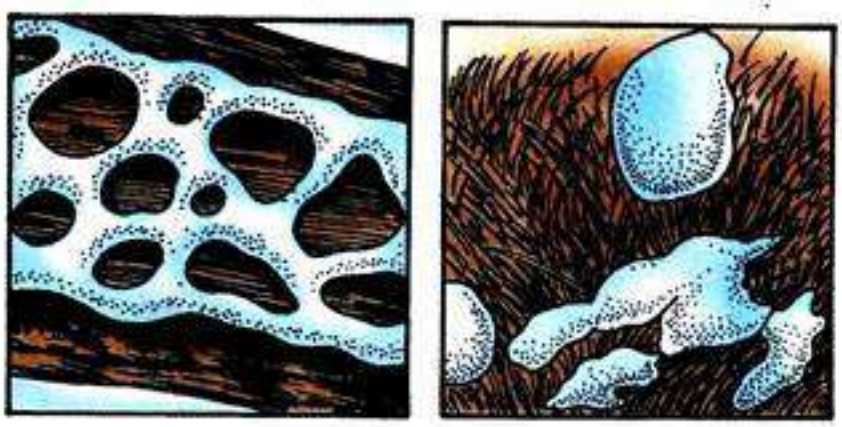


Fig. 2.3. Aethalia (A) and plasmodiocarp (B) in slime molds.

Figure 10: Types of sporophore in Myxomycetes

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 on 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 interconvertible, with the presence of water favoring the flagellate form and drier conditions inducing the amoeboid form.* Swarm cells as such do not divide, whereas 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 11.

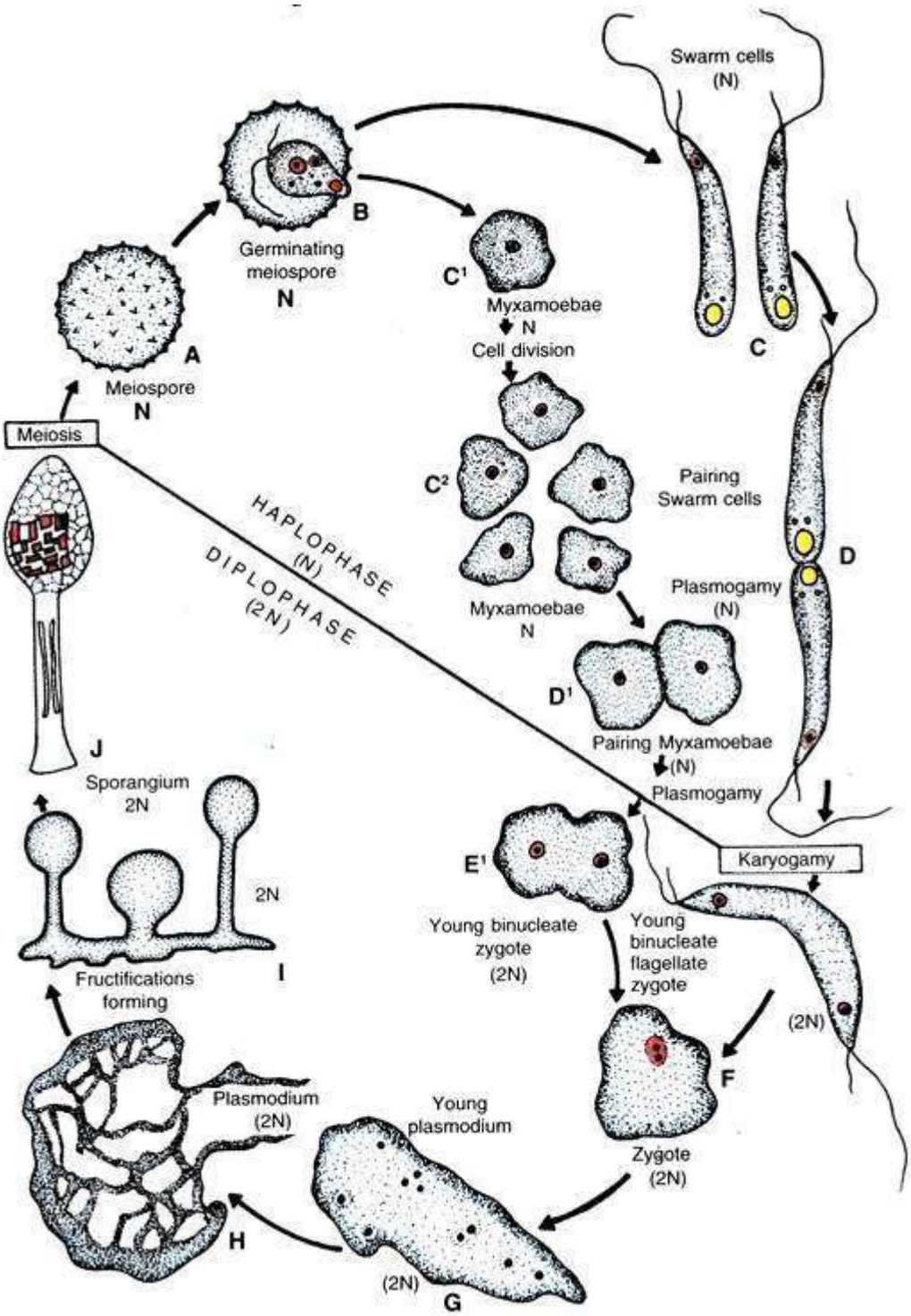


Fig. 2.13 (A-J). *Slime molds*. Pictorial life cycle of *Physarum polycephalum*.

Figure 11: Life cycle of a typical myxomycetes

Classification of Class 1: Myxomycetes:

The class myxomycetes classified into two subclasses **according to the type of spore:**

Subclass 1: Ceratiomyxomycetidae

Order: Ceratiomyxales

Genus: *Ceratiomyxa*

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

Subclass 2: Myxogastromycetidae

Spore borne internally in various sporophores –Endospores-. This subclass involves four orders according to:

1- The color of spores.

2- Presences or absence of capillitium.

3- Presence or absences of lime.

4- Presence or absences of columella

Order1: Liceales:

- Spores in mass are pallid or brightly colored.
- The capillitium and columella are lacking.
- Pseudocapillitium is often present.
- Ex:- *Lycogala*

Order 2: Trichiales

- Sporangium is large, stalked or sessile.
- Columella is lacking.
- Sporangium contains spores and capillitium.
- Ex: *Arcyria*.

Order 3: Stemonitales:

- Spores are dark or black in color.
- Columella is presence.

- Lime is absences.

- Ex: *Stemonitis.*

Order 4: Physarales

- The same characteristics of order Stemonitales except **lime is presence.** Ex: *Physarum.*

Class 2: Plasmodiophoromycetes:

General characteristics:

- The somatic phase is a plasmodium that develops within the host cells- **Endoparasite**-

- Produce two types of spores –**zoospores** and **resting spores**-.

-When the resting spores are germinated give zoospores.

Family: Plasmodiophoraceae

Ex:- *Plasmodiophora brassicae*

Causes: Club-root disease in Cruciferae Figure 12.

Figure 12: - 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 13.

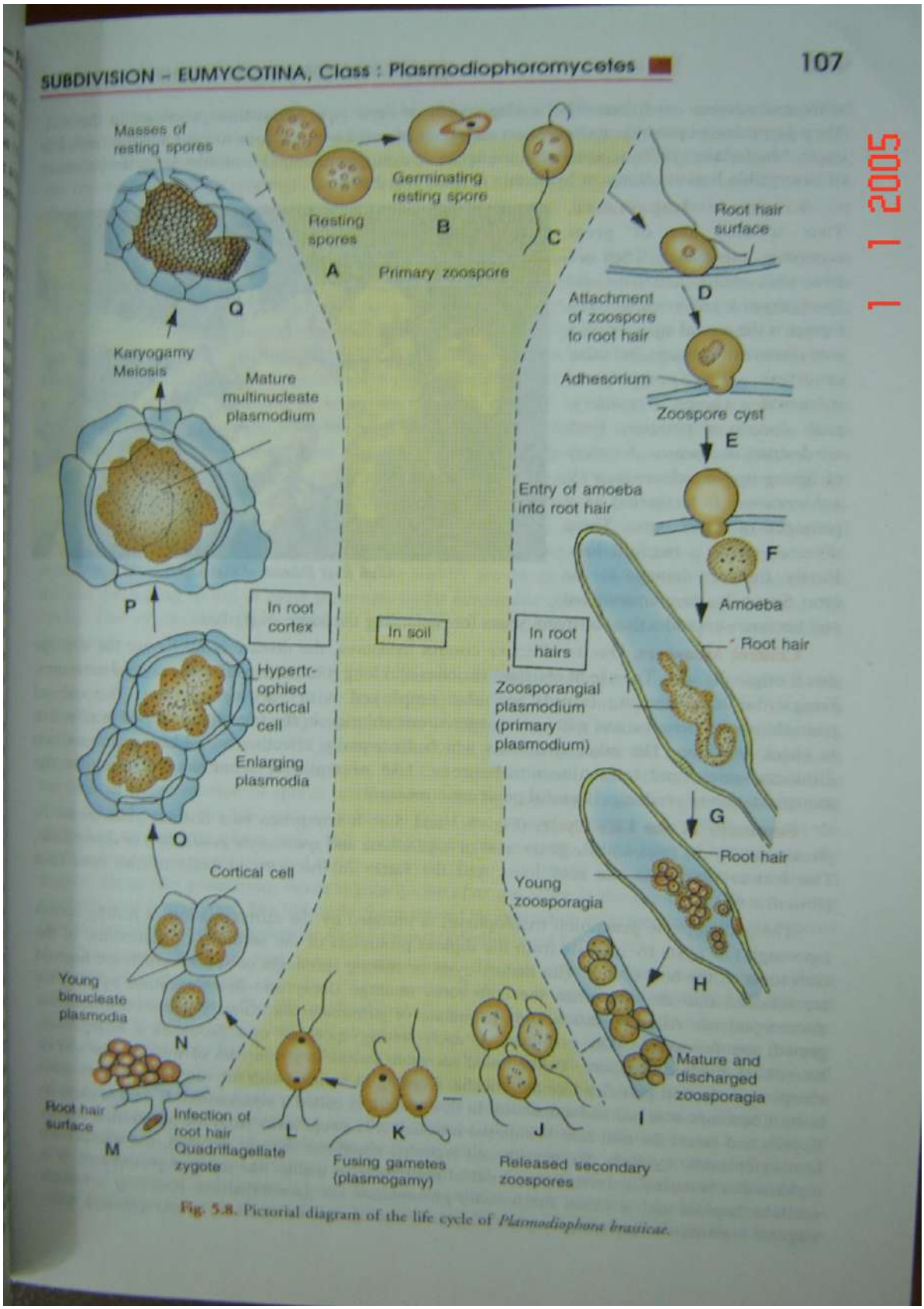


Figure 13: Life cycle of *Plasmodiophora brassicae*

Lecture 4:

Division 2: Eumycota

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 (in some individuals).

Classification of Class: Chytridiomycetes:

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-. Figure 14.

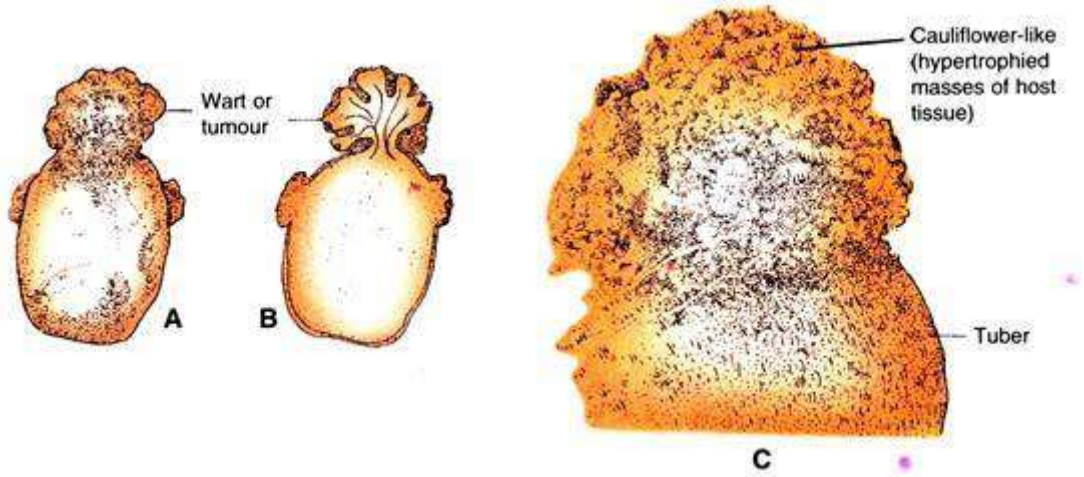


Figure 14: - Black wart of Potato

Life cycle of *Synchytrium endobioticum:*

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 it self 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 penetrate the host again. * -Asexual cycle-

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 penetrate the host cell. * The parasite will increase in size and converting to resting sporangium, then the nucleus is undergoing division to give zoospores. Figure 15.

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

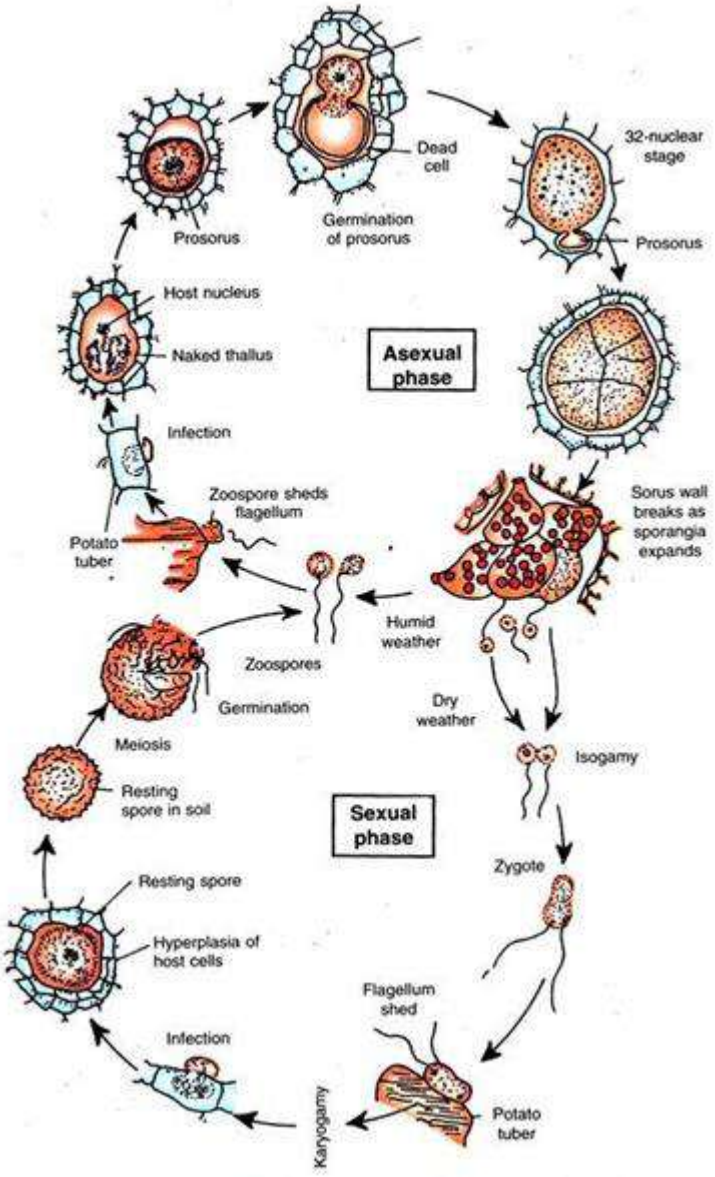


Figure 15: Life cycle of *Synchytrium endobioticum*

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

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.

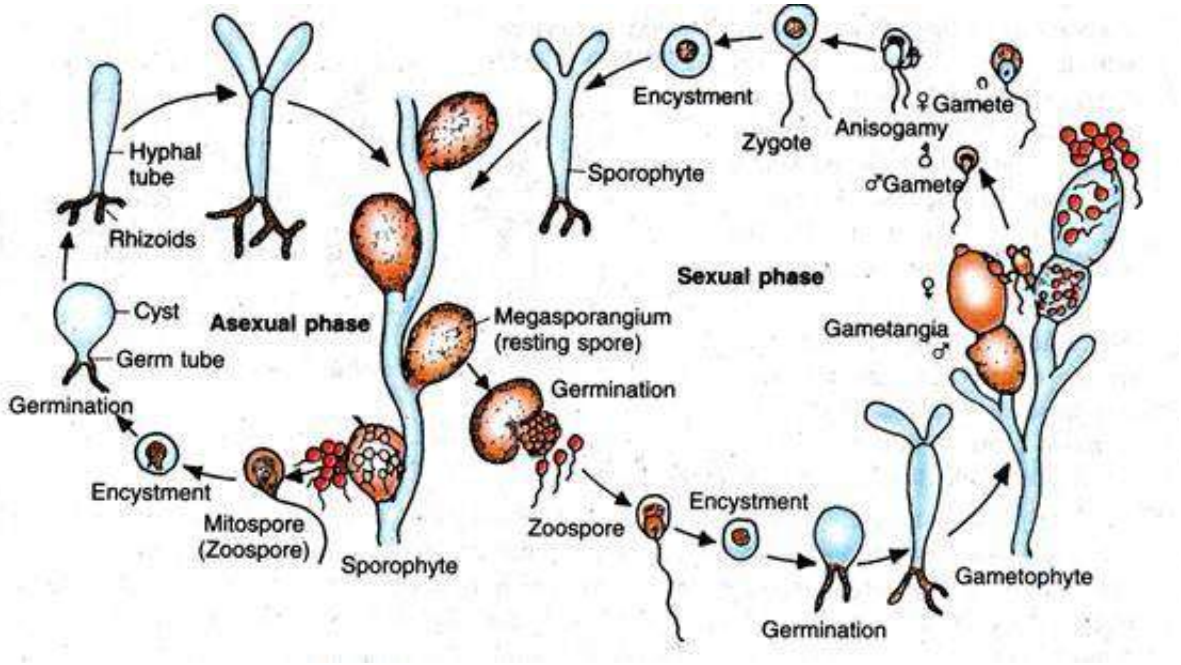


Figure 16: Life cycle of *Allomyces macrogynus*

Order 3: Monoblepharidales

Family: Monoblepharidaceae

Genus: *Monoblepharis*

<u>Life cycle of *Monoblepharis polymorpha:*</u>

The somatic thallus consists of hyphae whose protoplasm which is highly vacuolated, appears foamy. Elongated sporangia are borne singly at the hyphal tips. * They are generally no larger in diameter than the somatic hypha. * The sporangia are subtended by a septum, multinucleate from the first, the sporangial protoplast becomes divided into many uninucleate portions, each of which develops into a posterior uniflagellate zoospore. * The zoospores are released from the tip of sporangium, swim for a time, become rounded, and germinate, each by a germ tube, forming a new mycelium –Asexual cycle-. *The same thallus that produces the sporangia produces gametangia –male and female-.*The male is the narrow elongated antheridia being borne on the rounded, large

oogonia.* A number of uniflagellate gametes, called antherozoids, are formed within and released from each antheridium.*The protoplast of the oogonium becomes rounded and forms uninucleate oospore.* After the antherozoids are released from antheridia, they swim or creep over the oogonia.* A single sperm enters the oogonium through a papilla present in the oogonial wall, penetrates the oosphere to give fertilized egg.* The fertilize egg soon emerges from the oogonium, and while still attached to the oogonial wall, secretes a thick wall around it self and develops into oospore.*Karyogamy is delayed until the oospore wall is partially formed, the oospore germinate under favorable conditions by producing a hypha that develops into new thallus.* Meiosis probably takes place during the germination of the oospore, when the zygote nucleus first divides. Figure 17.

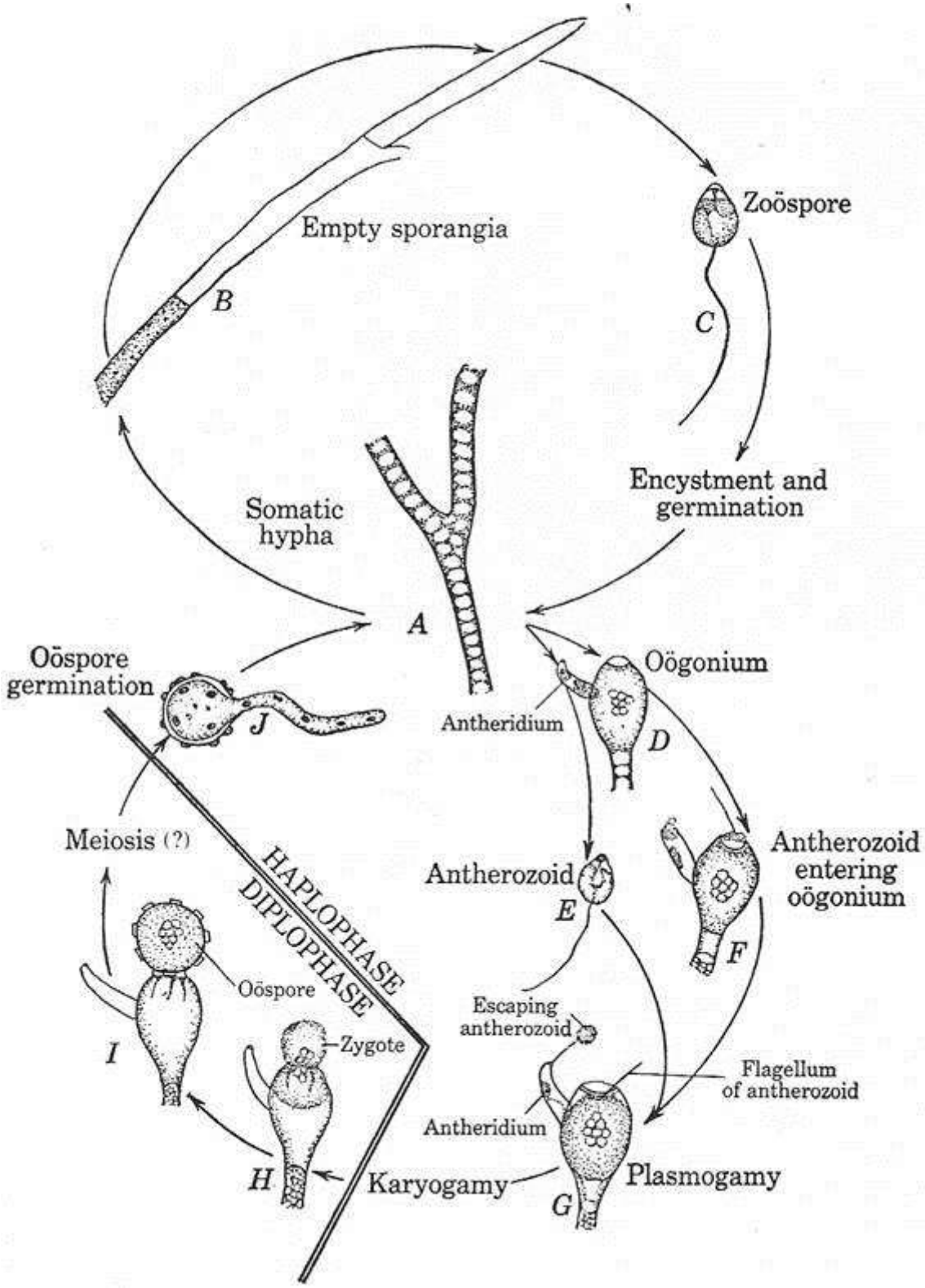


Figure 17**: - Life cycle of *Monoblepharis polymorpha***

Class 2: Hypochytridiomycetes:

-The hypochytridiomycetes, are aquatic, fresh-water or marine chytrid-like fungi whose motile cells are anterior uniflagellate, with a tinsel type flagellum.

- They are parasitic on algae and fungi or saprobic on plant and insect debris in the water in which they live.

- All are included in the single order hypochytridiales.

-Ex: *Rhizidiomyes*

Lecture 5

Class 3: Oomycetes

General characteristics:-

1- They produce biflagellate zoospores; one flagellum 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 are no chitin.

Order 1: Saprolegniales

General characteristics:-

1- Some species such as Saprolegnia parasitica causes diseases of fish and fish eggs.

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→ 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:

* 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; sporngia 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 hypha 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.

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.

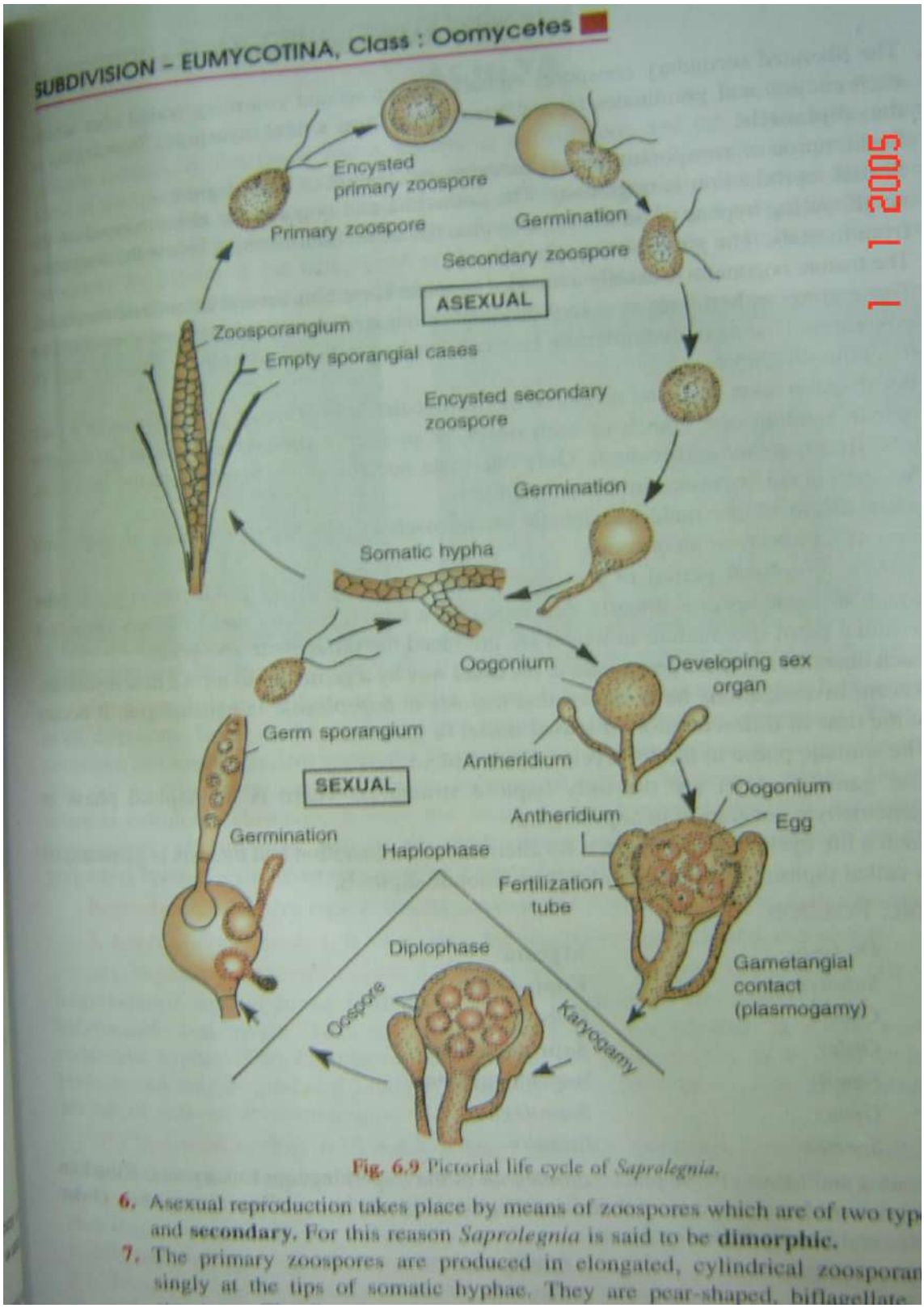


Fig. 6.9 Pictorial life cycle of *Saprolegnia*.

6. Asexual reproduction takes place by means of zoospores which are of two typ and **secondary.** For this reason *Saprolegnia* is said to be **dimorphic.**
7. The primary zoospores are produced in elongated, cylindrical zoosporan singly at the tips of somatic hyphae. They are pear-shaped, biflagellate

Figure 18: Life cycle of *Saprolegnia parasitica*

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 sporangiophores 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-

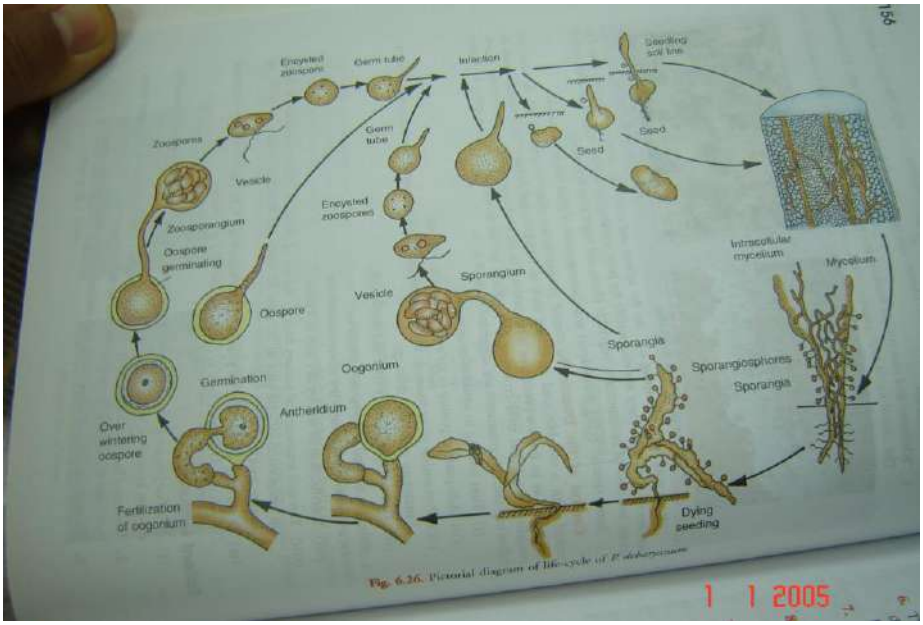


Figure 19: Life cycle of *Pythium debaryanum*

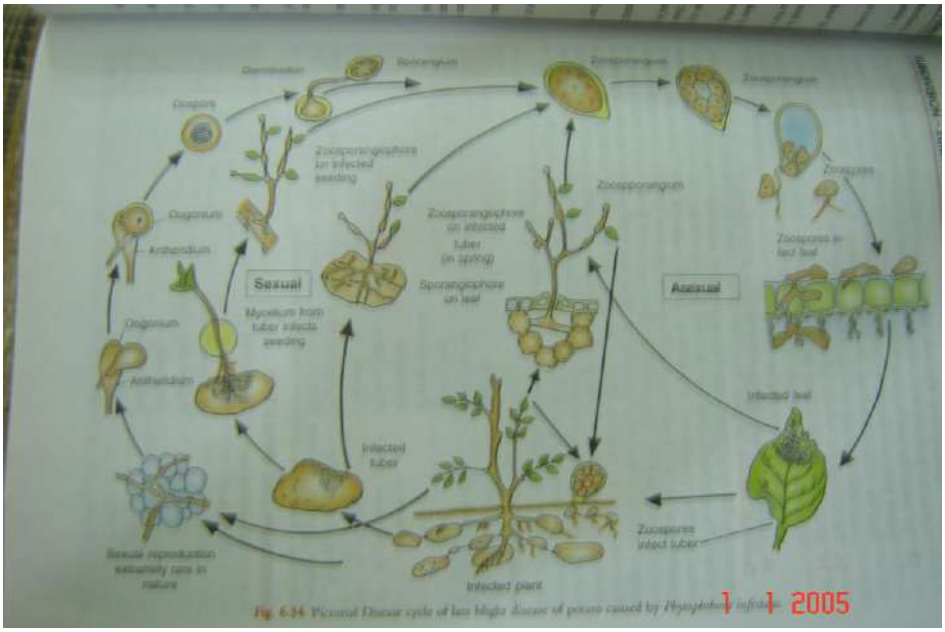


Figure 20: Life cycle of *Phytophthore infestans*

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-

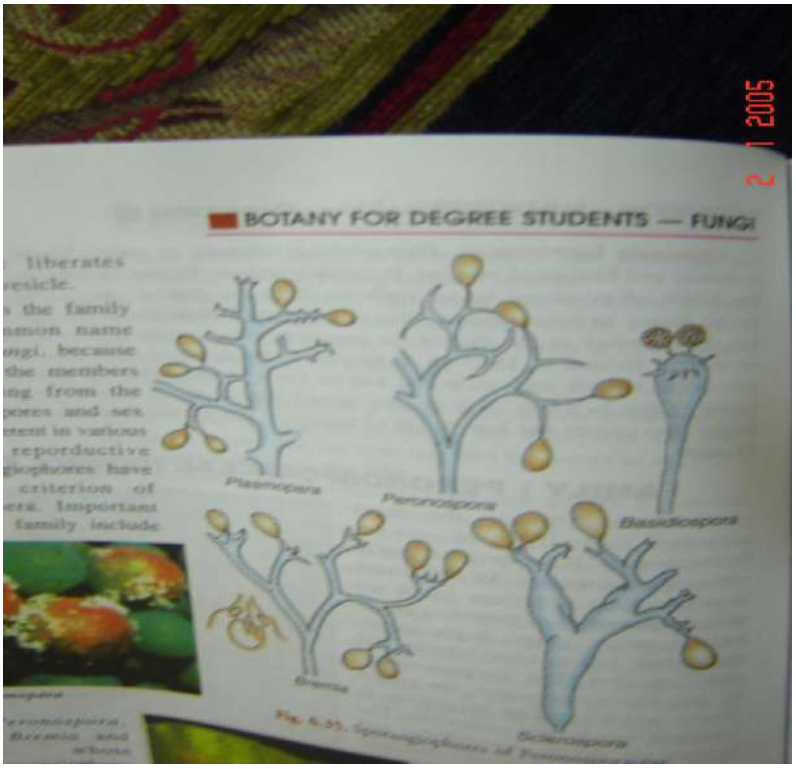


Figure 21

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.

<u>Life cycle of *Albugo candida*</u>:

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.

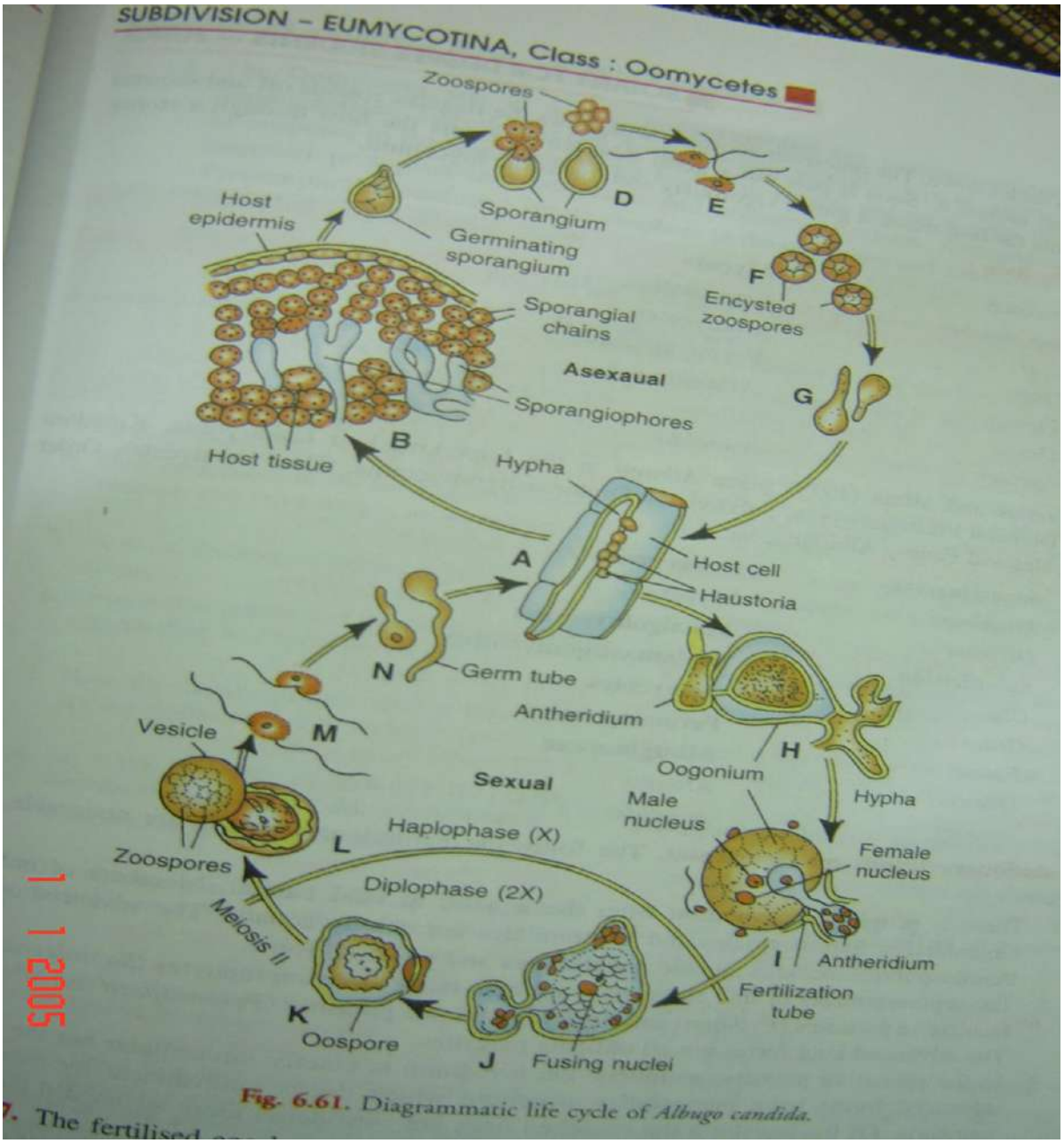


Fig. 6.61. Diagrammatic life cycle of *Albugo candida*.

Figure 22: Life cycle of *Albugo candida*.

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Lecture 6

Division 2: Eumycota

Class 4: 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.

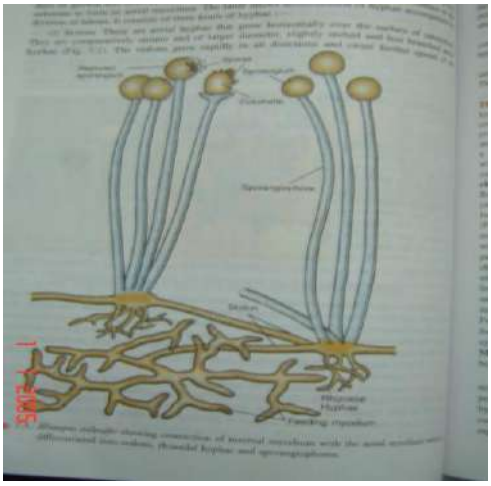


Figure 22*: Rhizopus stolonifer*

<u>Asexual Reproduction:-</u>

The Mucorales reproduce asexually by aplanospores 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 spores. Figure 23.

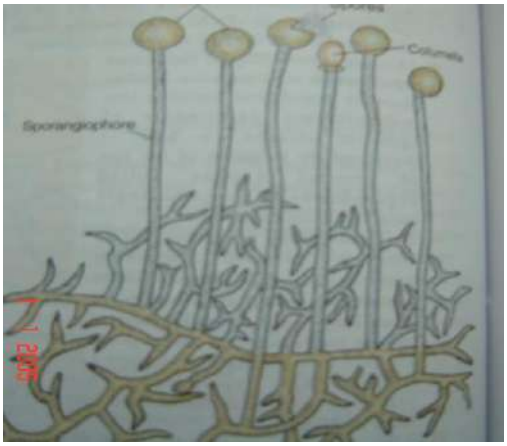


Figure 23: *Mucor* type

In this order the sporangia are developed toward decreasing in size and in the number of sporangiospores and in some cases reach to one spore -conidium-. We can distingusih two groups:-

Group 1:- Which contains globose form called **sporangiola** as in genus *Thaminidium*, the sporangiophore is branched dichotomously, first branch bearing normal sporangium and the other bearing sporangiola which contains a few numbers of spores between 6-10 and it does not contains columella also it is small in size.

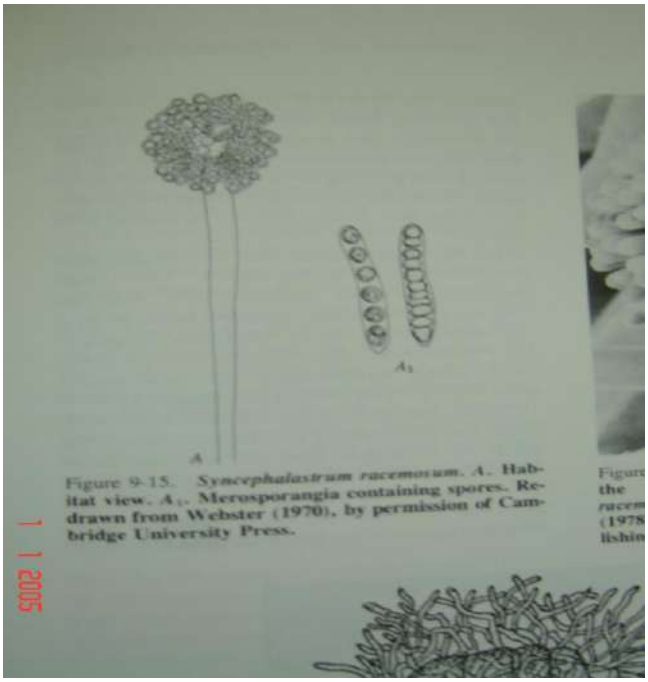
In *Choanephora trispora* there are three types of sporangia:

- Large multispored sporangium with columella.
- Smaller, few spores sporangium lacking columella.
- Sporangiola with only three spores and there is no columella.

The monosporous sporangiola of some species are extremely difficult to distinguish from true conidia such as in *Cunninghamella*.

Group 2: A number of Mucorales produce their spores in cylindrical sporangiola that we call merosporangia .

Merosporangie may be borne on the surface of an inflated sporangiophore tip and radiate out or they may be formed on sporocladia such as in *Syncephalastrum*. While in kickxellaceae the merosporangia contain only one spore bearing on pseudophialides as in *Kickxella*. Figure 24.



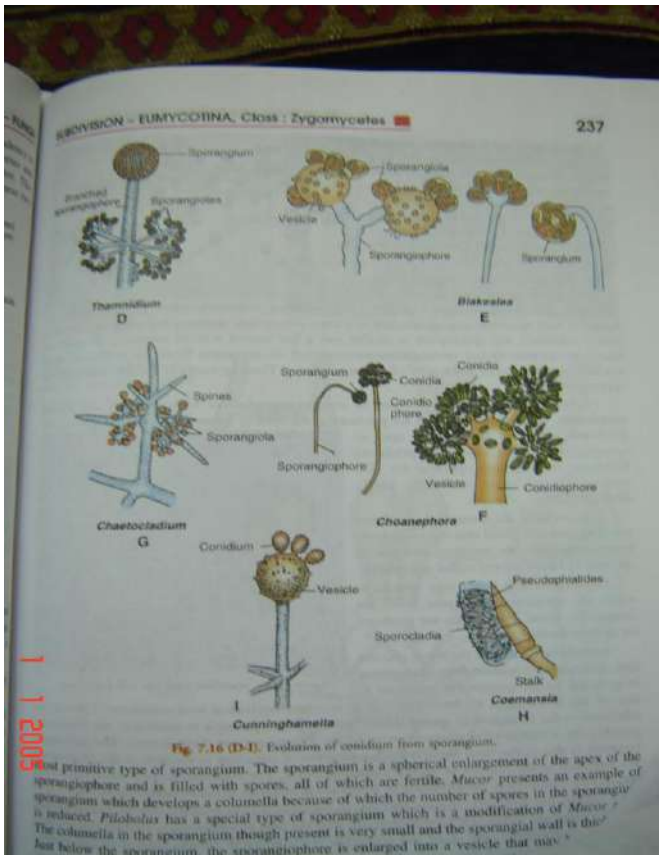


Figure 24: Types of sporangia in order Mucorales

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.

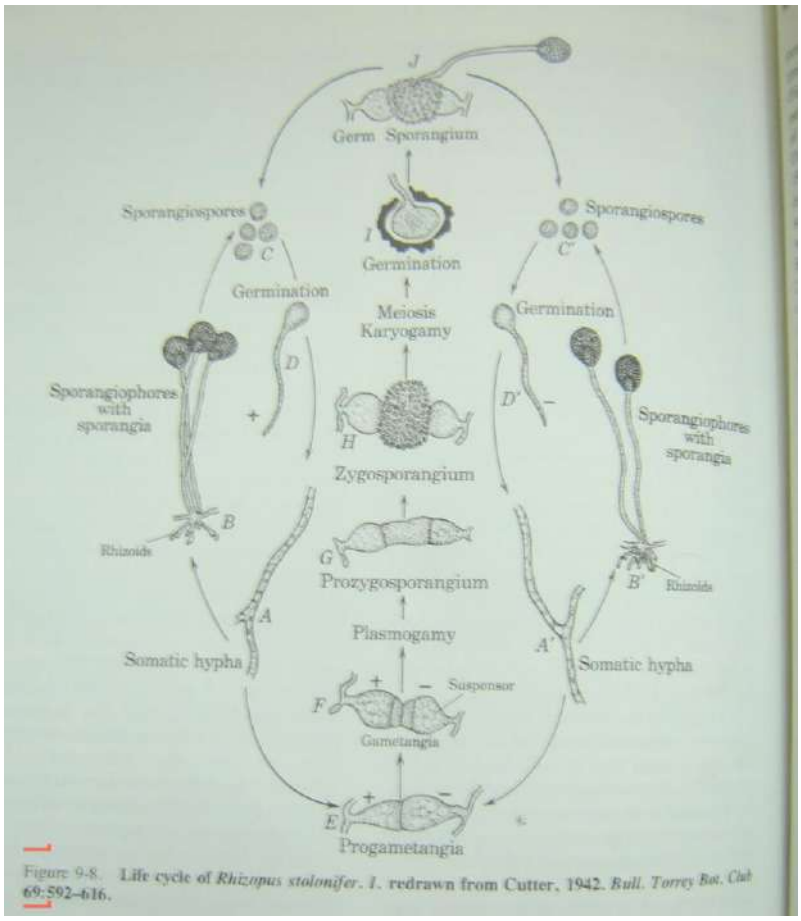


Figure 25: Life cycle of *Rhizopus stolonifer*

Order 2: Entomophthorales: -

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 -conidia- 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 unbranched 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.

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Lecture 7

Division 2: Eumycota

Class 5: Ascomycetes

General characteristics

1- The one character distinguishing the ascomycetes 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- Ascomycetes have 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 ascomycetes.

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. Sometimes 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 paraphyses – sin: paraphysis-.

8- With few exceptions, ascomycetes produce their asci in fruiting bodies called ascocarps. In general there are five major categories of ascomycetes, 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.

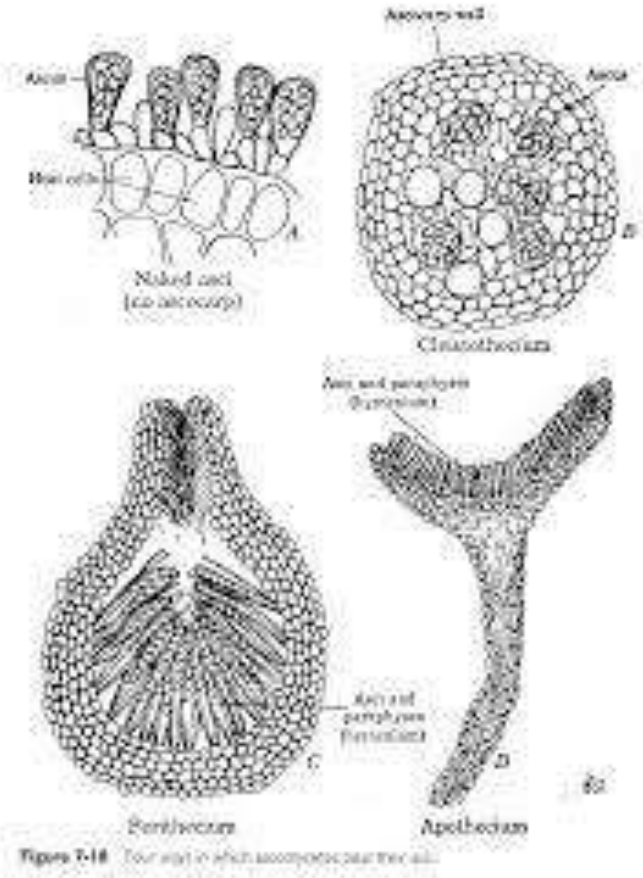


Figure 26: Four ways in which Ascomycetes bear their asci.

Classification of Ascomycetes

According to the type of ascocarps, Ascomycetes can be classified into three subclasses:-

Subclass 1: Hemiascomycetidae

Asci arising naked, no ascogenous hyphae or ascocarp produced.

Subclass 2: Euascomycetidae

Asci produced within ascocarp – Cleistothecium, Apothecium, or Perithecium.

Subclass3: Loculoascomycetidae: Asci form within Ascostroma.

Subclass 1: Hemiascomycetidae

This subclass involves fungi do not form ascocarp, so there is no ascogonium and antheridium.This subclass 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 ***Schizosaccaharomyces 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 27.

Family 2: Saccharomycetaceae

Ex; ***Saccaharomyces 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 27.

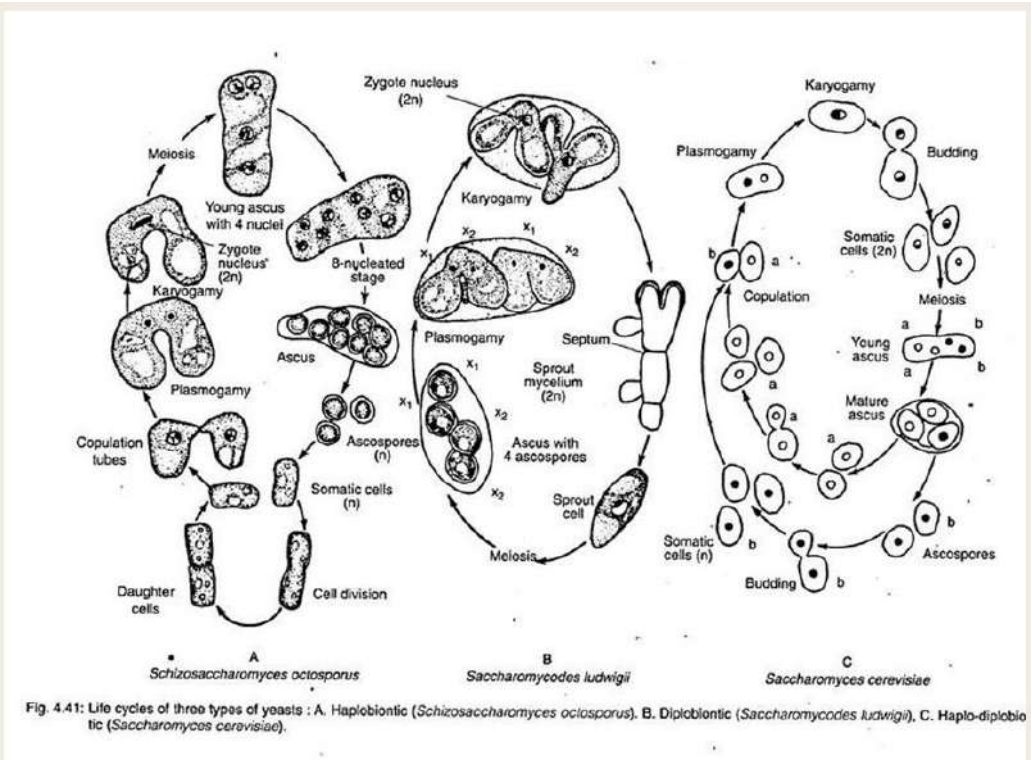


Fig. 4.41: Life cycles of three types of yeasts : A. Haplobiontic (*Schizosaccharomyces octosporus*). B. Diplobiontic (*Saccharomycodes ludwigii*). C. Haplo-diplobiontic (*Saccharomyces cerevisiae*).

Figure 27: Life cycle of ***Schizosaccaharomyces octosporu*** and ***Saccaharomyces 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.

Life cycle of *Taphrina deformans*:-

The ascospores, soon after they are formed, produce small, round or ovoid blastospores by budding. * The blastospores, like the ascospores, are uninucleate, and haploid.* 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.* At the time of germination, the conidial nucleus divides, and resulting pair of nuclei migrate into germ tube (C).* 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-.(D)* Karyogamy occrs within each ascogenous cell, and about this time the cell begins to elongate.(E)*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.(F)* A septum then develops between these two nuclei, separating the cells into a basal stalk cell and an upper ascus mother cell.(G)* 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. Figure 28.

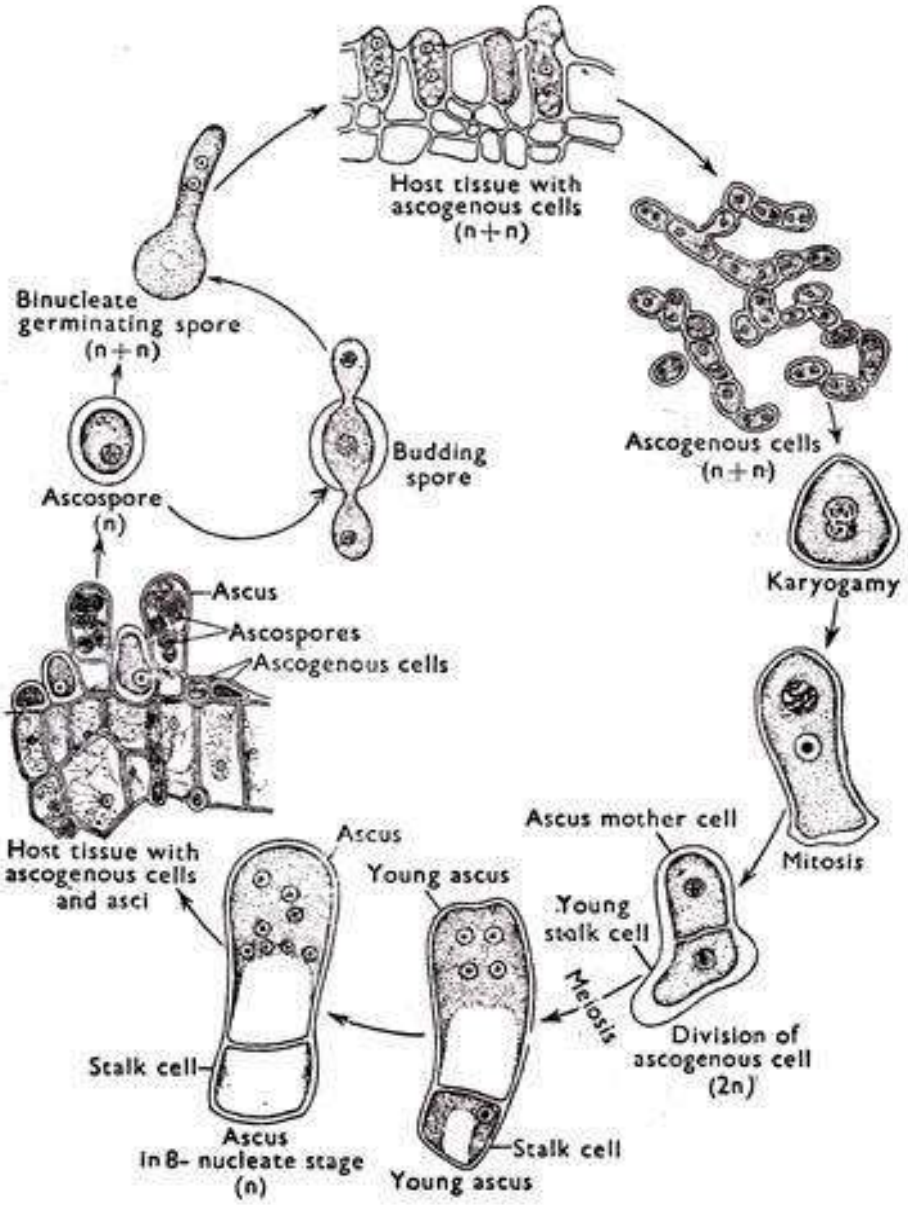


Fig. 223. Life cycle of *Taphrina deformans*.

Figure 28: Life cycle of *Taphrina deformans*

Lecture 8

Subclass 2: Euascomycetidae

General characteristics: -

1- Asci are unitunicate.

2- Producing the cleistothecium, perithecium and apothecium ascocarps.

3- Euascomycetidae have a large number of fungi, so it was divided into three series according to the type of ascocarp.

Series 1: Plectomycetes: producing cleistothecium ascocarp.

Series 2: Pyrenomycetes: Producing perithecium ascocarp.

Series 3: Discomycetes: producing apothecium ascocarp.

Series 1: Plectomycetes:

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 and great many varieties. 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.

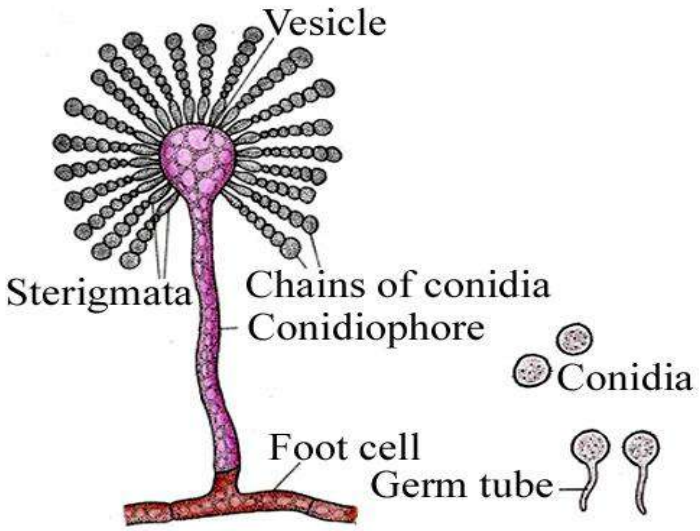


Figure 29: Somatic structure of *Aspergillus*

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.

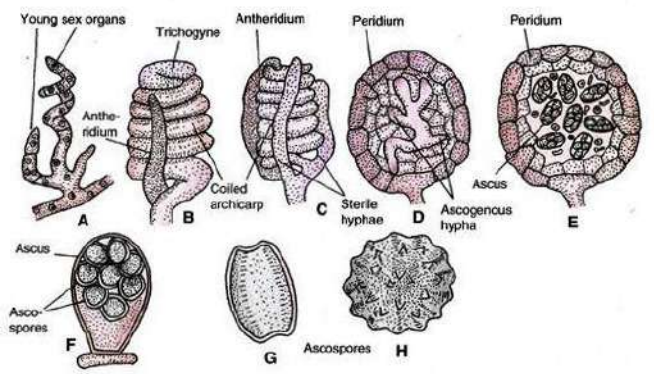


Fig. 10.5 (A–H). *Aspergillus sp.* Sexual Reproduction. A, Young sex organs; B. Coiled archicarp and an antheridium; C, archicarp enclosed by sterile hyphae, arising from its base; D, section of young cleistothecium showing ascogonium with ascogenous hyphae surrounded by peridium; E, section of mature cleistothecium showing asci surrounded by peridium; F, a single ascus containing 8 ascospores; G, ascospore from side view; H, ascospore (surface view).

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 *Rhizopus*.

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 Roquefort 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 phialides that bear the long conidial chain Figure 31.

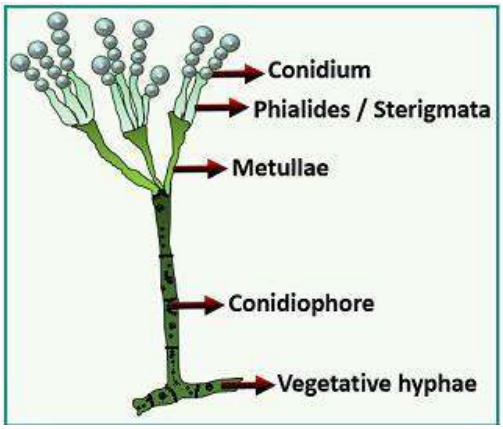


Figure 31: Asexual stage of *Penicillium* (conidial stage)

Series 2: Pyrenomycetes

The ascocarp is perithecium, there is only one order which has cleistothecium. Pyrenomyceres divided into five orders: -

Order 1: Erysiphales: - The ascocarp is cleistothecium, but the asci are arranged as hymenial layer.

Order 2: Chaetomyales: The ascocarp is perithecium, surrounding by hairs.

Order 3: Claviceptales: The ascocarp is perithecium type, and the ascospores are filamentous form.

Order 4: Shpaeriales: Perithecium is dark-black in color.

Order 5: Hypocreales: Perithecium is colored.

Order 1: 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 depends on the number of asci inside the ascocarp and the type of appendages as follows:

Genus 1: *Erysiphe*:

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

Genus 2: *Sphaerotheca*:

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

Genus 3: *Uncinulla:*

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

Genus 4: *Microsphaera*:

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

Genus 5*: Podosphaera*:

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

Genus 6*: Phyllactinia*

- Many asci.
- Bulbous appendages base.
- Cause P.M. on Morus.

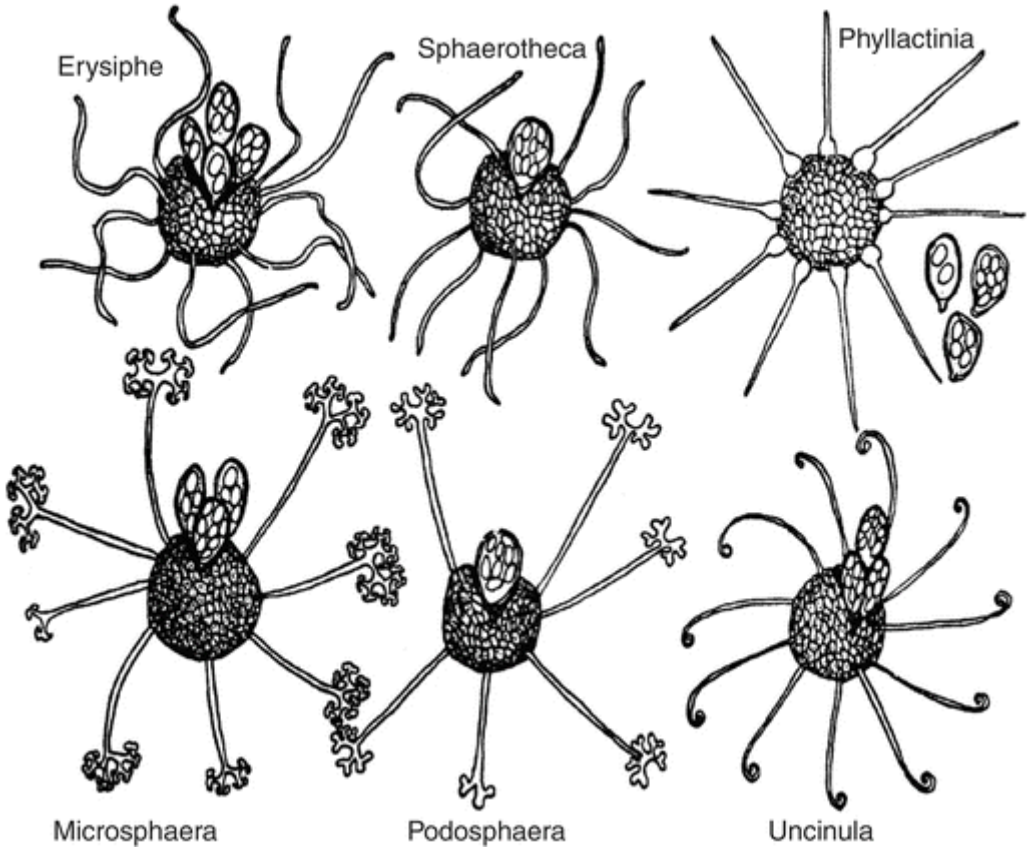


Figure 32: Types of appendages of Erysiphaceae

Order 3: Claviceptales

The Claviceptales produce their perithecia with a well- developed, stroma composed entirely of fungal tissue.

Family: Claviceptaceae

Example*; Claviceps purpurea*

<u>The Life cycle: -</u> *Claviceps purpurea*, the cause of ergot of Rye, will be used as an example of family Claviceptaceae. 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, send 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. During the harvesting operations, many sclerotia are knocked off the spikelet, 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 this 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.

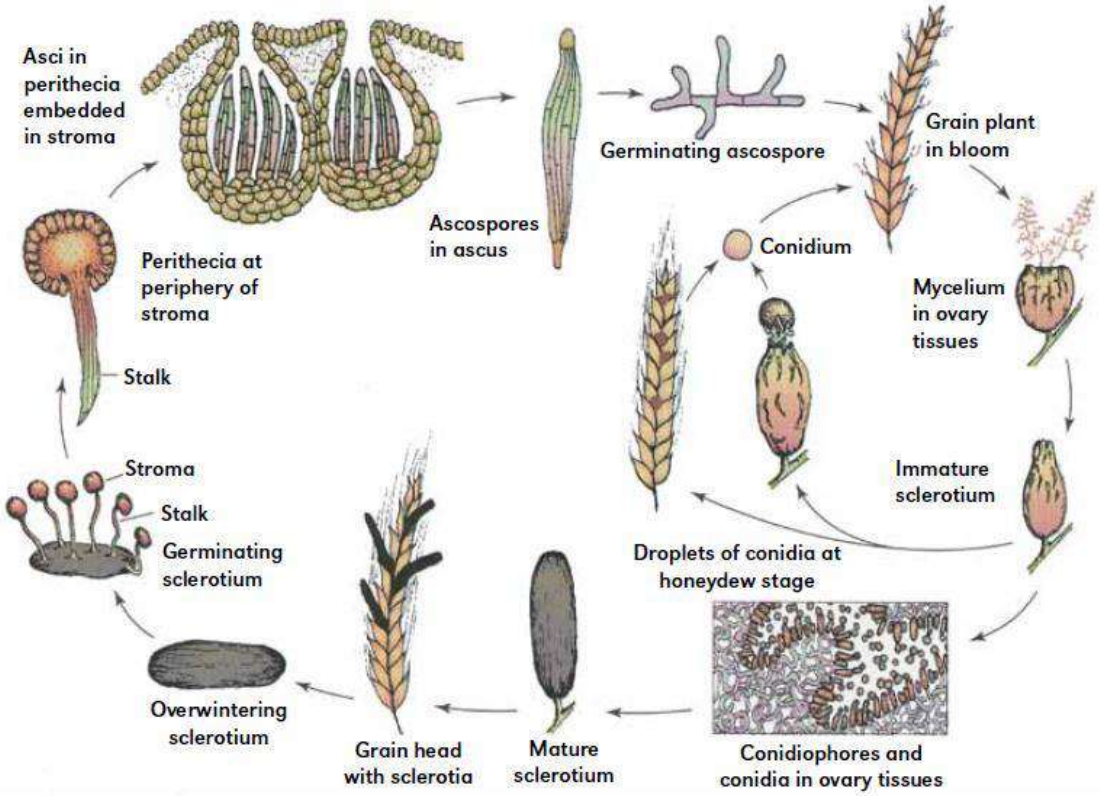


Figure 33: Life cycle of *Claviceps purpurea*

Lecture 9

Series 3: Discomycetes

General characteristics

1- Produce their asci in apothecia; we define apothecium as an open ascocarp.

2- Discomycetes contain fungi included, Morels, Truffle 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: Hypogean: which presence under the surface of soil.

Group 2: Epigean: which presence on the surface of soil, and they involved operculate and inoperculate.

Epigean inoperculate discomycetes

Most of them are parasites and causes plant diseases.

Order: 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*

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 produce a germ tube, invades the host, and thus spreads the disease (D). (Asexual cycle).

Note: - young peach fruits are resistant to the invasion of fungus, but as they approach maturity their resistance decreases 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 and 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).

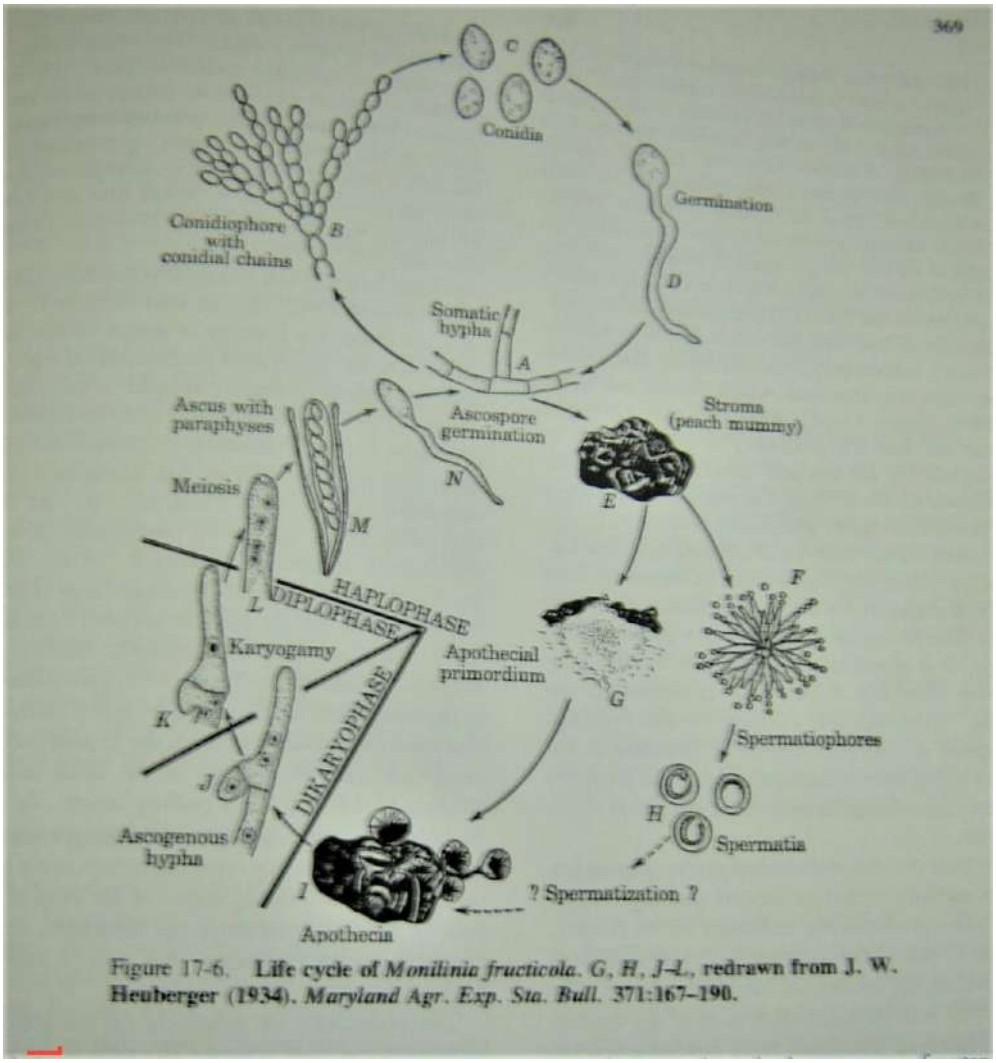


Figure 17-6. Life cycle of *Monilinia fructicola*. G, H, J–L, redrawn from J. W. Heuberger (1934). *Maryland Agr. Exp. Sta. Bull.* 371:167–190.

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.

These fungi 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.

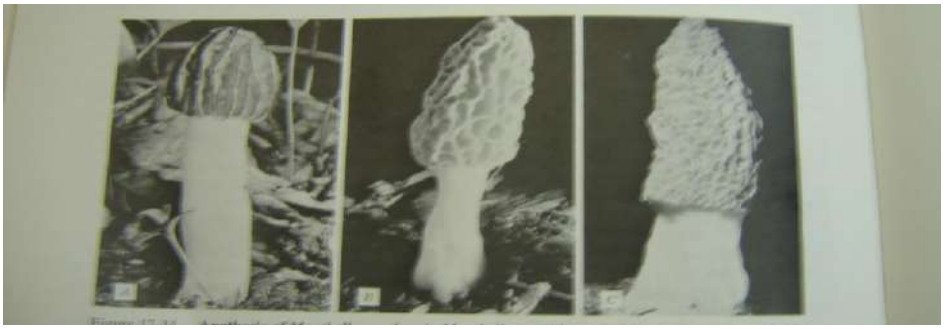


Figure 35: *Morchella spp.*

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: Tuberales

Fungi in this order are mycorrhizal fungi living in association with the roots of Oak and beech-trees. There are two families, **Tuberaceae** and **Terfeziaceae**, and two genera; ***Trimania*** and ***Terfezia***.

The ascocarp surrounding by a thick-wall cells called peridium. There is a vein which contain the hymenial layer (ascospores) Figure (36), in Genus*; Terfezia* the acospores are globose and eight in number, and the wall is smooth, while in *Trimania*, the wall is spiny and there are only four ascospores Figure (37).

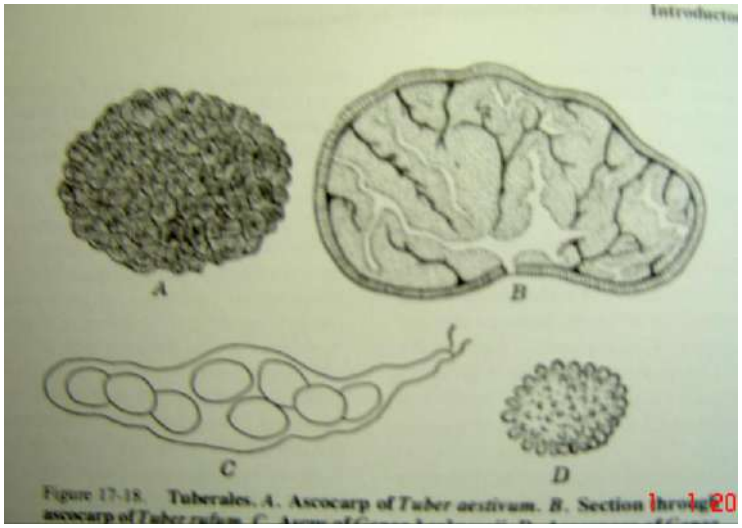


Figure 36: - Ascocarp of Tuberales

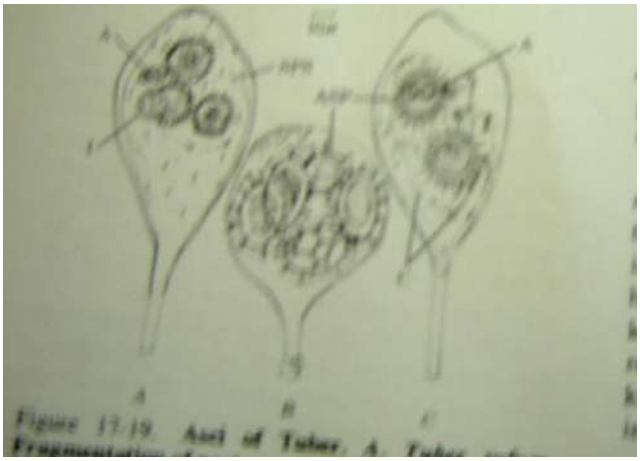


Figure 37

Subclass 2: Loculoascomycetidae

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 conidiophores (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).

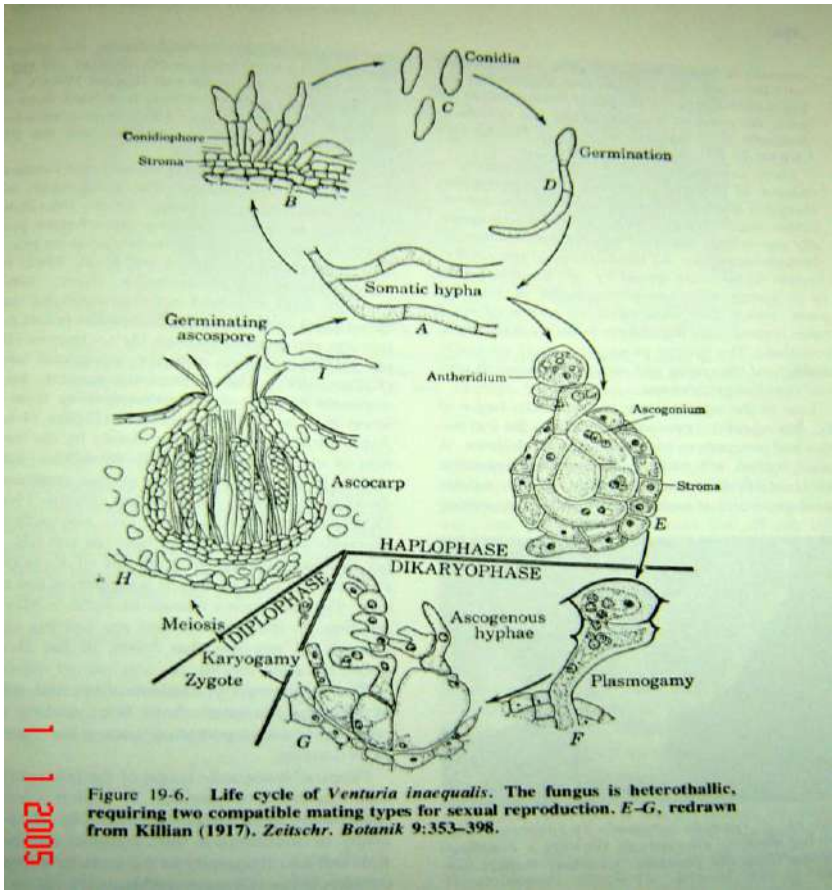


Figure: - Life cycle of *Venturia inaequalis*

Lecture 10

Division 2: Eumycota

Class 6: Basidiomycetes

General characteristics

1- Basidiomycetes consist of form people call mushroom. Some basidiomycetes are saprobes, 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 basidiomycetes passes through three distinct stages before the fungus completes its life cycle:

   A. **The primary mycelium (1n)**: - Usually develops from the germination of a basidiospore. It is septate and uninucleate from the beginning.

   B. **Secondary mycelium**: Usually involves an interaction between two compatible mycelia (n+n) (Dikaryon).

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

Basidiomycetes characterized by presence of clamp connections, that are formed during nuclear division when the binucleate cell is ready to dived, 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.

C. **Tertiary mycelium**: is represented by organized specialized tissues that compose the basidiocarps of the more complex basidiomycetes.

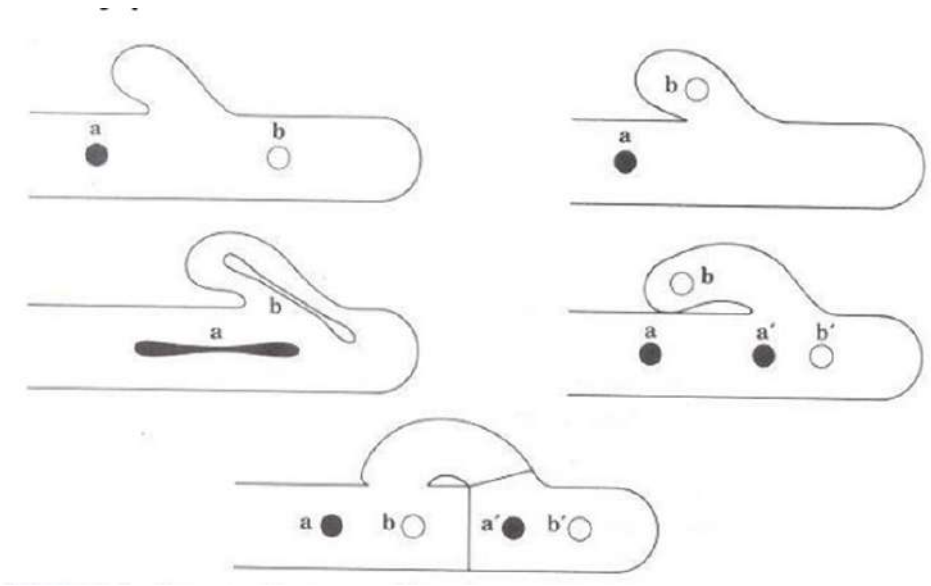


Figure 39: Diagram shows the formation of clamp connection in Basidiomycetes.

Asexual reproduction:

It does not important in this class, and it occurs either by budding or fragmentation.

The basidiocarps: - The more complex basidiomycetes produce their basidia in highly organized fruiting bodies of various types. In a basidiocarp the hymenium is a layer composed of basidia as well as any other sterile elements such as cystidium Figure 40.

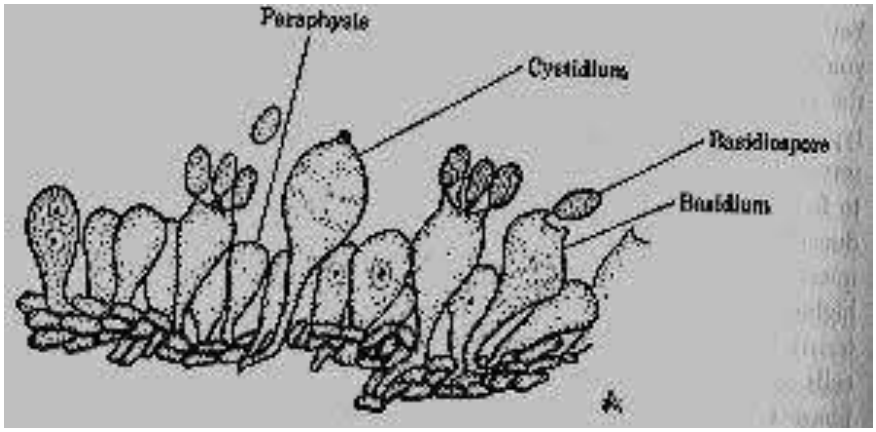


Figure 40: Hymenium of basidiomycetes

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 41 A.

2- **Phragmobasidium**: Divided into four cells by transverse or longitudinal primary septa Figure 41D&E.

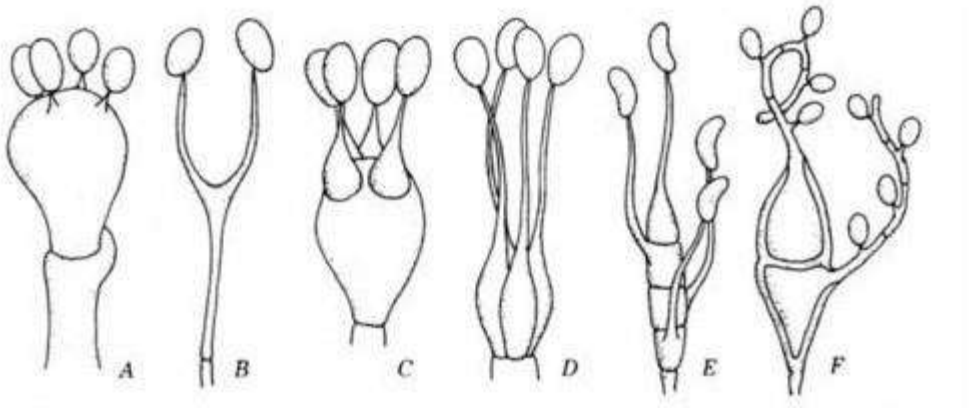


Figure 41: Types of basidium A- Holobasidium D&E-Phragmobasidium

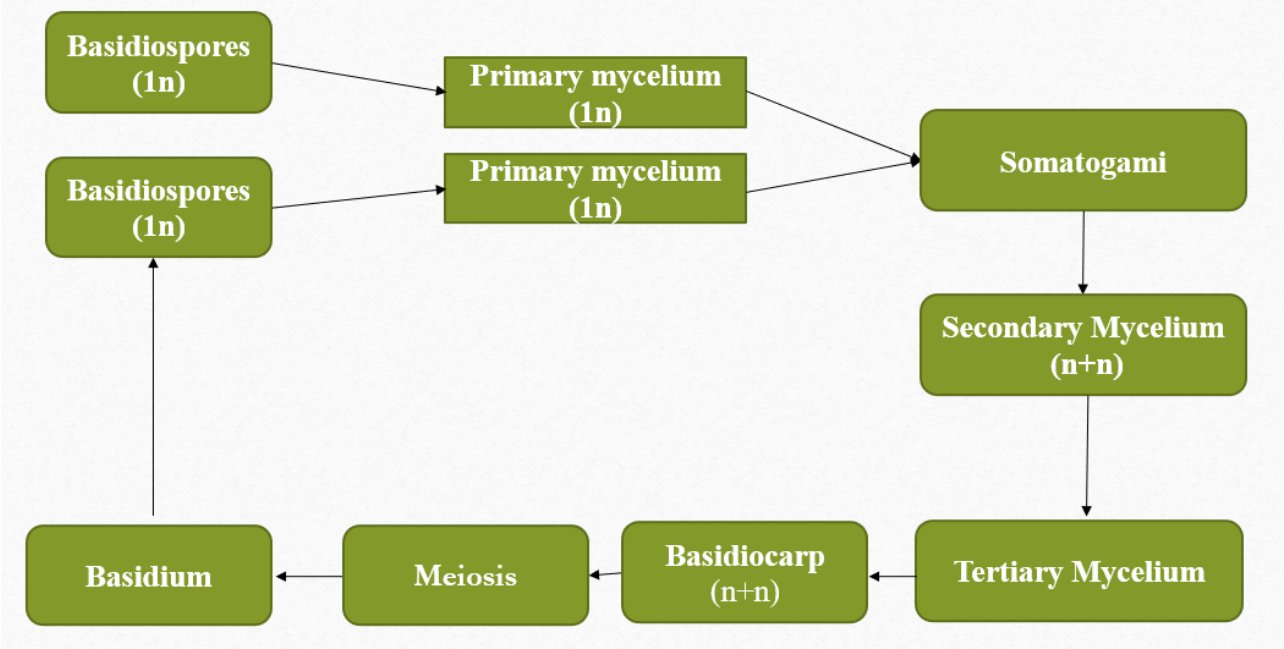


Diagram shows the life cycle of Basidiomycetes

Classification of Class Basidiomycetes

Subclass 1: Heterobasidiomycetidae

General characteristics:

1- There is no basidiocarp.

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

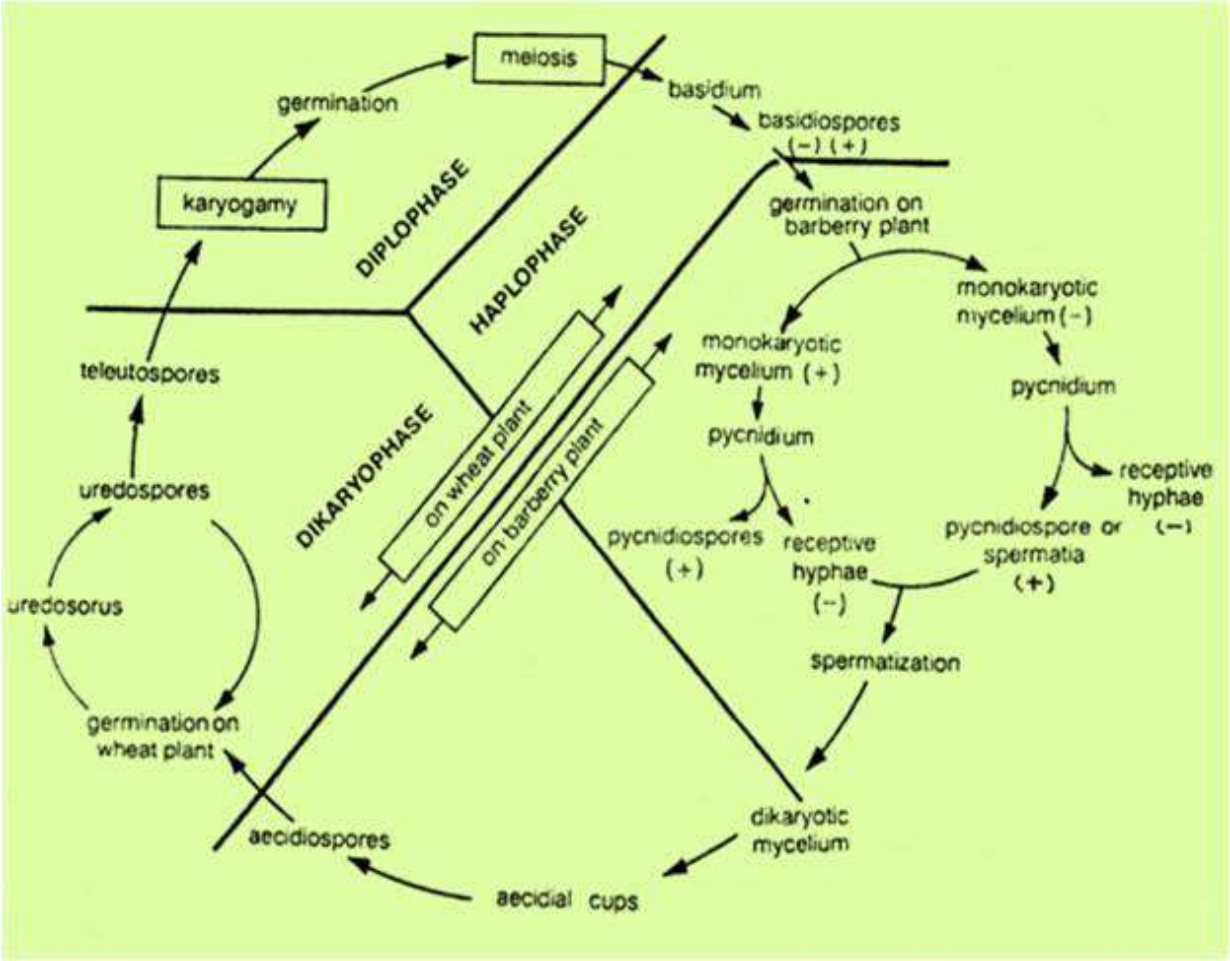
fungi which have five types of spore stages called macrocyclic rust which needed either one host

(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 *Melanospora lini* which causes flax rust. Macrocyclic heteroecious rust is *Puccinia graminis* which causes black rust on Gramineae.

Life cycle of *Puccinia graminis*

The two-celled teliospores (p) that produce in midsummer on the leaves and stems of wheat remain dormant until the following spring, passing the winter on the stubble in the fields. Over wintering takes place in the uninucleate, diploid stage after karyogamy has occurred. Early in the spring, each cell of the teliospore germinates and produces a promycelium (R) into which the diploid nucleus migrates, undergoes meiosis, and form four haploid nuclei. Septa are then laid down separating the nuclei from one another into four cells. Each cell of the promycelium produces a sterigma on which a minute basidiospore is formed. Two of the basidiospores are of one strain and two are of other (A). The basidiospores are carried away by the wind and then germinated producing germ tubes on barberry (B), with their germ tubes penetrating into the tissues of barberry through haustoria. Thus, a well-developed, branched, monokaryotic mycelium develops; its nuclei carry the factor (A1 or A2) that the parent basidiospore happens to carry (C). A few days after infection, the hyphae of the fungus nearest the upper epidermis of the host develop. Spermogonia -in the manner already described- that open to the surface of the leaf (D). Each spermogonium contains numerous spermatiophores that cut off a succession of minute spermatia (F). Several periphyses are also formed in the upper part of the spermogonium. Each spermatium contains a large nucleus carrying the A1 or A2 factor, depending on the strain of mycelium that

produced the spermogonium. The same mycelium that produces the spermatia also gives rise to receptive hyphae with the same genetic makeup as the spermatia. These arise in the spermogonia and protrude through the ostioles (E). If (A1) spermatia thus happen to be transferred to (A2) receptive hypha or (A2) spermatia to (A1) receptive hyphae, spermatization is affected and the spermatial contents pass into the receptive hyphae by a pore dissolved in the walls at the point of contact (G). Meanwhile the mycelium has penetrated the entire leaf, and the hyphae near the lower epidermis have formed a number of aecial primordia (H). The aeciospores that first binucleate spores produced in life history of the fungus. The aeciospore chains eventually break through the lower epidermis of barberry, permitting the spores to escape (I). The aeciospores are now disseminated by the wind and germinate (J). If germination occurs on a susceptible grass host, infection results and binucleate mycelium develops (K). Soon after infection, the binucleate mycelium in the grass host begins to form masses of cells – the uridinia- from which binucleate urediniospores are arise on rather long stalks. The urediniospores are oval, yellowish and spiny. The pressure from the developing spores causes a break in the host epidermis and an elongated streak-like rust-red pustule develops (L). The urediniospores upon germination produce binucleate mycelium (N) that grows between the cells of the grass plant and in a few days produces new uredinia and a new crop of urediniospores. This repeating cycle of *Puccinia graminis* recurs several times in the spring and summer. About the time the grain is ripening, the uredinia begin producing a few teliospores and a fewer uridiniospores are produced until finally only teliospores are formed (O). The pustules that produce teliospores are known as telia and constitute the black stage of the rust. The uredinia thus gradually change into telia Figure 42.


meiosis
germination
basidium
basidiospores
(−) (+)
karyogamy
DIPLOPHASE
HAPLOPHASE
germination on
barberry plant
monokaryotic
mycelium (−)
monokaryotic
mycelium (+)
teleutospores
pycnidium
pycnidium
DIKARYOPHASE
on wheat plant
on barberry plant
receptive
hyphae
(−)
uredospores
pycnidiospores
(+)
receptive
hyphae
(−)
pycnidiospore or
spermatia
(+)
uredosorus
spermatization
germination on
wheat plant
dikaryotic
mycelium
aecidiospores
aecidial cups

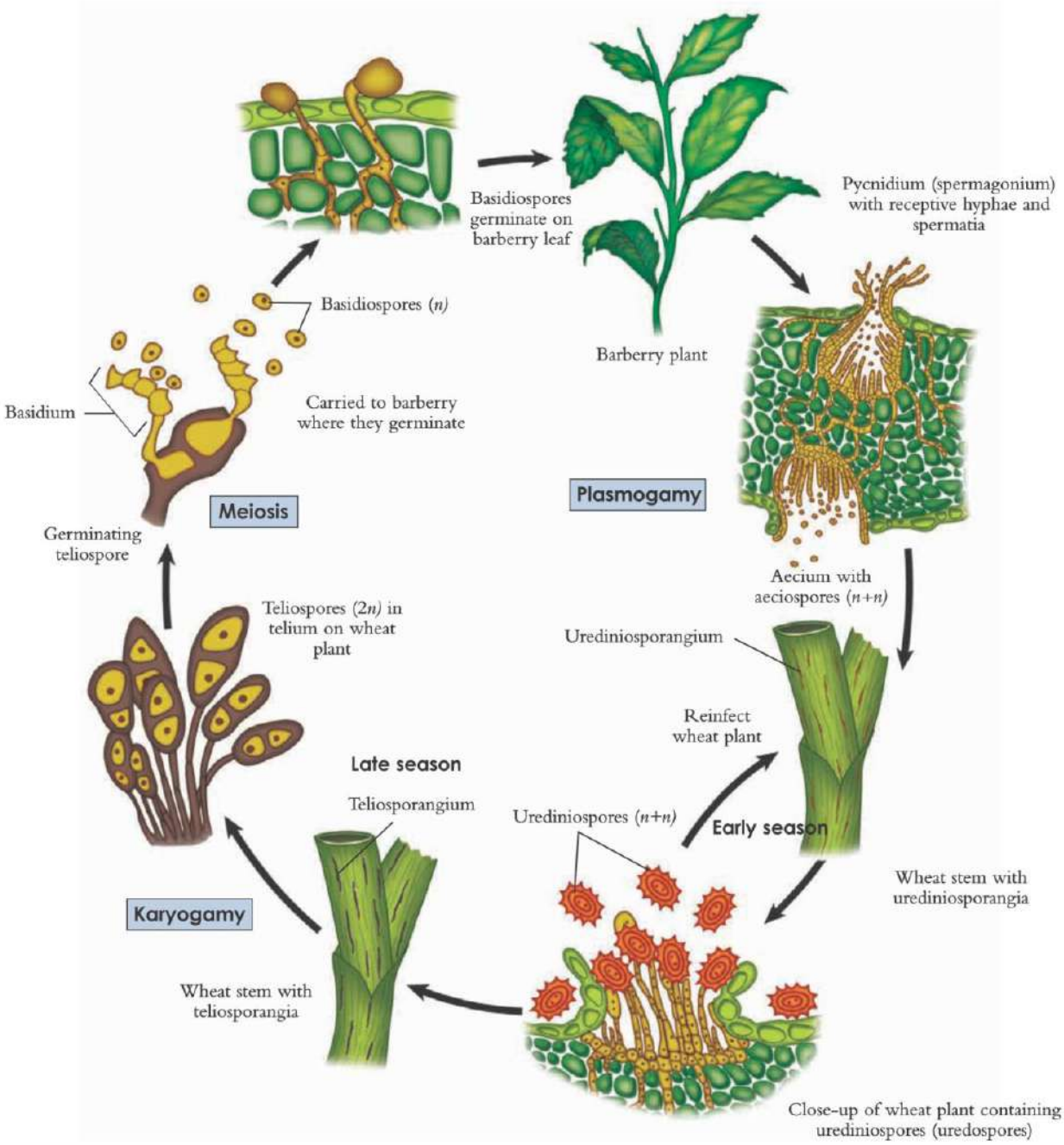


Figure 42: Life cycle of *Puccinia graminis*

https://youtu.be/m0UMYrJPQac , https://youtu.be/AeuP5IYP5HA

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.

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.

Tilletia caries causes stinking smut on wheat.

Tilletia foetidae causes stinking smut on wheat.

Urocystis agropyri causes flag smut on wheat