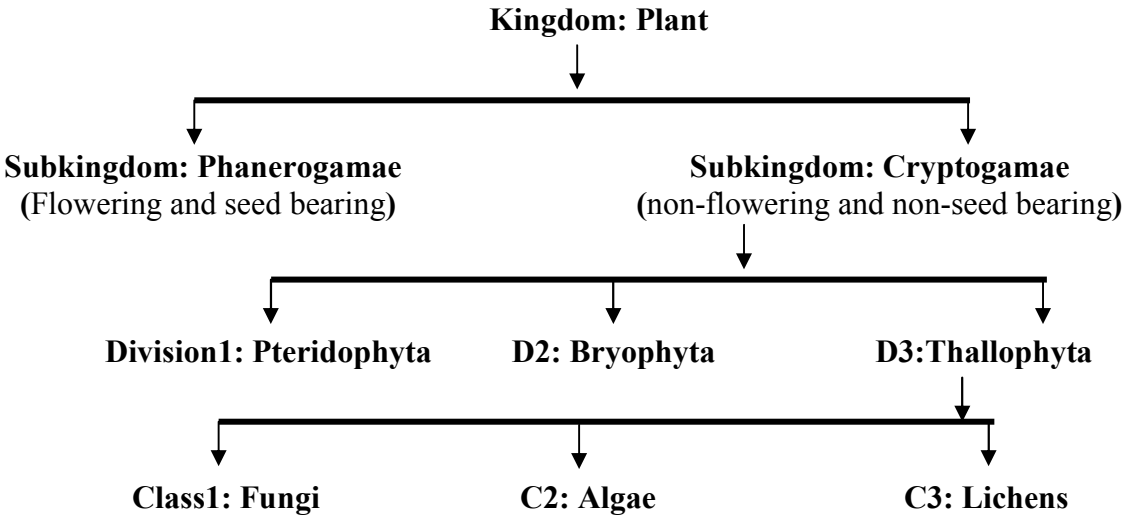
Importance of Fungi:

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.

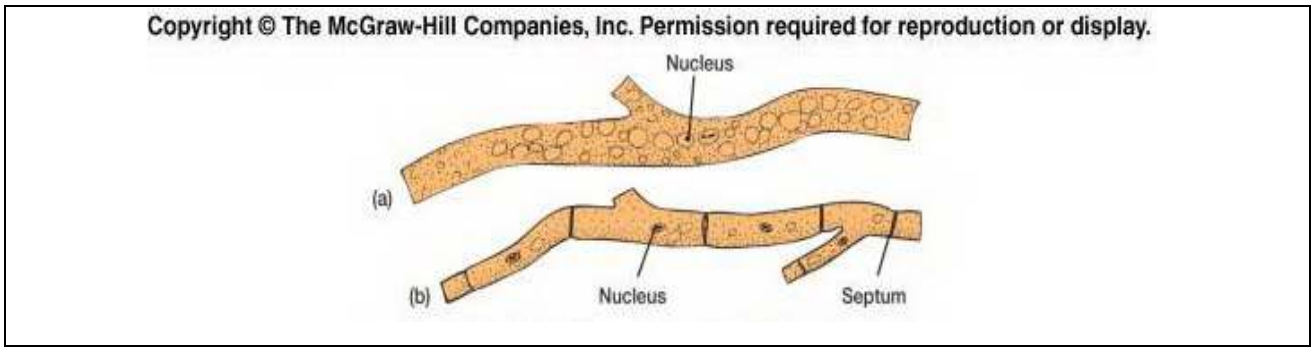


Figure 1

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.

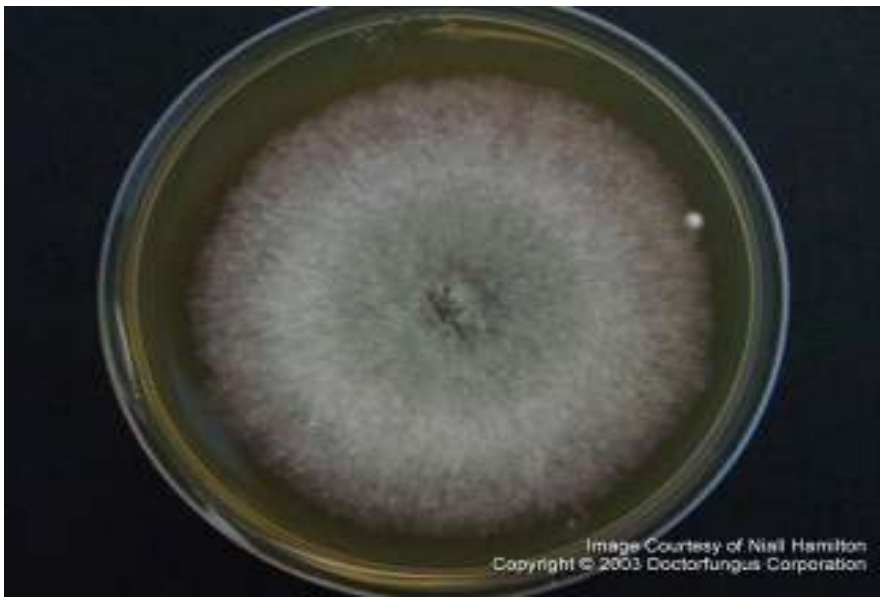


Figure 2

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.*

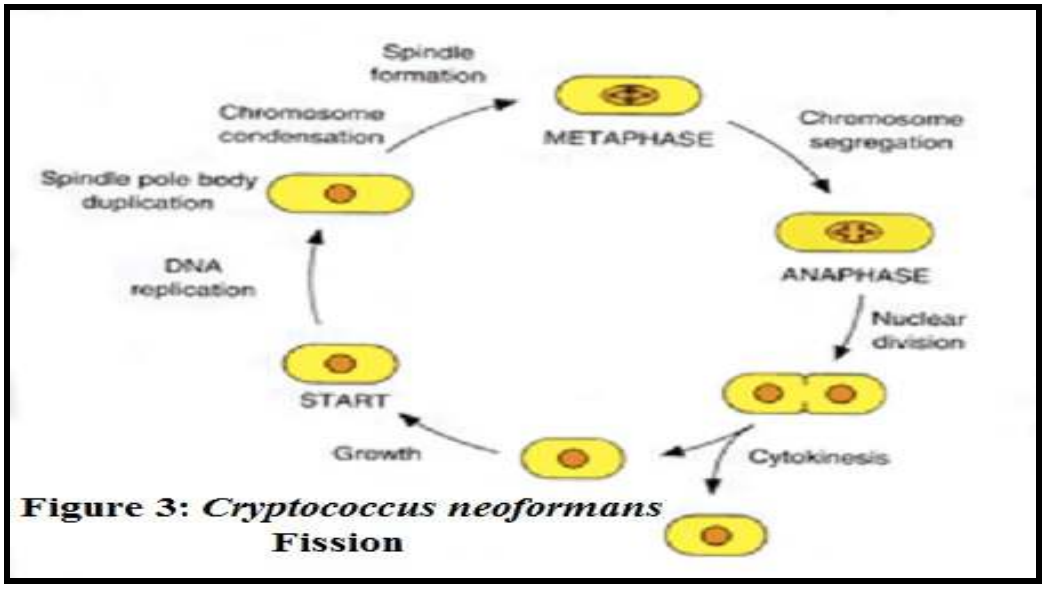
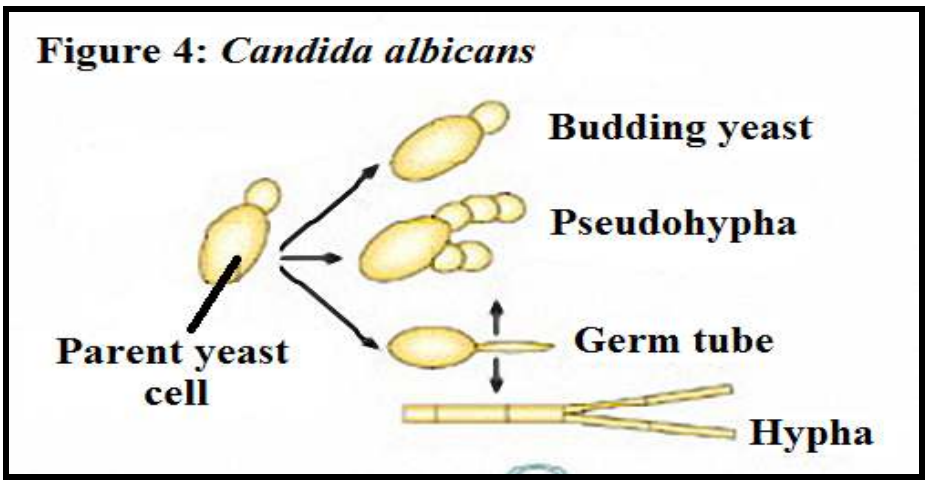


Figure 3: *Cryptococcus neoformans* Fission



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.

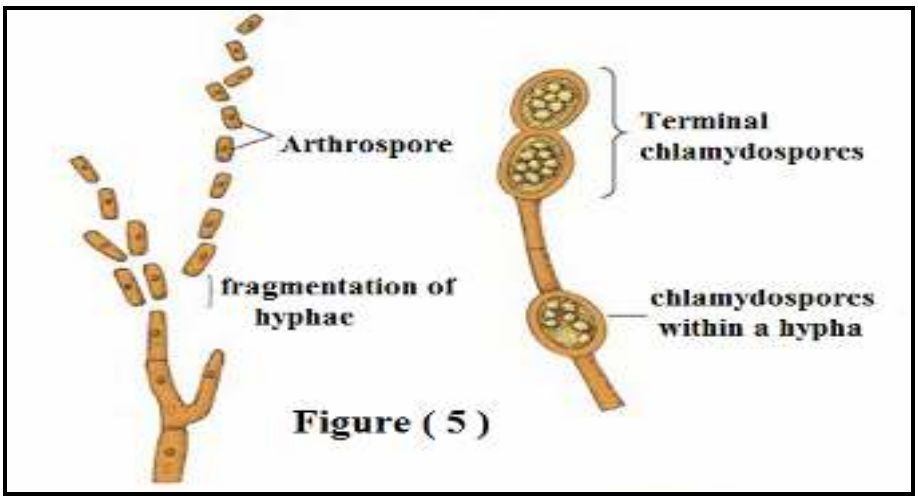


Figure (5)

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.

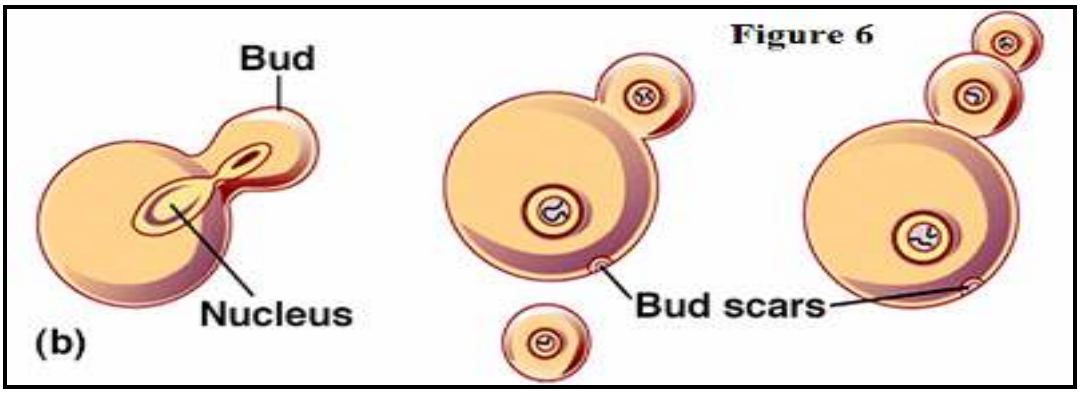


Figure 6

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.

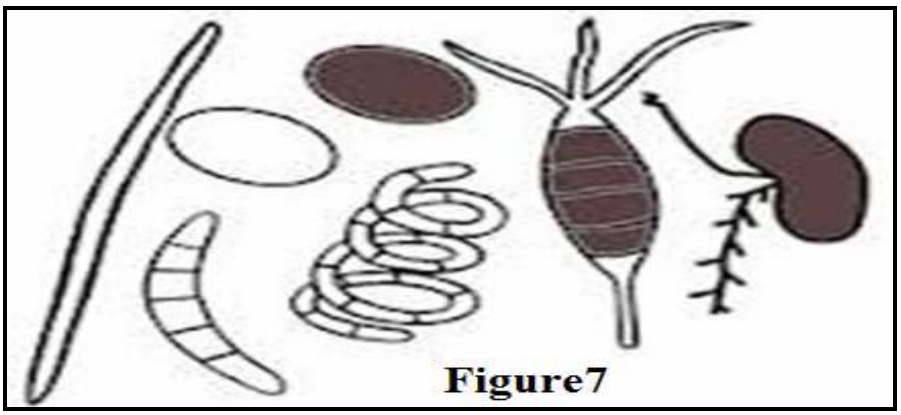


Figure7

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.

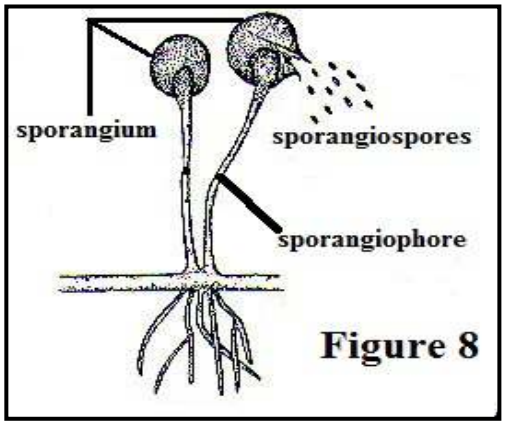


Figure 8

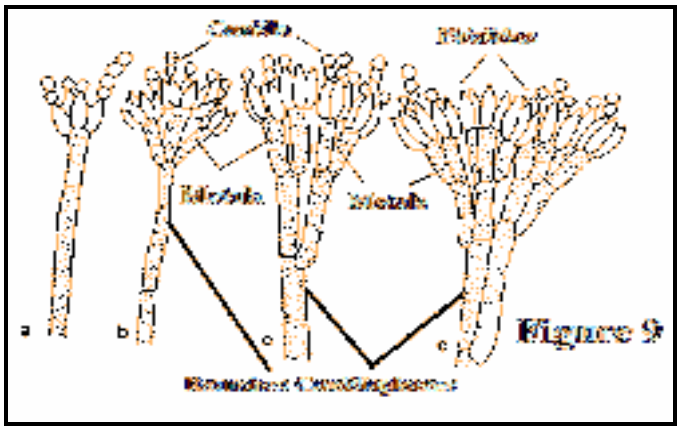


Figure 9

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.

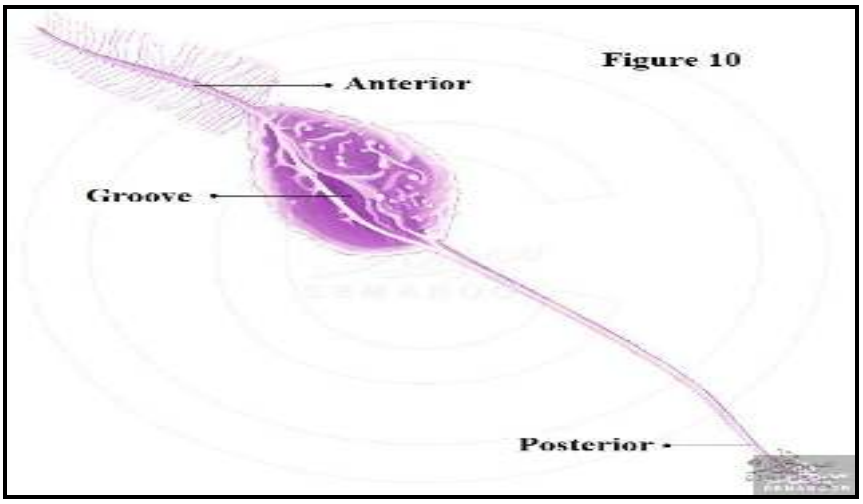


Figure 10

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 septate 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*.

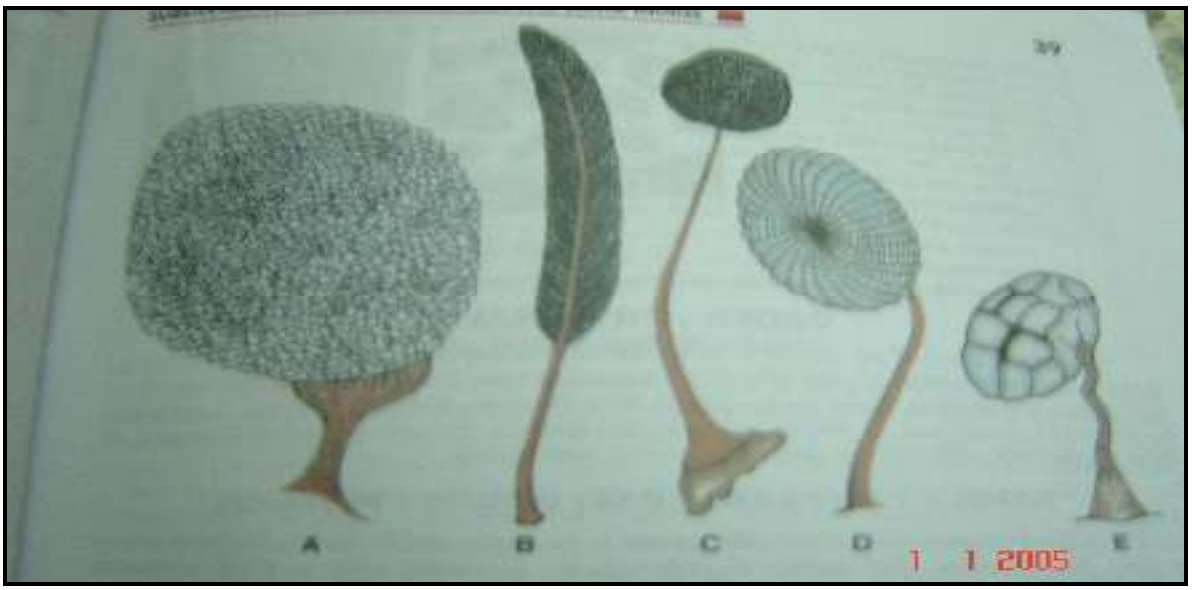


Figure 11: Types of Sporangium in Myxomycetes

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.

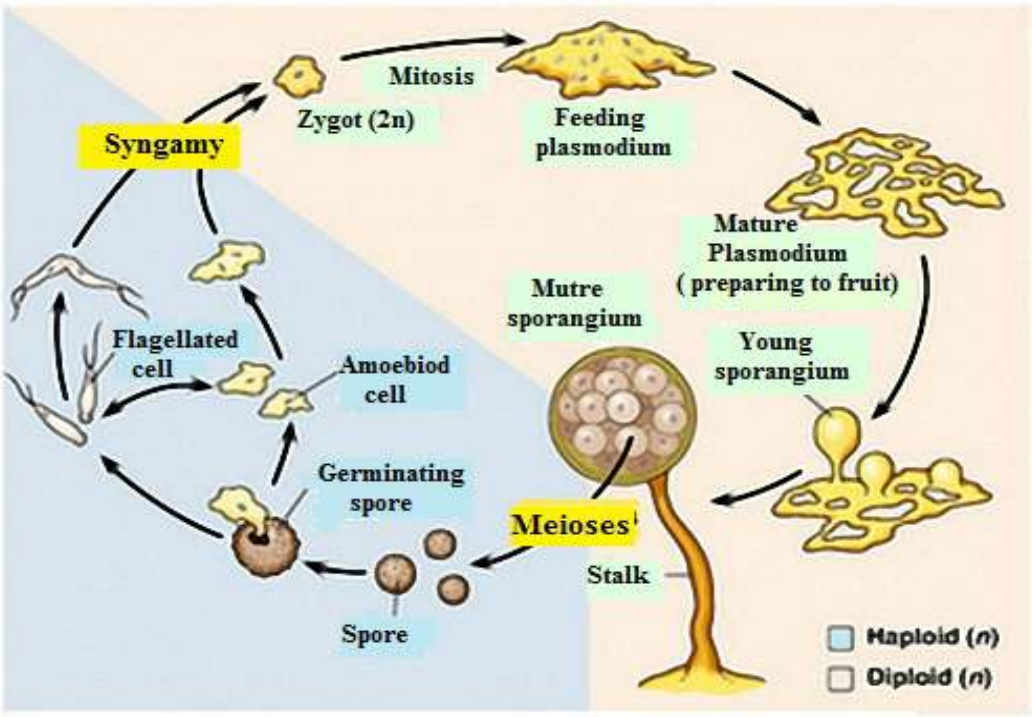


Figure 12: Life cycle of a typical Myxomycetes:

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. .

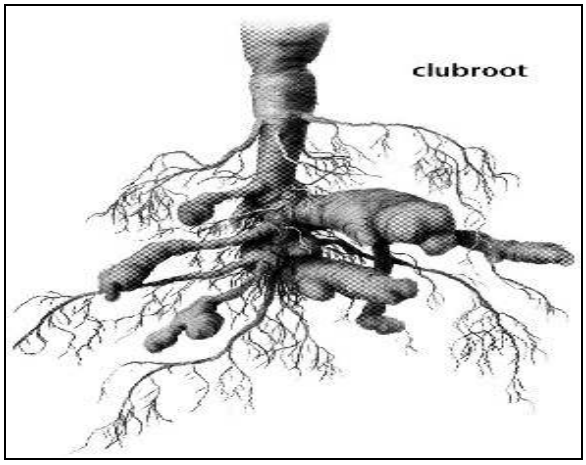
Class 2: Plasmodiophoromycetes:

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.

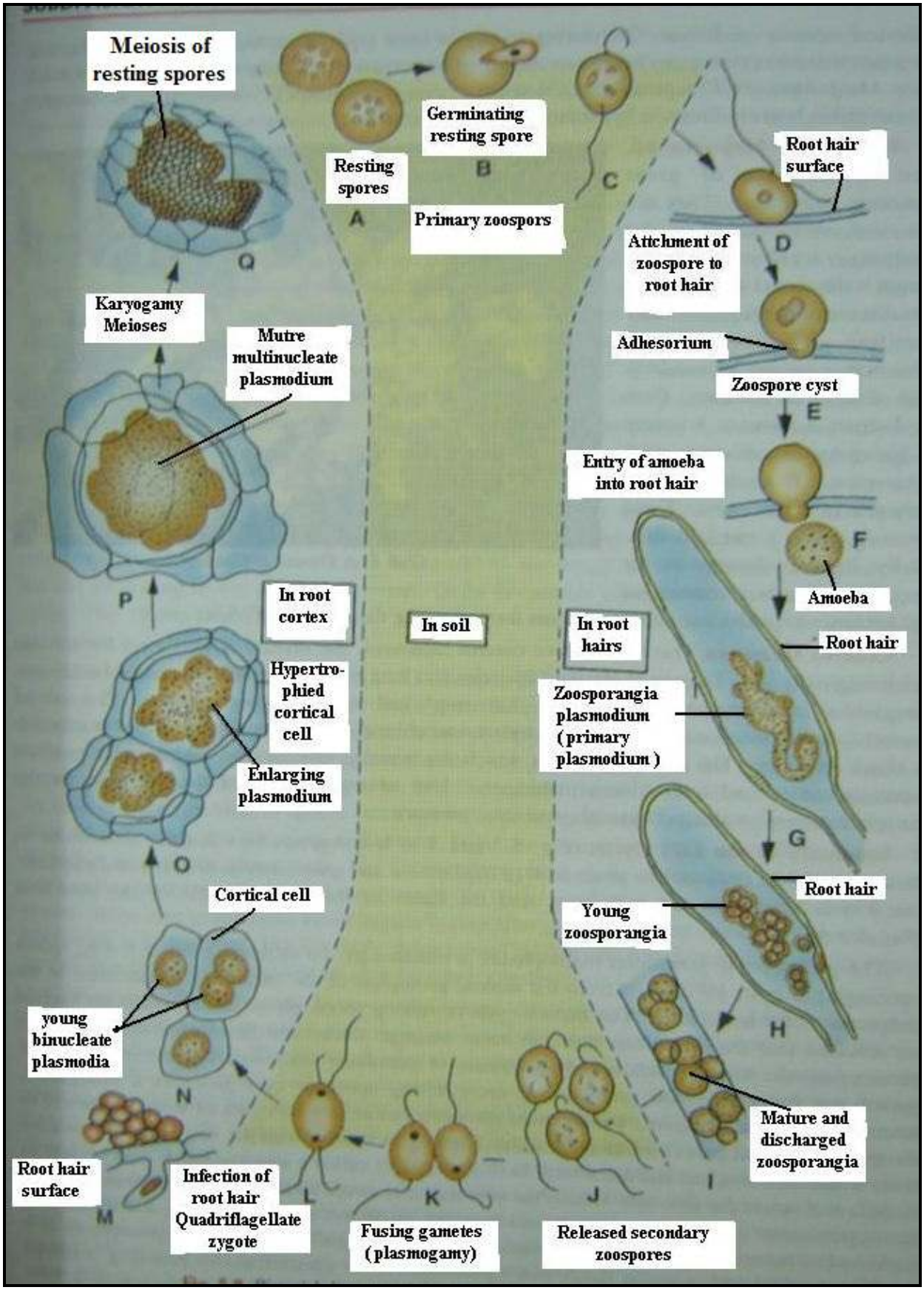


Figure 13: Life cycle of *Plasmodiophora brassicae*