B. Sc. SEMESTER-I, PAPER-II

Unit I (FUNGI)

Fungi:-

General characteristics,

Classification (Alexopoulos 1996), Economic importance

Life history of: -

Albugo,

Mucor.

Puccinia,

Cercospora

FUNGI

General characteristics:

1.Fungi are eukaryotic organisms means they have true nucleus which are enclosed in membranes.

2.They are non-vascular organisms. They do not have vascular system. Xylem and Phloem are absent.

3.Fungi have cell walls (plants also have cell walls, but animals have no cell walls).

4.There is no embryonic stage for fungi.

5.They reproduce by means of spores. There are sexual and asexual spores. Sexual spores are Oospores, Zygospores, Ascospores, Basidiospores, etc. and Asexual spores are Sporangiospores, Aplanospores, Zoospores, Conidia, etc.

6.Depending on the species and conditions both sexual and asexual spores may be produced.

7.They are typically non-motile.

8.Fungi exhibit the phenomenon of alteration of generation. They have both haploid and diploid stage.

FUNGI

General characteristics:

9. Fungi are achlorophyllous, which means they lack the chlorophyll pigments present in the chloroplasts in plant cells and which are necessary for photosynthesis.
10. The vegetative body of the fungi may be unicellular or composed of microscopic threads called hyphae.
11. Hyphae can grow and form a network called a mycelium.
12. Yeasts are unicellular fungi that do not produce hyphae.
13. The structure of cell wall is similar to plants but chemically the fungi cell wall are composed of chitin (C8H13O5N)n.
14. The cell membrane of a fungus has a unique sterol and ergosterol.
15. Fungi are heterotrophic organisms. They obtains its food and energy from organic substances, plant and animal matters.
16. Fungi grow best in acidic environment (tolerate acidic pH).
17. Fungi digest the food first and then ingest the food, to accomplish this the fungi produce exoenzymes like Hydrolases, Lyases, Oxidoreductase, Transferase, etc.

FUNGI

General characteristics:

18. Fungi store their food as starch.
19. Biosynthesis of chitin occurs in fungi.
20. Many of the fungi have a small nuclei with repetitive DNA.
21. During mitosis the nuclear envelope is not dissolved.
22. Nutrition in fungi – they are saprophytes (gets energy from dead and decaying matters), or parasites (lives in a host, attack and kill) or symbionts (mutually beneficial).
23. Optimum temperature of growth for most saprophytic fungi is 20-30°C while (30-37)°C for parasitic fungi.
24. Growth rate of fungi is slower than that of bacteria.
25. Reproduction in fungi is both by sexual and asexual means.
26. Sexual state is referred to as teleomorph (fruiting body), asexual state is referred to as anamorph (mold like).

FUNGI

General characteristics:

27.Reproduction occurs by both asexual (Axamorph) and sexual (Teliomorph) mode: **Asexual methods:** fragmentation, fsomatic budding, fission, asexual spore formation **Sexual methods:** gametic copulation, gamate-gametangium opulation, gametangium copulation, somatic copulation and Spermatization.

28.Pheromone is a chemical substance produced by fungi, which leads to the sexual reproduction between male and female fungi cells.

29.Some fungi are macroscopic and can be seen by naked eyes. Mold or mushrooms are examples of macroscopic form of fungi.

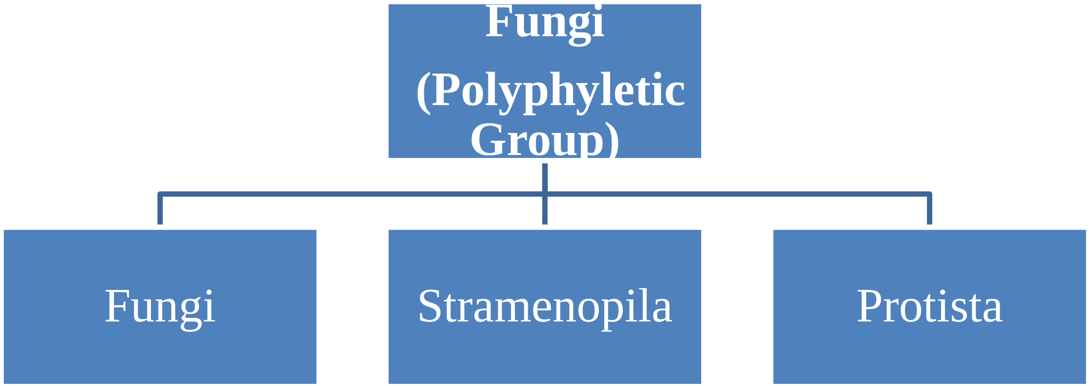
30.In 1991, a landmark paper estimated that there are 1.5 million fungi on the Earth.

31.Only about 300 species of fungi are infectious to human.

32.Examples: *Candida albicans*, *Aspergillus*, *Blastomyces*, *Coccidioides*, *Cryptococcus neoformans*, *Histoplasma*, *Pneumocystis jirovecii*, etc.

Classification of Fungi (Alexopoulos 1996):

C. J. Alexopoulos (1996) classified fungi (polyphyletic group) into three kingdoms that are fungi, stramenopila and protista. Kingdom further divided into phylum. The outline of classification is as follows:



FUNGI (Polyphyletic group)

Kingdom I: Fungi (It includes four phylum)

1. Chytridimycota
2. Zygomycota
3. Ascomycota
4. Basidiomycota

Kingdom II: Stramenopila (It includes three phylum)

1. Oomycota
2. Hypochytriomycota
3. Labyrinthulomycota

Kingdom III: Protista (It includes four phylum)

1. Plasmodiophoromycota
2. Dictyosteliomycota
3. Acrasiomycota
4. Myxomycota

Economic Importance of Fungi

Other than medicinal and agricultural benefits, fungi also have some **economic benefits**. Some of the important economic benefits of fungi are given below.

•There are some edible fungi such as mushrooms which provide different essential nutrients like vitamins, amino acids and lipids.

•The most common **fungi yeast** is used in the production of bread and beer.

•A free living fungi named trichoderma sps. are present in the root ecosystem to act against plant pathogens.

•Some species of fungi penicillium is used to produce roquefort and camembert cheese.

•Fungi are also used in the commercial production of different enzymes and organic acids.

ALBUGO

Mycelium of Albugo:

It is well developed and consists of branched, aseptate, coenocytic hyphae. The hyphae live and ramify in the intercellular spaces of the susceptible host tissue. The hyphal wall contains cellulose and not chitin. The hyphal protoplasm is granular and vacuolate in the older parts.

It contains numerous nuclei, oil globules and glycogen. Electron micrographs reveal the presence of mitochondria, endoplasmic reticulum and ribosomes.

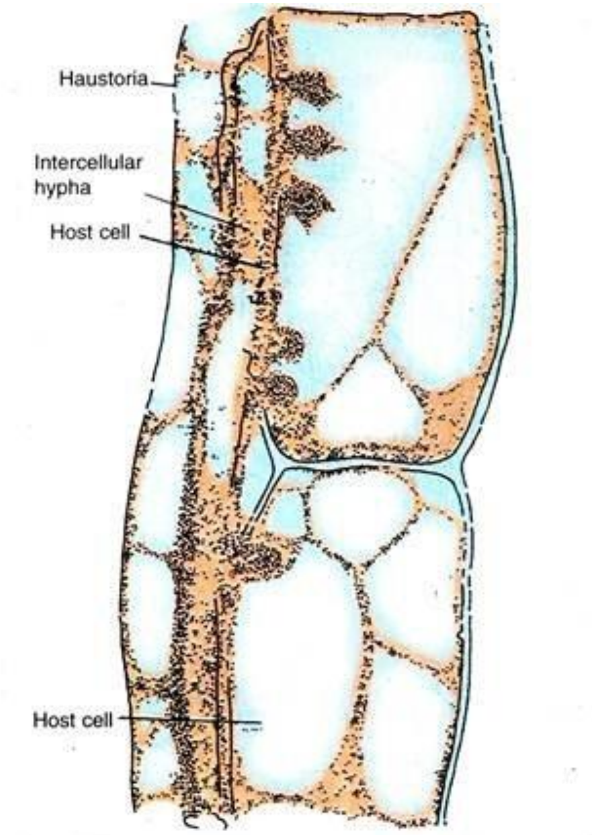


Fig. 6.50. *Albugo candida.* Section through the host stem showing a portion of the mycelium bearing haustoria. (Diagrammatic).

The cytoplasmic membrane which is closely appressed to the hyphal wall forms lomasomes. Septa remain suppressed in the actively growing hyphae but appear to separate reproductive structures and to seal off injured parts.

The fungus mycelium grows vigorously. The hyphae branch and ramify within the host attacking the tissues adjoining the point of infection. Sometimes both Albugo and Peronospora occur on the same host particularly Capsella bursapastoris. Albugo can, however, be distinguished from Peronospora by the smaller diameter of its hyphae and more numerous, vesicular haustoria.

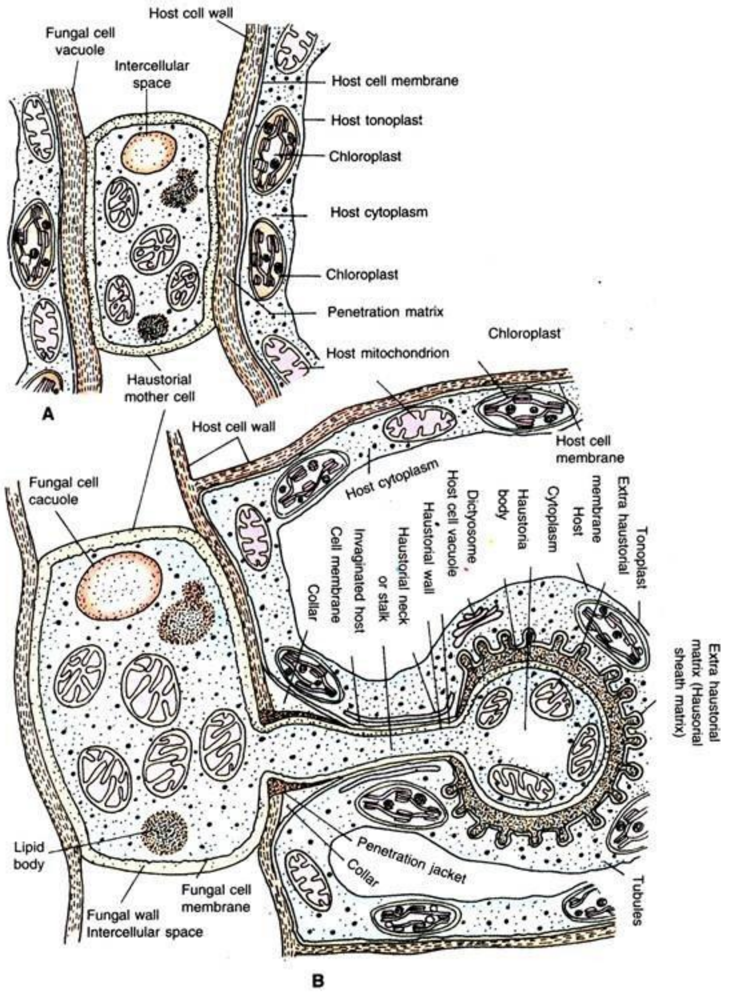


Fig. 6.51. (A-B). *Albugo candida.* Diagrammatic representation of ultrastructure of the haustorial apparatus in section passing through the host mesophyll cell (Based on Coffey)

The intercellular hyphae of this obligate parasite produce intracellular haustoria in the mesophyll cells of the host. The haustorium arises as a lateral outgrowth at the site where the hyphal wall is tightly pressed against the mesophyll cell wall.

An electron- dense amorphous material known as the penetration matrix is usually deposited at the site of contact between the host and the hypha cell walls. It is described as the penetration site

The slightly crescent-shaped bulge of the haustorial mother cell known as haustorial initial perforates the host cell wall at the penetration site and protrudes into the lumen of the mesophyll cell to develop into a haustorium. It is bordered by the invaginated host plasma membrane.

With light microscope the haustorium is seen as a small, spherical structure consisting of two parts namely:

(i) The haustorial stalk or neck and

(ii) The terminal haustorial head or body.

The haustorial stalk passes through the penetration site to connect the haustorial body to the hyphal wall in the intercellular space between the mesophyll cell. Usually one or two, sometimes more, haustona are seen in the thin peripheral layer of the host cell cytoplasm adjacent to the chloroplasts.

Reproduction in Albugo:

Asexual Reproduction in Albugo:

When the mycelium has reached a certain stage of maturity it epidermis produces pads of hyphae at certain areas just below the epidermis. The tips of hyphae constituting the mat grow verticlly into short, upright, thick-walled, unbranched club-shaped hyphae.

These are the sporangiophores (=conidiophores). They are arranged in a closely packed palisade like layer forming a sorus between the epidermis and the mesophyll of the host leaf. Each sporangiophore appears constricted at its junction with the subtending hypha.

The lower two-third portion of sporangiophore is narrow, thick-walled, with a undulating surface whereas the upper one-third is broader, thin-walled with a smoother surface. According to Khan (1977), the sporangiophore wall towards its proximal end consists of two layers, the outer more electron-dense and thicker than the inner layer.

(a) Abstriction of sporangia:

In the lower fungi (Phycomycetes) Albugo is unique in that its lemon- shaped sporangia are produced in basipetal chains at the tips of clavate sporangiophores. Two different views have been put forth to explain their mode of development.

According to one view, the sporangial chains in Albugo are abstricted by percurrent proliferation. The second view advocates the blastic mode of development.

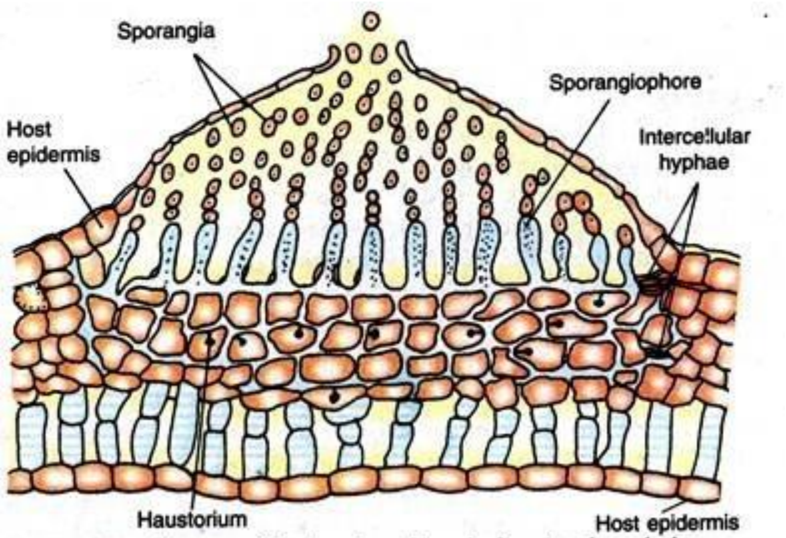


Fig. 6.52. *Albugo candida.* A section of host leaf passing through the sporangial sorus.

(i) Percurrent Proliferation (Fig. 6.53):

The sporangia in Albugo which are cut off in succession are arranged in a basipetal chain on the sporangiophore. According to Hughes (1971), they are produced by successive proliferations of the sporangiophore subtending a sporangium.

This mode of development of sporangia is termed per-current proliferation. Generally the sporangiophore increases in length as each successive sporangium is cut off from each successive proliferation at a higher level than the previous one. The first formed sporangium is a aleuriosporangium.

Reaching a certain size it is delimited from the sporangiophore by a basal septum. The latter eventually splits into two halves so that the subsequent proliferation of sporangiophore involves the exposed half septum. In Albugo each successive sporangium is capable of seceding from the sporangiophore or from the young sporangium.

The second sporangium is thus formed by proliferation of the sporangiophore with total involvement of the half of the fractured transverse septum exposed by the seceding first sporangium above it. Apart from this, septum is seen at the apex of the young sporangium.

The second sporangium is delimited in the same manner as the first. As the second sporangium increases in size it pushes the first upward without disjunction. The process is repeated resulting in a chain of sporangia. Probably the septum seen at the apex of each younger sporangium thickens on both sides to form a connective between the successive sporangia in the chain.

According to Hughes, besides increase in length of sporangiophores, this method of sporangium development is accompanied by marked lamination and thickening of the walls of the sporangiophores. The mature sporangiophores are thus longer, more thick-walled and show annellations.

Thakur (1977) corroborated findings of Hughes (1971) on formation of sporangia by percurrent proliferation in Albugo.

(ii) Blastic mode of Sporangium development (Fig. 6.54):

According to Khan (1977) the sporangiophore has a fixed sporogenous locus at its apex. The sporangial initial arises as a bud from it (A). It contains about 4-6 nuclei and dense cytoplasm.

The two wall layers of the sporangium initial are continuous with those of the sporangiophore wall. Reaching a certain size, the initial is delimited by a basal septum near the sporogenous locus. It becomes the first sporangium and the oldest in the chain (B).

The septum is formed by the centripetal growth of the inner layer of the sporangiophore wall (C). A nearly complete septum has a narrow central canal and consists of three layers, upper and lower electron dense and the thick middle one of less electron density (D).

After the completion of the basal septum and conversion of the initial into a full-fledged sporangium, a new sporangium initial grows as a bud from the sporogenous locus (B). It pushes the newly-formed sporangium upward. Thus only one sporangium is formed at a time.

As the second sporangium initial grows to the normal size, it is also delimited by the formation of a basal septum as the first. The repetition of the process results in the formation of a basipetal chain of sporangia. Soon after the formation of the first sporangium, the breakdown of its basal septum begains.

It is the middle layer which starts disintegrating from its periphery inwards whereas its upper layer fonns the wall of the upper sporangium and the lower layer completes that of the lower sporangium (E-F).

The fibrous product of dissolution of the middle layer is held in position by the pellicle which covers both the sporangia and the sporangiophore. It is seen as a connective or disjunctor between the successive sporangia in the chain. Khan (1977) did not notice any increase in length of the sporangiophore during sporangia formation nor did he observe any annellations on the sporangiophore surface.

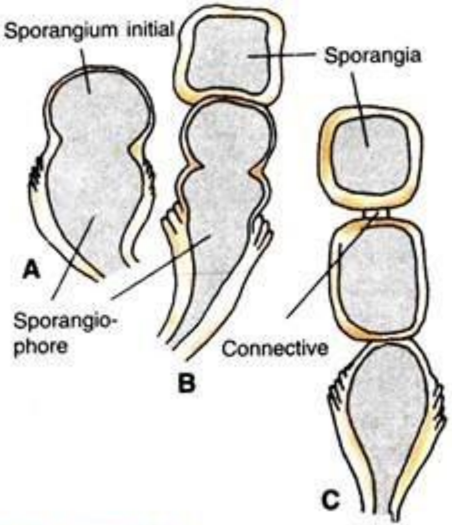


Fig. 6.53 (A-C). *Albugo ipomeae-pandurantae* showing stages in percurrent proliferation of sporangia (After Hughes)

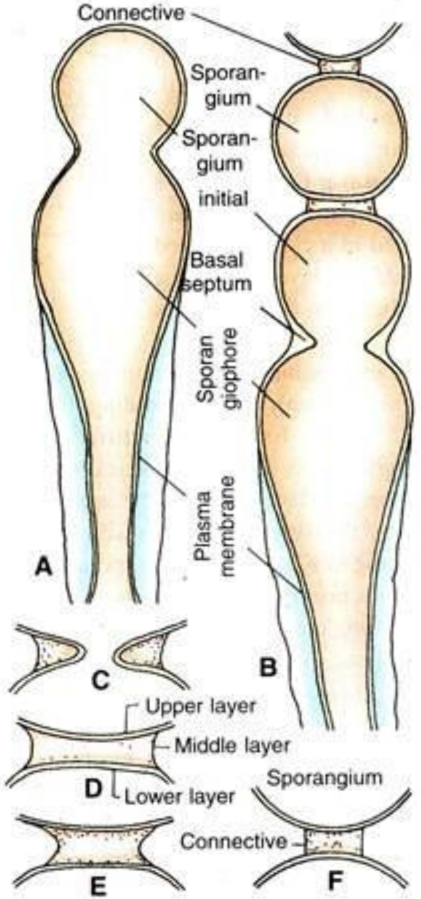


Fig. 6.54 (A-F). *Albugo candida* showing blastic mode of development of sporangia (After Khan)

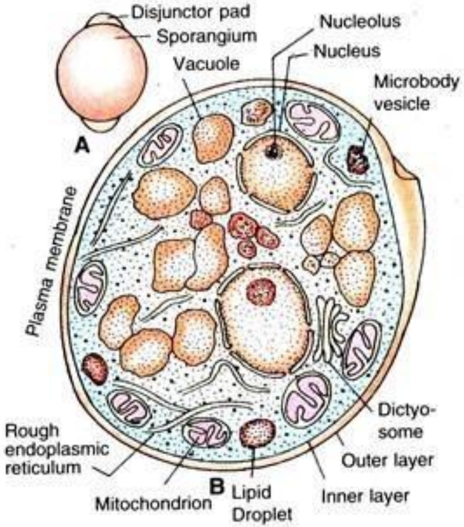


Fig. 6.55 (A, B). *Albugo candida*. A, Sporangium with remains of the disjunctor pads at both ends; B, ultrastructure of sporangium (Based on Khan).

Sporangia

They are small, hyaline, nearly spherical or lemon- shaped structures with a smooth or somewhat punctate surface.

The basipetal arrangement of sporangia in the chain (with the oldest at the top and the youngest at the base of the chain) serves two useful purposes:

(i) It permits ready dispersal of the oldest sporangia by air currents or rain water, and

(ii) It helps in the proper nourishment of the younger ones.

(i) Ultrastructure of sporangium (B):

According to Khan (1977), each newly formed sporangium is lemon-shaped and is about 19- 22 by 14-17 µ m in size. It bears remnants of the connectives or disjunctor pads at both the ends. The sporangium wall is differentiated into two distinct layers. The outer is more electron dense than the inner.

Within the sporangium wall is the highly convoluted plasma membrane enclosing the dense cytoplasm containing up to 4 nuclei. Besides, the cytoplasm contains endoplasmic reticulum, mitochondria, perinuclear, dictyosomes, ribosomes both free and attached to endoplasmic reticulum, vesicles of various kinds and lipid droplets.

Towards maturity the sporangial wall especially, its inner layer increases in thickness and the number of lipid droplets decrease as the sporangia matured. The oldest sporangia have none.

The endoplasmic reticulum becomes accumulated in the peripheral cytoplasm. Towards the end of sporangial maturation, the dictyosomes become quiescent, mitochondria decreased in number and also the amount of endoplasmic reticulum. The sporangial wall increased 3-fold the thickness.

(ii) Dispersal of sporangia:

The chains of sporangia lengthen and press on the epidermis above. This causes the leaf surface to bulge. The overlying epidermis eventually bursts over the growing sporangial sorus and exposes the white shining pustules consisting of masses of sporangia.

The pustules look like white blisters. The exposed sporangia are white. The distal ones by this time have matured. As the sporangia mature the connectives or gelatinous pads between them dry, shrink and finally disintegrate in moist air. The sporangia in the chain thus separate. They are then blown away in the air by wind or washed away by rain water.

Germination of sporangia (Fig. 6.56):

Landing on a suitable host the sporangia begin to germinate within two or three hours under suitable conditions.

At the time of germination they behave in either of the following two ways depending on temperature conditions:—

Indirect Germination (Fig. 6.56 B-E):

In the presence of moisture and low temperature, the sporangium functions as a zoosporangium (B). The optimum temperature for germination of sporangia is 10°C. It absorbs water and swells. A few vacuoles appear in its granular cytoplasm.

Later the vacuoles disappear and the multinucleate protoplast undergo division. It divides to form five or eight polyhedral uninucleate daugher protoplasts. Meanwhile an obtuse papilla forms on one side of the sporangium.

Each daughter protoplast shapes into a slightly concave-convex zoospore (E). It has a disc-like contractile vacuole on one side and is furnished with two flagella, one short and one long. The former is of tinsel type and the later whiplash. The flagella are attached laterally near the vacuole.

As the zoospores are differentiated, the papilla swells and opens. The zoospores still immobile, emerge usually one by one (Fig. 6.56 C). According to Vanterpool, the zoospores are, at first, released in a sessile vesicle formed by the swelling of the papilla. The vesicle soon vanishes.

Germination of zoospore and infection of host (Fig. 6.56 F-H):

Moisture on the surface of the host is essential for germination and infection. The released zoopores swim about in water for a while (E). Finally they settle down on the host, retract the flagella and round off.

Each secretes a wall around it (F). The encysted zoospore (cyst) then germinates. It puts out a germ tube (G) which gains entrance into the host thought a stoma (H). Once within the host tissue the germ tube grows and forms the mycelium

(ii) Direct Germination (Fig. 6.56 I-J):
At high temperature and under comparatively dry conditions the sporangium behaves like a conidium (I). It germinates directly to form a germ tube (J). The conidial method of germination of sporangia in Albugo is, however, not common.

The germ tube penetrates the host through a stoma or, through an injury in the epidermis. Within the host it develops into a mycelium. Re-infection of the host and infection of other healthy plants in the vicinity goes on by the production of sporangia throughout the growing season.

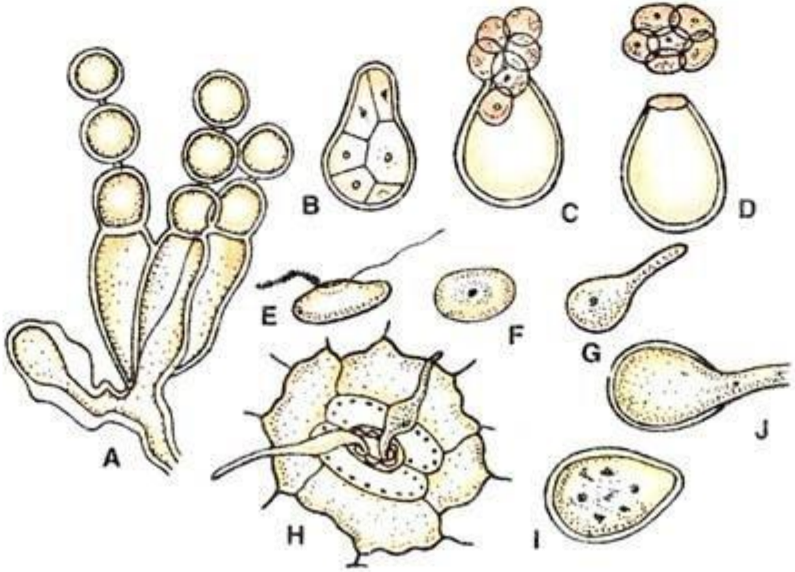


Fig. 6.56 (A-J). *Albugo candida*. A, cluster of sporangiophores bearing sporangia in chains; B-D, differentiation and liberation of zoospores; E, liberated zoospore; F, encysted zoospore; G, germination of cyst to form a germ tube; H, infection through a stoma; I-J, direct germination of sporangium. (After De Bary)

Sexual Reproduction in Albugo:

It is oogamous:

The male sex organ is called an antheridium and the female oogonium (A). They are developed near each other in the intercellular spaces of host tissues towards the end of the growing season. When the mycelium ages, some hyphae grow deep and lie buried in the intercellular spaces of the tissues of the stem, or petioles.

The sex organs arise on separate hyphae called the male and the female hyphae (A). The two soon establish contact. The antheridium comes in contact with the oogonium at the side. The development of sex organs within the host tissue is externally indicated by hypertrophy and distoration in shape in the particular organ.

(a) Oogonium:

It arises as a globular enlargement of the tip of the female hypha. Sometimes the oogonium is intercalary in position. The swelling is multinucleate(A) Across wall appears below this inflation (B). It separates the terminal oogonium from the rest of the female hypha. The young ooglum has highly vacuolated contents.

The numerous nuclei and vacuoles are evenly distributed and the usual cell organelles are dispersed throughout the oogonium. The nuclei divided mitotically and increase in number as the oogonium advanced towards maturity. After the first Sc division the ooginial cystoplasm shows marked zonation (C).

It becomes differentia into two distinct regions with the rearrangement of the numerous nuclei and other cellular organellers. Most of the original cytoplasm of the oogonium forms the central,rounded dense ooplasm. It is multinucleate and contains only a few mitochondria,ribosomes and cisternae of ER. It is rich in lipid vesicles and reserve vesicles containing electron dense inclusions (reserve globules).

The ooplasm is surrounded by the peripheral cytoplasm constituting the periplasm. It is more vacuolate and spongy. The vacuoles are large. Besides, the periplasm is rich in nuclei, mitochondria endoplasmic reticulum and ribosomes. It has protoplasm of thinner consistency. Sometime after all the nuclei of ooplasm migrate into the periplasm (D) and become arranged in a ring.

Here they divide mitotically with the spindles lying in such a way that one pole of each that one pole mitosis one daughter nucleusthe ooplasm and the other in the periplasm (E). At the end of mitosis one daughter nucleus of each spindle goes to the ooplasm and the other to the periplasm (F). However, the ooplasm at maturity has a single centrally located nucleus (G).

There are two views with regard to this uninucleate condition of the mature ooplasm. According to one view, all the nuclei excepting one are extrude from the ooplasm and are deposited in the periplasm. The second view IS that in the later stages of development all the nuclei in the ooplasm excepting one degenerate and disappear. The uninucleate ooplasm functions as the female gamete or egg or oosphere (G).

(b) Antheridium:

It is an elongated club-shaped cell (A). It is multinucleate. The antheridium is developed at the end of a male hypha lying close to the oogonium. The end of the male hypha enlarges into club-shaped swelling.

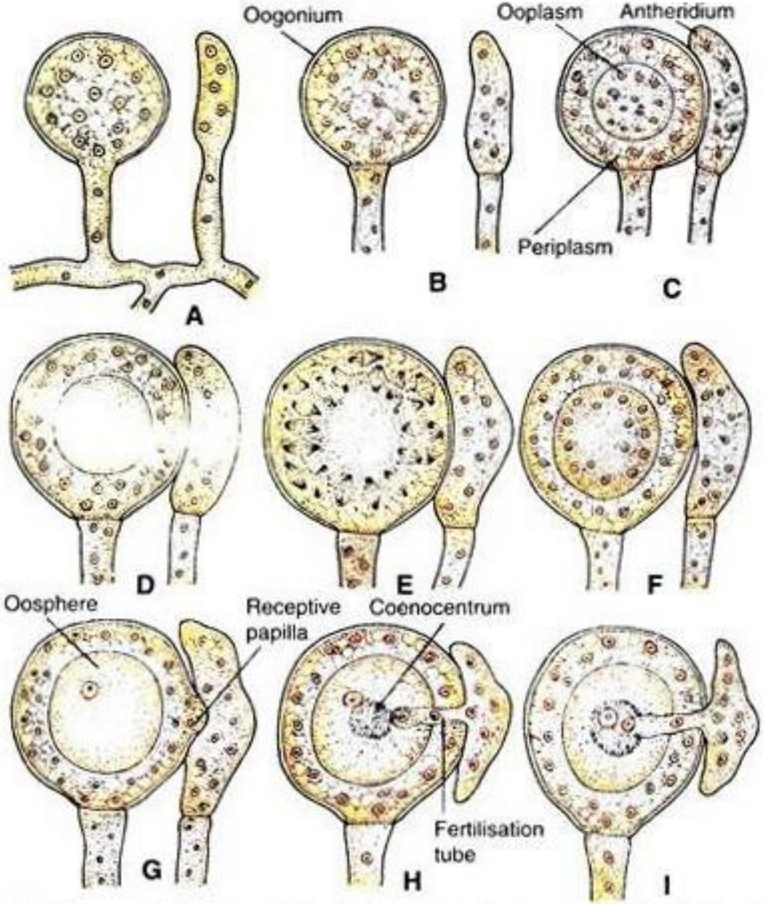


Fig. 6.57 (A-I). *Albugo candida.* Stages in the development of sex organs and fertilisation. Explanation in the text.

The latter is then cut off by a cross wall from the rest of the male hypha (B). This terminal dub-shaped cell is called an antheridium. It contains several nuclei (usually 6-12), but only one is functional. The paragynous antheridium comes in direct contact with the oogonium at the side (C).

(c) Fertilisation:

At the point of contact of antheridium with the oogonium, the walls become very thin. A portion of the contents of the oogonium surrounded by a thin membrane grows into a papilla-like outgrowth (G).

This papilla-like oogonial bulging is called the receptive papilla It is functionless. The receptive papilla bulges (G) into the antheridium but soon disappears. This is followed by the formation of a slender tubular outgrowth from the antheridium.

It is the fertilisation tube (H). The fertilisation tube passes through the thin spot in the oogonial wall and enters the multinucleate periplasm. It then dips deep into the ooplasm. Prior to this a spherical and granular cytoplasmic body appears in the centre of the oosphere (H). It is known as the coenocentrum. The single functional female nucleus is attracted towards it and becomes attached to a point near it.

The fertilisation tube finally reaches the coenocentrum and ruptures (I) at the tip to introduce a single male nucleus which fuses with the female nucleus. Thereafter the fertilisation tube collapes but persists and the coenocentrum vanishes. On removing or displacing the attached antheridium Tewan and Skoropad (1977) observed a clear hole surrounded by some fibrous material.

Oospore (Fig. 6.58 A-C):

Tewari and Skoropad (1977) investigated the fine structure and development of A. Candida oospores. According to them, the young oospore is delimited from the vacuolate periplasm by an electron-dense cell wall.

The single layered cell wall of the young oospore encloses dense cytoplasm containing a group of reserve vesicles, lipid vesicles and a few membranous organelles. It is surrounded by periplasm rich in vacuolate cytoplasm containing membranous organelles.

Further development of oospore if marked by the deposition of 4 layers, two on the outer and two on the inner side of the first (original) layer of the young oospore. The mature oospore thus has a thick highly differentiated 5-layered wall.

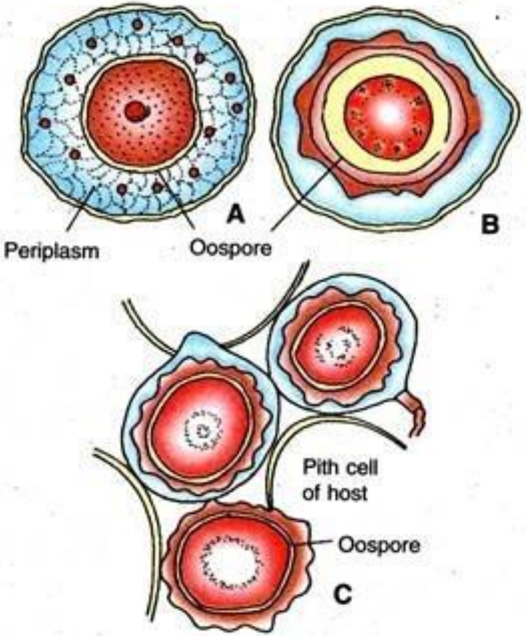


Fig. 6.58 (A-C). *Albugo candida.* Showing structure of oospore as seen under light microscope.

External to the oospore wall are the two addition protective investments formed by the persistent periplasm and the oogonial wall. The thick highly differentiated oospore wall together with the two surrounding additional layers contributes to the longevity of Albugo oospore. The authors suggest that periplasm plays an active part in deposition of oospore wall layers.

Within the fully developed oospore wall is the scanty cytoplasm surrounding a large central reserve globule. Some small bodies resembling the reserve globules in appearance and numerous lipid vesicles occupy most of the space between the oospore wall and the central reserve globule.

The highly differentiated thick, oospore wall together with the two additional layers constituted by the persistent perisperm and the oogonial wall provides protection and the numerous lipid vesicles in the oospore cytoplasm furnish energy for the long dormancy or overwintering by oospores in Albugo.

The outer layer of the oospore wall is comparatively thicker. It is warty or tuberculate. In other species it may have a network of ridges or other patterns.

Germination of Oospore (Fig. 6.59):

On the onset of conditions favourable for growth, the oospore germinates. The central globule and the lipid droplets gradually disappear. The contents of the oospore assume uniform granular appearance.

The diploid nucleus undergoes repeated divisions to form many nuclei (about 100 or even more). A small amount of cytoplasm gathers around each daughter nucleus. Numerous uninucleate daughter protoplasts thus result. Each of these metamorhoses into a biflagellate zoosore.

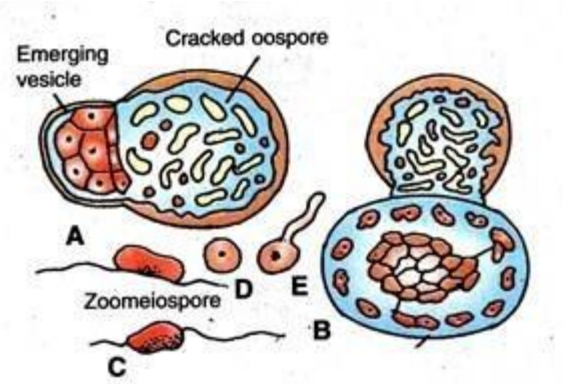


Fig. 6.59 (A-E). *Albugo candida.* A-B, Germination of Oospore; C, liberated zoospore; D-E, germination of zoospore. (After De Bary)

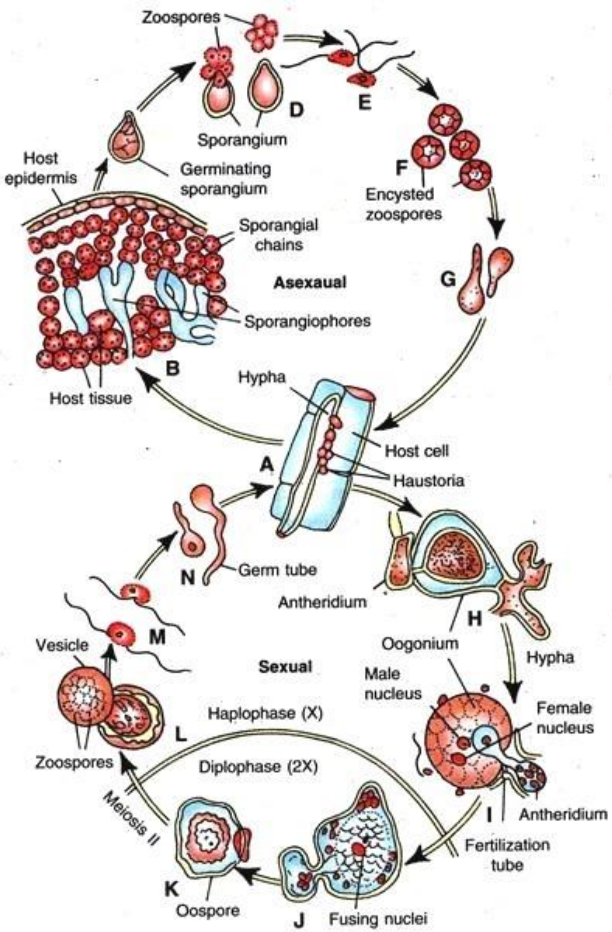
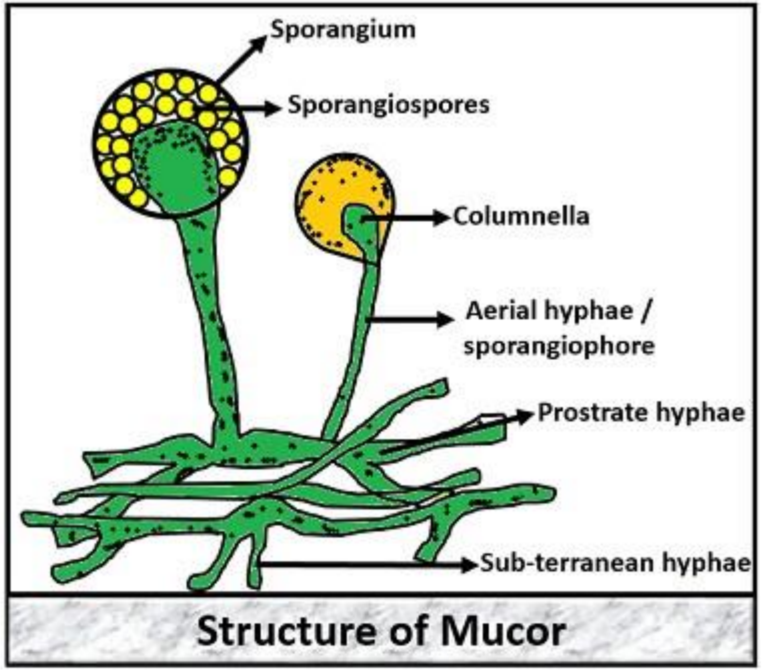


Fig. 6.61. Diagrammatic life cycle of *Albugo candida.*

Mucor

Mucor is a mould or a type of fungi, that is found everywhere. There are many species of Mucor (around 50) that are distributed worldwide. It can cause diseases particularly called mucormycosis that might affect the mucous membrane, lungs, eyes, skin etc. Mucor species are fast-growing fungi, which have a highly developed mycelium and branched hyphae. The hyphae in Mucor are generally coenocytic, but septa may appear in the mature hyphae. The cytoplasm of the hypha appears granular.



Habitat: Mucor lives in a habitat like organic soil, a dead decaying matter of fruits, vegetables and plants.

Characteristics of Mucor

1. Mucor is also called "**Black** or **Bread mould**".
2. It belongs to the class of Zygomycetes.
3. For most of the Mucor, the mode of nutrition is "**Saprophytic**" (grows in the dead decaying matter), and for others, it is "**Coprophilous**" (grows in cow dung or the dung of other herbivorous animals).
4. Mucor grows on a variety of substrates like bread, jam, jellies, vegetables etc. The absorption of nutrition is through the mycelial surface or hyphae.
5. The vegetative body of Mucor is "**Eucarpic**" because in this the only thallus differentiates into the reproductive structure.
6. The major reserve food material is in the form of glycogen and oil droplets.
7. The cell of Mucor is composed of mainly cellulose and chitin.

Structure of Mucor

Morphological Features

Mycelium: The mycelium of Mucor is highly branched, and it forms a fine network of hyphae. A mycelium is simply a cluster of hyphae.

Hyphae: These are the thread-like and very thin structures that form a "Mycelial network". Hyphae of Mucor is filamentous, aseptate or coenocytic. In Mucor, the hyphae are of three types:

1. **Sub-terranean hyphae** are the type which is highly branched, more penetrating and is present horizontally to the substratum.
2. **Prostrate hyphae** are the type which is also present horizontally between or under the substratum. These two hyphae, i.e. sub-terranean and prostrate hyphae, help in absorption of water and nutrition.
3. **Aerial hyphae** are the type, which originates vertically out from the prostrate hyphae.

Sporangiophore: It is elongated, slightly narrow in shape.

Columella: Sporangiophore swells up to form a dome-like structure called "Columella" which can vary in both shape and size.

Sporangium: It is the round and thick outer covering which carries numerous spores inside it. It can be globose to spherical.

Spores: These are the reproductive structures forms within the sporangium which are simple, flattened and variable in shape and size.

Nucleus: Multinucleate nuclei present in Mucor.

Macroscopic Features

The colony of Mucor shows rapid growth.

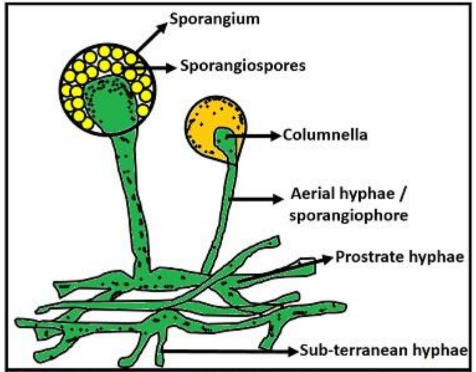
The colour of the colony is usually white to grey and turns to brown when the culture becomes old.

Microscopic Features

Hypha: Coenocytic and branched

Spores: Generally black in colour but can vary with different species.

The spores can be motile or non-motile and can exist in variable shapes.



Structure of Mucor

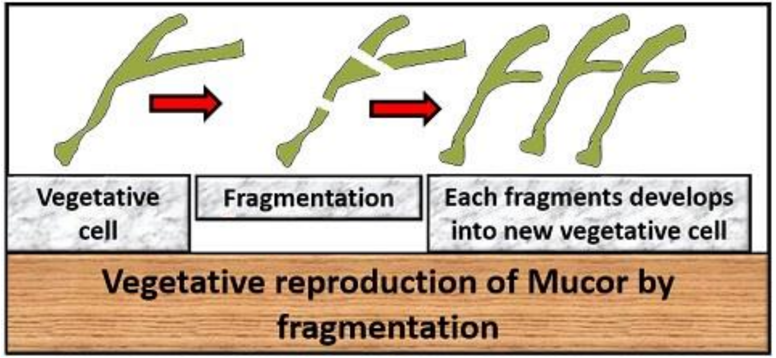
Life Cycle of Mucor

It has three modes of reproduction in its lifecycle:

1. Vegetative reproduction
2. Asexual reproduction
3. Sexual reproduction

Vegetative Reproduction

It occurs by the fragmentation method, where a vegetative cell breaks into several fragments during some unfavourable conditions. After which, each fragment then develops into a new vegetative body.



Asexual Reproduction

It occurs through the asexual and non-motile spores like:

1. Sporangiospores
2. chlamydospores
3. Oidiospores

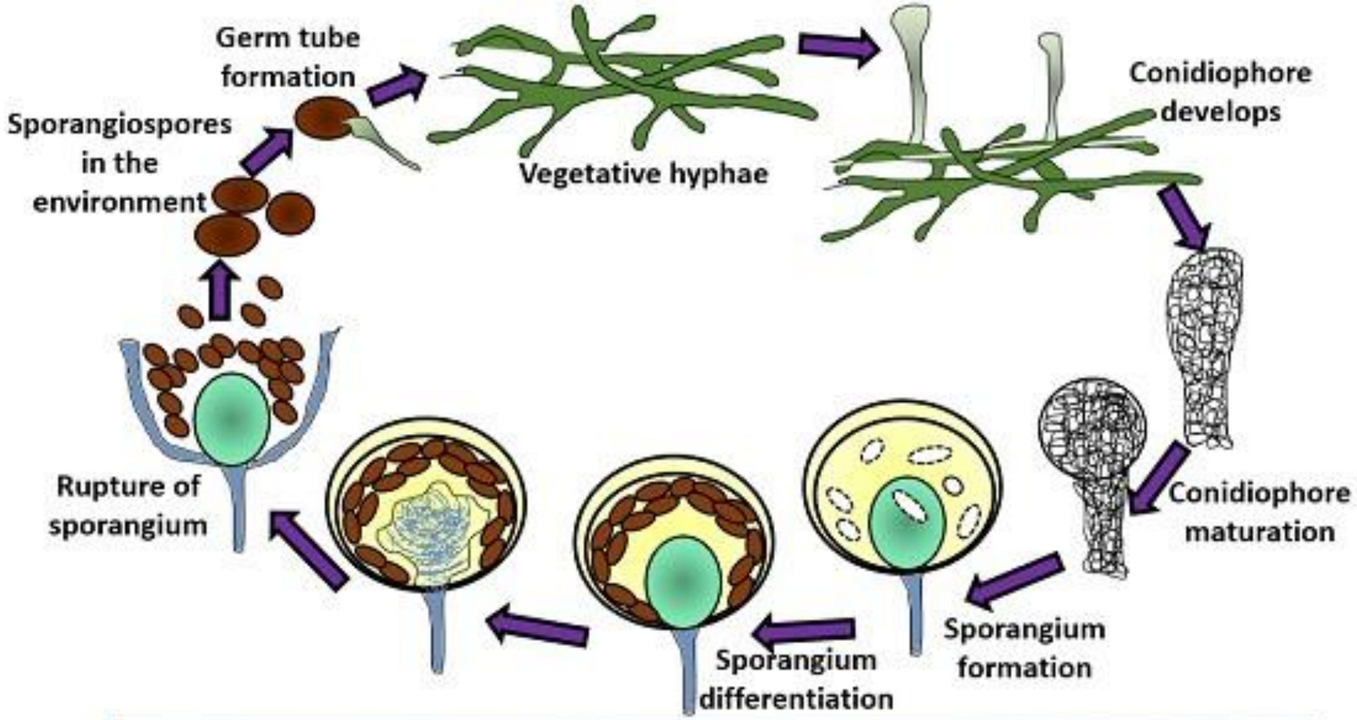
Sporangiospores

These are the spores that form within the cell or sporangium and are non-motile. There are following steps involved in the asexual reproduction of Mucor through sporangiospores:

From the hyphae, first **sporangiophores** arise singly that are erect in position and unbranched.

Then, maturation of sporangiophore occurs where the cytoplasm and nuclei push upwards by making the aerial hyphae swollen from the apical end.

After that, it develops a large round **sporangium**.



Asexual reproduction of Mucor by sporangiospores

During the maturation phase, sporangium differentiates into:

Sporoplasm: It is thick, dense, multinucleate and present inside the sporangial wall.

Columellaplasm: It is vacuolated and nucleated towards the centre.

After this, several small vacuoles appear between these differentiated portions. The space between the vacuoles forms cleavage furrows (cavity for cleavage).

Then, a septum forms to the inner side of the cavity, which further divides into the **inner columella** and **upper sporoplasm**. This septum then grows to form a dome shape and later it pushes itself into the sporangium.

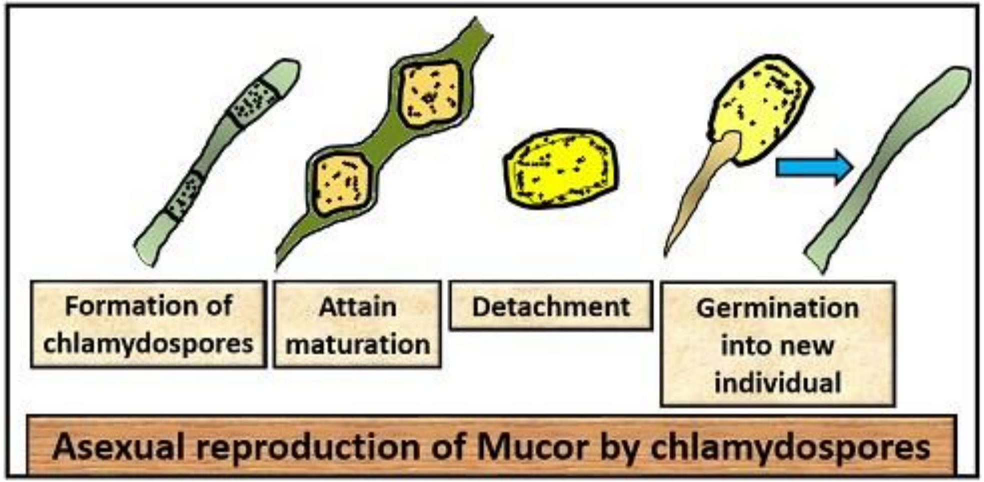
Cleavage occurs in the sporoplasm between the nucleus and the cytoplasm. This division forms a wall around many thin-walled, multinucleate spores called “**Sporangiospores**”.

The sporangiospores then releases out of the sporangia after the columnella swells up due to the pressure exerted on the sporangial wall. As a result, **cell lysis** occurs.

The spores remain dormant for some time, and when they obtain suitable substratum, they germinate to a new vegetative body through the germ tube.

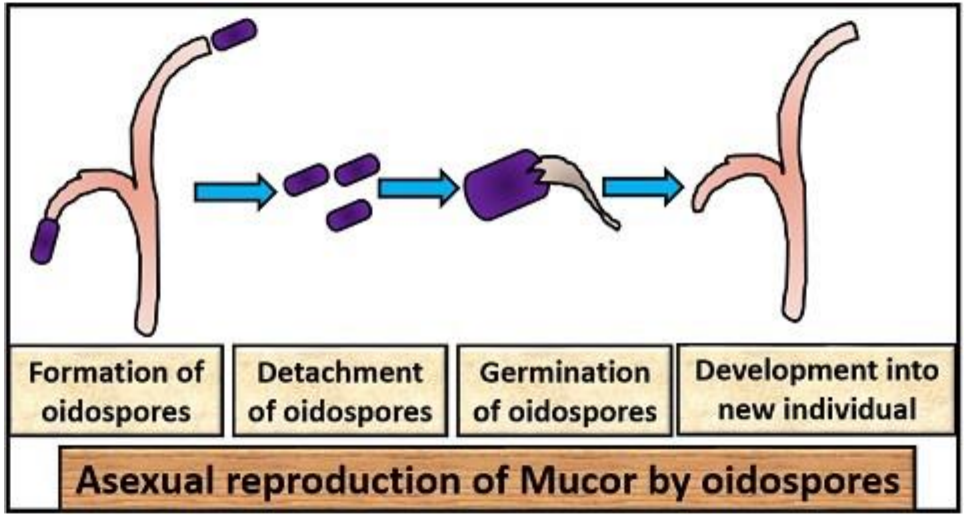
Chlamydospores

A hard wall covers these spores, and it develops inside the vegetative cell during unfavourable conditions. In unfavourable conditions, mycelium becomes septate by the accumulation of nuclei and cytoplasm in a certain portion and becomes surrounded by a thick wall called chlamydospores. This spore then detaches from the mycelium and remains dormant. On favourable conditions, they form a germ tube.

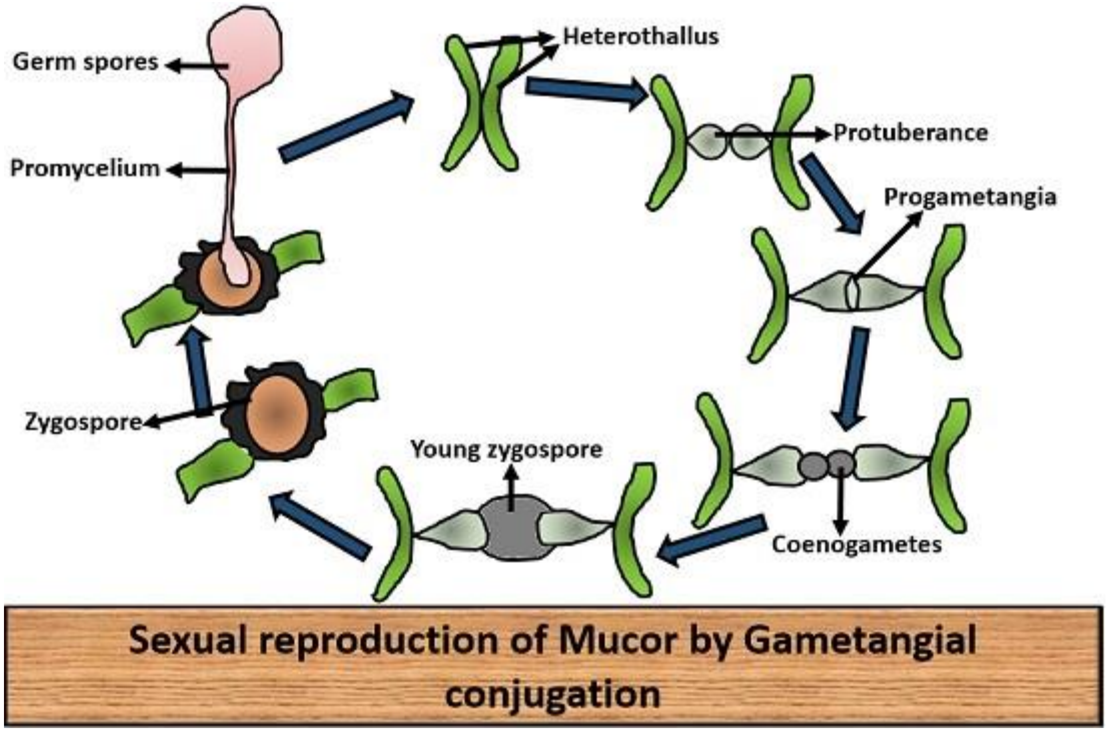


Oidiospores

When a mycelium grows in a substrate (rich in sugar), some small, thin-walled and pearl-like reproductive structures form that detaches out of the vegetative cell as in budding of yeast. Then oidospores remain dormant for some time and on favourable conditions, it forms a germination tube to form a new vegetative body.



Sexual Reproduction
In Mucor, the sexual reproduction occurs by the method that is called as Gametangial conjugation, which involves the following steps:



1. First, the thallus of two opposite strains, i.e. one is (+), and other is (-), comes in contact with each other.
2. When they come in contact, there develops a small outgrowth or protuberance from both of the thalli.
3. After that, the outgrowth swells to form “**Progametangium**”.
4. Then septum develops between the progametangium, and the fusion of progametangia occurs that results in the formation of gametes called “**Coenogametes**”.
5. Then gametes of both the strains fuse to form a “**Zygote**”.
6. The zygote then enlarges in size and get surrounded by a thick-walled structure called “**Zygospore**”.
7. Zygospore is dark black in colour, which gets covered by the two layers, namely:
    1. Outer layer: Also called **Exosporium**.
    2. Inner layer: Also called **Endosporium**.
8. The zygospore remains dormant for some time and on favourable conditions, promycelium develops out from the zygospore, forming a new vegetative body.

PUCCINIA

Puccinia graminis causes stem rust of different cereals like wheat, rye, oat etc. The isolate of wheat cannot infect oat or any other host and vice versa, which indicate their host specificity. The phenomenon where a specific pathogen infects only a specific host is called biological specialisation.

The vegetative body is mycelium. Mycelia are of two types: dikaryotic and monokaryotic. Both the types are septate, much branched, grow intercellularly and produce special haustoria, which penetrate the host cell.

Simple pore if present in the septum, maintains protoplasmic continuity between neighbouring cells. The cell wall is composed of chitin and glucan. The cytoplasm also contains vacuoles, oil globules, glycogen bodies etc.

The dikaryotic mycelium (n + n) occurs in wheat plant i.e., the primary host and the monokaryotic mycelium occurs on barberry plant i.e., the alternate host of the pathogen.

Different Type of Spores Found in Puccinia Graminis:

Puccinia graminis tritici produces five different types of spores in its life cycle. These are uredospore, teleutospore, basidiospore, pycniopore and aeciospore.

Uredospores and teleutospores grow on wheat, the primary host; basidiospores on soil or on dead plants upon soil that developed from teleutospore; and the pycniospores and aeciospores on barberry plant, the alternate host of the pathogen.

1. Uredospore:

The uredospores are borne on uredosorus (Fig. 4.58A, 4.59A). The uredosorus develops on wheat plant from the dikaryotic mycelium produced by germination of aeciospore, which comes from barberry plant generally through wind dissemination.

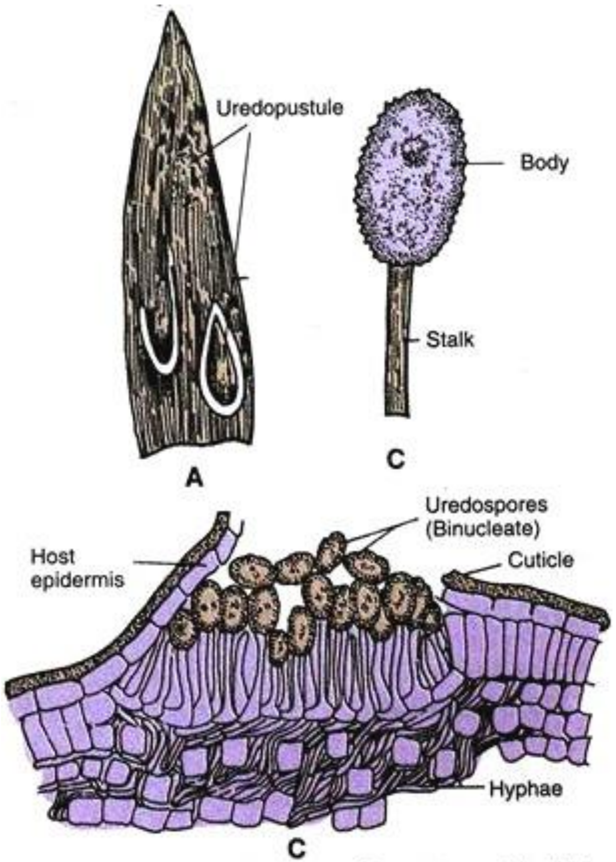


Fig. 14.14 (A-C). Uredineal stage of *Puccinia graminis tritici*. A, Uredosori on wheat leaf; B, A section through the uredosorus; C, A single uredospore.

The aeciospore after reaching the wheat plant may attack leaf, stem or glumes. On germination, the aeciospore produces dikaryotic mycelium which enters through stomata and grows intercellularly. The mycelium of the subepidermal region develops erect hyphae, those produce binucleate uredospores at their tips.

The uredospores develop in groups under the epidermis, called uredosorus, which appear in the form of reddish-brown pustules. With maturity, the host epidermal wall bursts by pressure of developed spore and uredospores become exposed.

Uredospores are stalked, oval, unicellular, brown, thick walled with 4-round equatorial germ pores measuring outer layer 25-30 µm 17-20 pm. The spore wall is thick with echinulate outer layer (Fig. 4.59B).

The uredospores in favourable condition (i.e., in winter season) again germinate (Fig. 4.59C), thus infect the wheat plant (Fig. 4.59D) and develop next crop of uredospore. The procedure may repeat several times in a single season.

2. Teleutospore:

At the end of wheat season, the uredosori also produce teleutospore along with uredospore. At that time the sorus is known as mixed sorus. The mixed sorus gradually converts solely into teleutosorus (Fig. 4.58B, 4.60A). Teleutosorus develops exclusively by the infection of uredospore. The teleutosori look black raised streak that developed on leaf sheath and also on stem.

The teleutospores (Fig. 4.60B) are stalked, spindle-shaped, thick and smooth-walled with round or pointed apex, 2-celled and slightly constricted at the septum. Spores are chestnut brown in colour and measure about 15-20 µm x 40-46 µm.

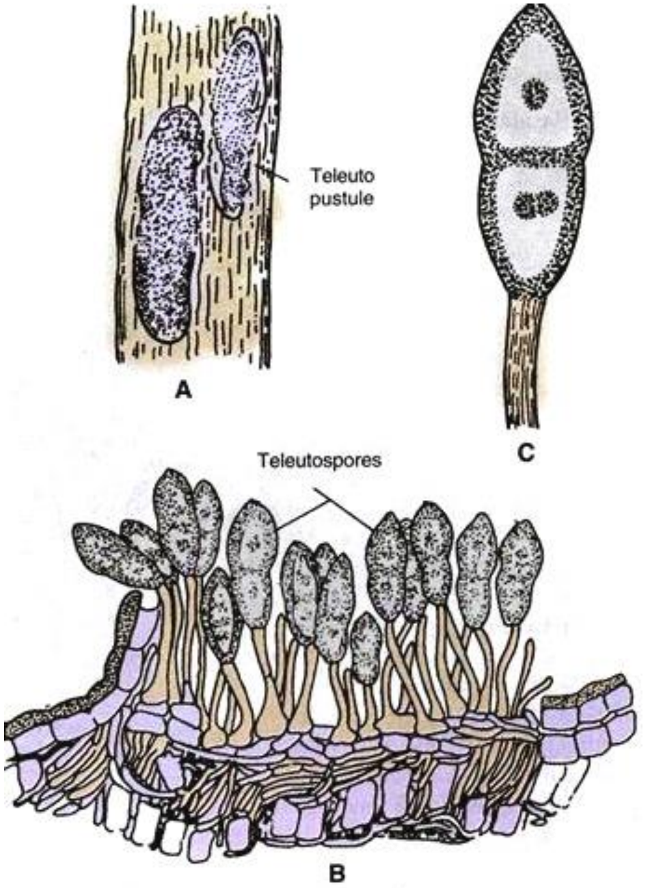


Fig. 14.16 (A-C). Telial stage of *Puccinia graminis tritici*. A, Teleutosori on wheat; B, A section through the teleutosorus; C, Single teleutospore with a fusion nucleus in each cell.

Each cell is dikaryotic (n + n) having one germ pore. The germ pore is at the top of the apical cell and it is below the septum in the lower cell. Both the nuclei in a cell fuse together and form a diploid (2n) nucleus

The teleutospores become exposed by rupturing the host epidermis. It acts as a resting spore and survives during unfavourable condition. With the onset of favourable condition of low temperature with high humidity, the teleutospores germinate on soil either detached or attached condition with the dead host.

3. Basidiospore:

It develops on germination of teleutospore. The teleutospore germinates by producing one germ tube from each cell. The germ tube has limited growth and is called promycelium, probasidium or epibasidium. The diploid nucleus passes inside the probasidium and undergoes meiosis to form four haploid nuclei, two (+) and two (-) type. The probasidium now becomes four celled by transverse wall. Each cell then develops small projection, the sterigma through which nucleus and cytoplasm push outside and develop basidiospores, of which two are (+) and two of (-) type

Basidiospores are unicellular, thin-walled and very small. After discharge from basidium by explosive mechanism, they are disseminated by air current. The basidiospores can survive for a few days. They can infect only the leaves of alternate host, the barberry, otherwise they die.

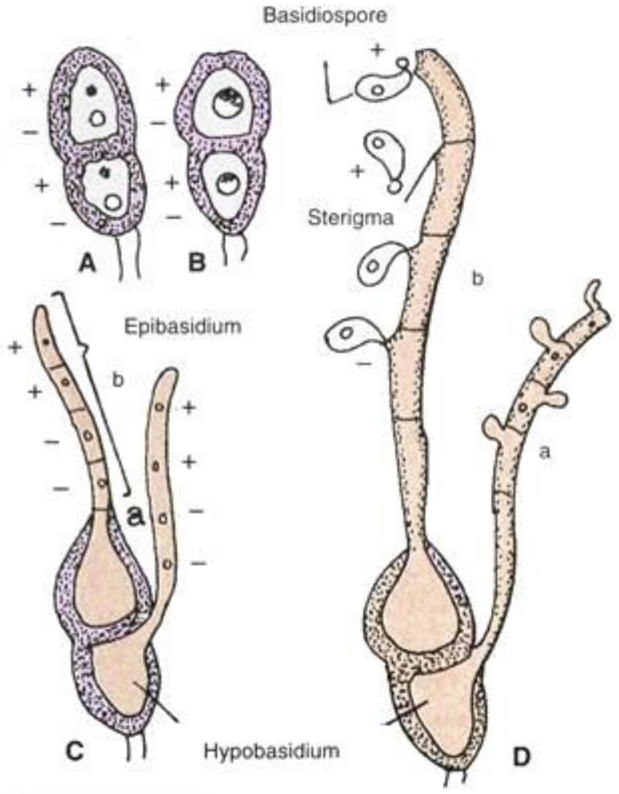


Fig. 14.17 (A-D). *Puccinia graminis tritici.* A, Young teleutospore; B, mature teleutospore; C, germinating teleutospore and meiosis; D, basidial stage.

4. Pycniospore:

During favourable condition, the basidiospore germinates on contact with barberry leaflet towards the upper surface by producing germ tube. The germ tube penetrates the epidermis and grows there intercellularly.

The nature of the mycelium depends on the nature of basidiospore, either of + or – type. Within few days, the growing mycelium becomes aggregated under the epidermis and forms a yellowish flask-shaped structure, called Pycnium or Spermogonium. The Pycnium has small sterile mycelium at the neck, called periphyses, which intermingle with much larger thin-walled simple and branched receptive or flexuous hyphae.

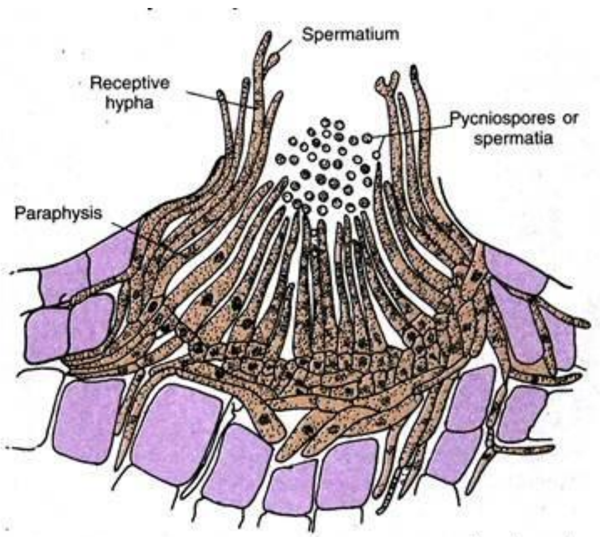


Fig. 14.18. *Puccinia graminis tritici*. A mature spermagonium in section.

The bottom of the inner side of pycnium is lined by many uninucleate tapering cells, the pycmophores or spermatiophores, which develop many small oval to spherical uninucleate cells, called pycniospores (spermatia).
Depending on the nature of basidiospore, the pycnium and pycniospore may be of + or – type. Numerous pycnia of different types (+ and -) can grow in cluster on the upper surface of the leaf. The pycniospore or spermatium does not infect any host.
The mature pycnium (+ and – type) secretes nector drops during release of mature pycniospores which get intermixed.
The insects get attracted by nector and help in the transfer of pycniospore or spermatium to the flexous hyphae of opposite mating type. The wall at the point of contact dissolves and the nucleus of pycniospore (spermatium) passes to the flexuous hyphae, thus dikaryotic condition is established. This process is known as spermatisation.

5. Aeciospore:

During development of Pycnia, some hyphae of + and – type goes downward towards the lower side of the leaf and forms respective immature aecia (Protoaecium or aecial primodium). Further growth is initiated within few days of spermatisation.

The spermatial nuclei pass downward through the hyphae and after crossing the inner tissue they reach and dikaryotise the basal cells of the aecial primordium. The aecial primordium then stimulates to further growth and within few days, on the lower surface of the leaf, aecium (PI. aecia) or cluster cup (n + n) is formed.

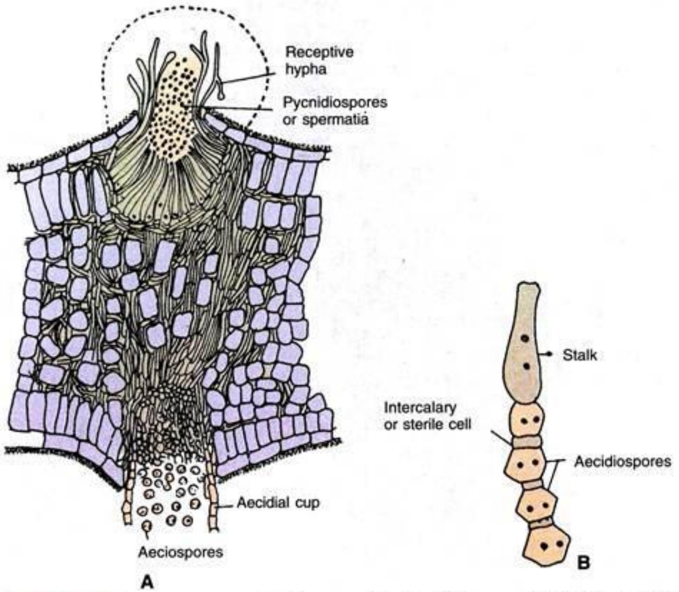


Fig. 14.22 (A-B). *Puccinia graminis tritici*. Spermagonial and aecidial stages. A, V. S. Berberis leaf showing a spermagonium (pycnidium) on the upper surface and an aecial cup on the lower surface; B, showing mode of development of aecidiospores.

The young aecium is buried inside the tissue below the lower epidermis, but with maturity it pushes and ruptures the epidermis, thereby spores are exposed. The aecium is inverted cup-shaped structure (Fig. 4.61 B, 4.62A) with outer margin composed of short cells, called peridium.

The stalk cell after becomes dikaryotised, divided mitotically into chain of alternately arranged large and small cells (Fig. 4.62A, C). The large cells form the aeciospores (n + n) and the small one becomes sterile, called disjunctor cell. The disjunctor cell helps in spore dispersal.

The aeciospores are unicellular, binucleate (n + n), thin-walled and orange in colour. The young aeciospores are polyhedral in shape, but becomes globose with maturity. They are dispersed by air current and can infect only the graminaceous host i.e., wheat plant. After falling on wheat plant (stem and/or leaf), they germinate by producing germ tubes (n + n), that penetrate inside the host tissue and establish infection.

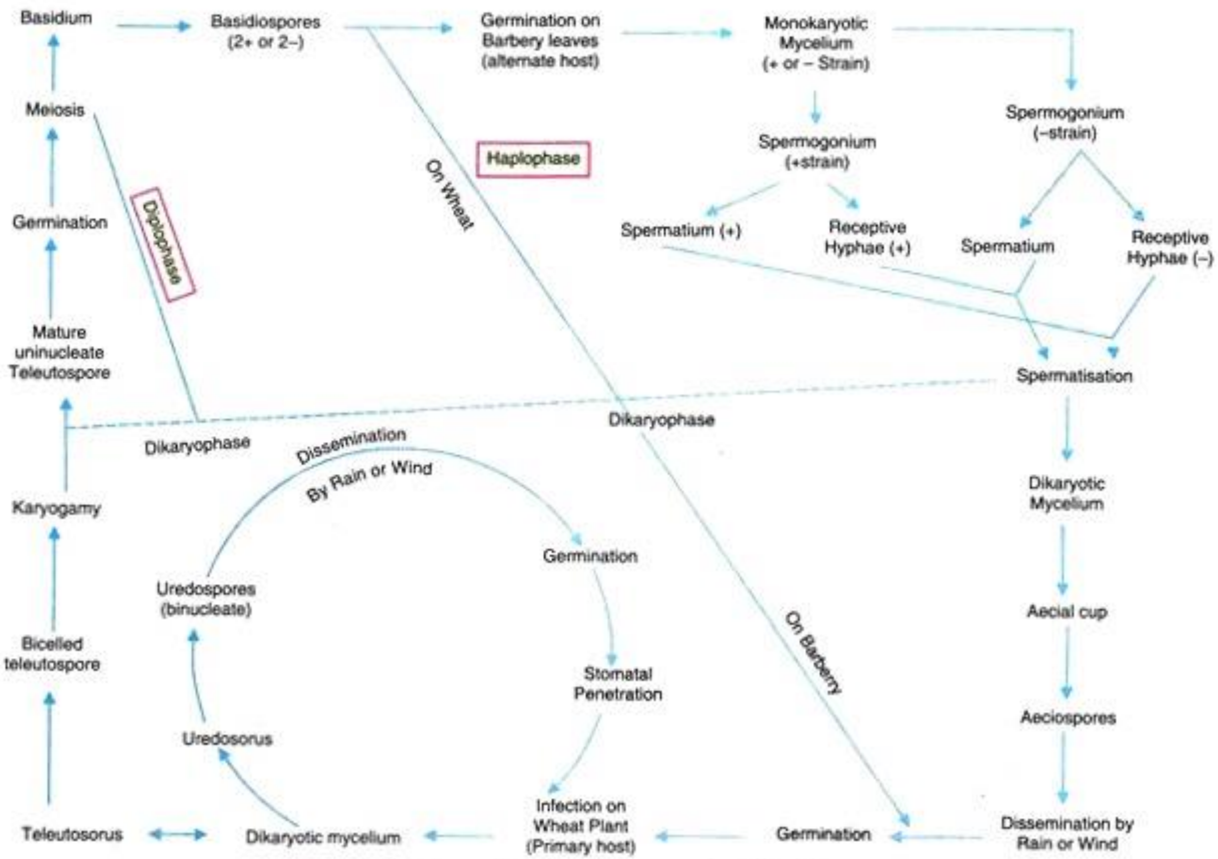


Fig. 14.23. *Puccinia graminis*. Schematic representation of life cycle.

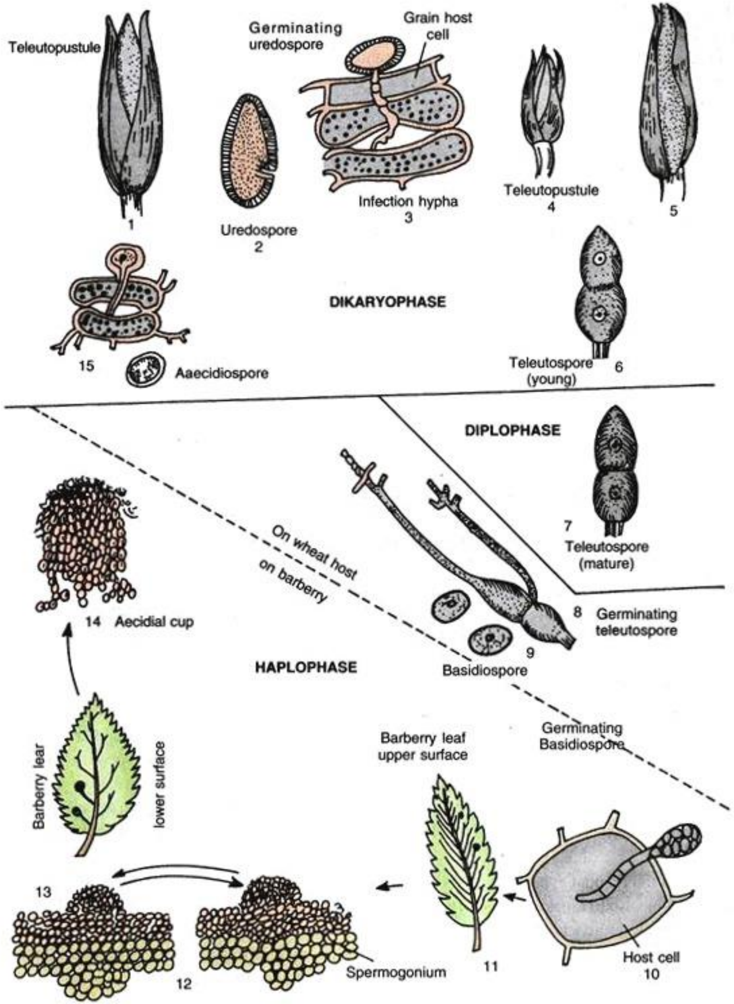


Fig. 14.24. Diagrammatic representation of the life cycle of *Puccinia graminis*.

Cercospora:

The form-genus Cercospora includes about 3,800 form-species. Majority of them are plant pathogens which cause leaf spot diseases of higher plants of economic value (Fig. 16.11 A).

Commonly the leaf spot disease is called the tikka disease. C. personata and C. arachidicola are the two commonly known form-species which are responsible for the leaf spot (tikka) disease of groundnut (Archis hypogea).

Cercospora – acervulus

Cercospora arachidicola on ground nut leaf

Tikka Disease of Groundnut

Mycelium of Cercospora:

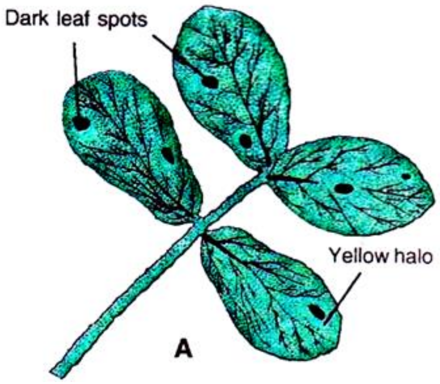
The mycelium in many species (C. personata) is entirely internal. The hyphae ramify in the intercellular spaces between the mesophyll cells of the host leaf obtaining nutrition by sending branched haustoria into the spongy and palisade cells.

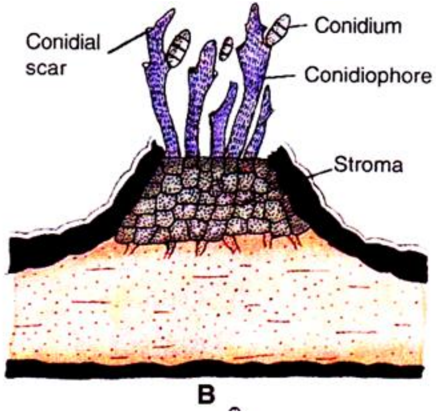
In some form species (C. arachidicola) the mycelium consists of both external and internal hyphae. The latter in the beginning are intercellular but later on become intracellular. They do not produce haustoria.

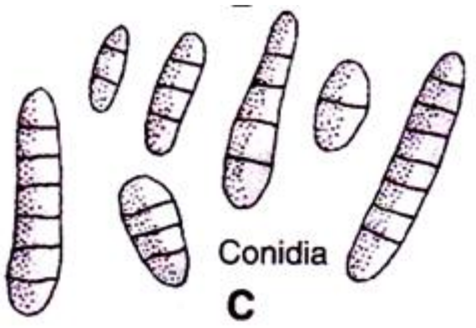
Before the mycelium enters the reproductive phase, the hyphae accumulate and become compacted to form brown to black globular mass of hyphae, the stroma immediately beneath the epidermis of the host leaf in a substomatal cavity

Asexual reproduction:

It takes place by means of long, cylindrical usually hyaline, multiseptate conidia (C) which are abstricted successively at the tips of unbranched, dark conidiophores (B). The latter arise in tufts from a stroma lying in a substomatal cavity and emerge by rupturing the overlying epidermis. The conidiophores are geniculate (Knee-jointed) and 1-2 septate. The conidium, as it falls off, leaves a scar on the conidiophore.







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