Botany

UG, Semester-II

Course-BOTHC-3

(Mycology And Phytopathology)

Unit:1-7

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Unit 1: Introduction to true fungi

General characteristics;
Affinities with plants and animals;
Thallus organization;
Cell wall composition;
Nutrition;
Classification.

General characteristics of fungus

1. A fungus is a heterotrophic achlorophyllous **eukaryote** that digests food externally by extra cellular enzymes and **absorbs nutrients** directly through its cell walls through absorption.
2. Most fungi reproduce by spores and have body (thallus) composed of microscopic tubular cells called **hyphae** which branch to form a net-like interconnected form of hyphae called **mycelium**.
3. Fungi are **heterotrophs** and, like animals, obtain their carbon and energy from other organisms.
    1. Some fungi obtain their nutrients from a living host (plant or animal) and are called **biotrophs**;
    2. others obtain their nutrients from dead plants or animals and are called **saprotrophs** (saprophytes, saprobes).
    3. Some fungi infect a living host, but kill host cells in order to obtain their nutrients; these are called **necrotrophs**.

- **Secondary metabolites:** The ability of fungi (especially saprobes) to grow on simple **defined medium** and produce secondary metabolites, antibiotics and other bioactive compounds

- **Distribution:** Ubiquitous, present in every conceivable niche.

- **Reserved food material**: e.g. trehalose, glycogen, sugar alcohols and lipids.

- **Total fungi on earth**: In 1991, a landmark paper estimated that there are 1.5 million fungi on the Earth and only 70000 fungi had been described at that time.

- **Fungal Code: International Code of Nomenclature for algae, fungi, and plants (ICN),** Melbourne Code adopted by the Eighteenth International Botanical Congress , Melbourne, Australia, July 2011.

FUNGI: GENERAL CHARACTERISTICS

What are fungi? How fungi differ from other plants?

- Fungi (fungus) in Latin literally means mushrooms
- They are eukaryotic organisms
- With true nucleus and membrane bounded organelles
- They are non-vascular Cryptogams
- Included in Thallophyta along with algae and Lichen
- Have undifferentiated plant body
- Study of fungi: mycology
- Latin 'mykes' means fungus

FUNGI: GENERAL CHARACTERISTICS

How fungal cell wall is different from the cell wall of other plants?

- Protoplast of fungi is surrounded by distinct cell wall
- In slime molds (lower fungi, closely related to Protistis) the cell wall is absent
- Main component of cell wall is chitin (a major difference of fungal cell wall from plant cell wall)
- Chitin is a polymer of an N-acetylglucosamine, a derivative of glucose
- In some lower fungi (Oomycetes) cell wall is composed of cellulose and glucan

Nature of Fungi

- **Cell**: Represent a **heterogeneous assemblage** of eukaryotic cell.

- **Nutritional mode: Heterotrophic** (saprotroph, biotroph, necrotroph, symbiotic) or assimilative for organic carbon and some non elemental source of nitrogen.

- **Nutrition takes up:** Fungal cells imbibe or absorb, rather than ingest nutrients and have rigid cell walls.

- **Reproduction**: Vast majority are haploid organisms reproducing either sexually or asexually through spores. Although there is a **multitude of spore forms**; basic 2 types

    - Sexual spores followed by meiosis **(meiospores)** and borne on specialized generative structures frequently clustered into a fruit body.

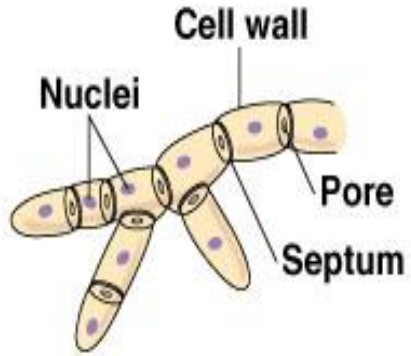
    - Asexual spores followed by mitosis (**mitospores**)

Distribution fungi

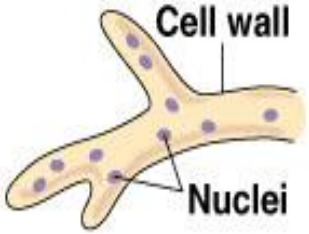
- Ubiquitous, present in every conceivable niche (Water, Air, Soil and within living organisms)
-
- In 1991, a landmark paper estimated that there are 1.5 million fungi on the Earth and only 70000 fungi had been described at that time.

- **Fungal Code: International Code of Nomenclature for algae, fungi, and plants (ICN),** Melbourne Code adopted by the Eighteenth International Botanical Congress , Melbourne, Australia, July 2011.

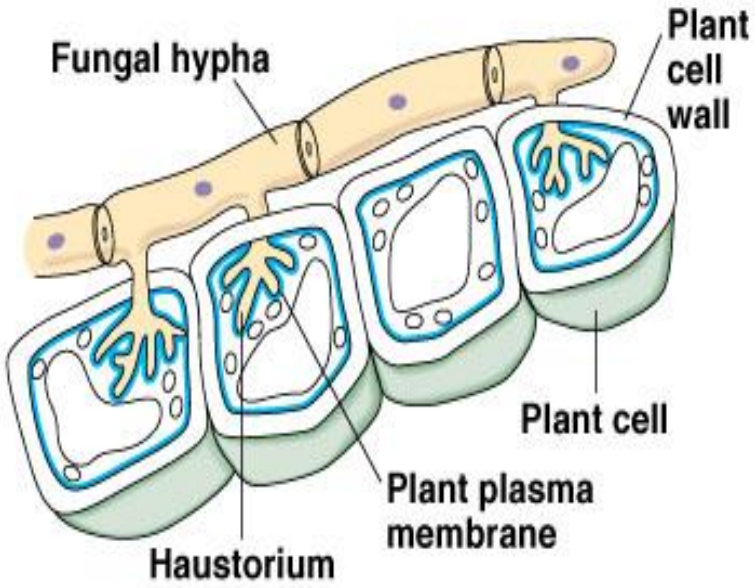
Modifications of hyphae



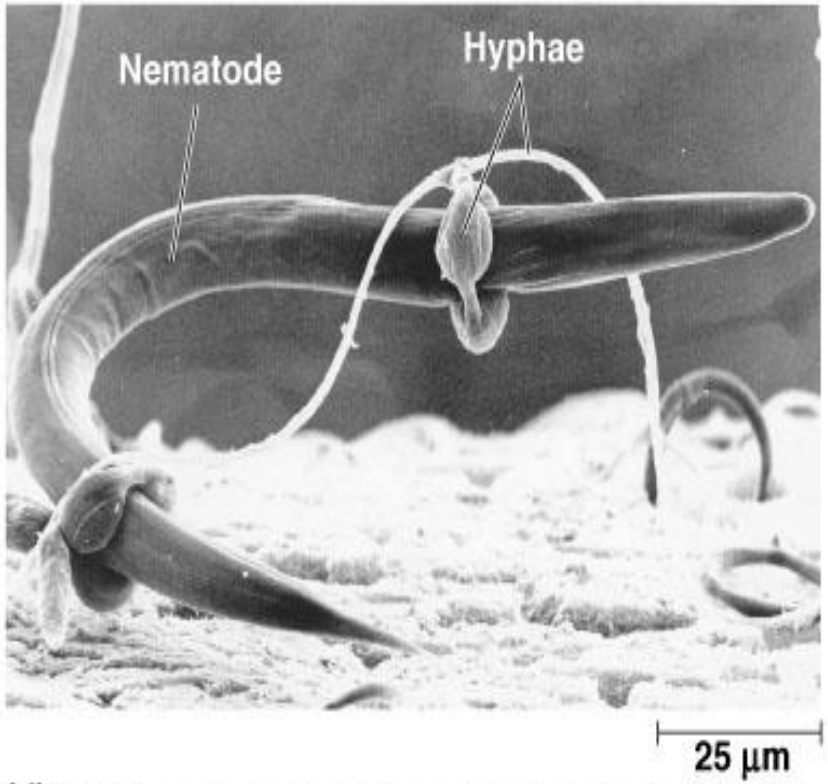
(a) Septate hypha



(b) Coenocytic hypha



(c) Haustoria



(d) Hyphae adapted for trapping and killing prey

FUNGI: GENERAL CHARACTERISTICS

What is dolipore septum?

- In Basidiomycetes (a division of fungi) the septa is highly advanced, here dolipore septa occurs
- On both sides of dolipore septum a double membrane structure called septal pore cap or parenthosome occurs
- Parenthosomes of dolipore septa act as valves which can regulate the passage of cell contents between cells

Mode of Nutrition

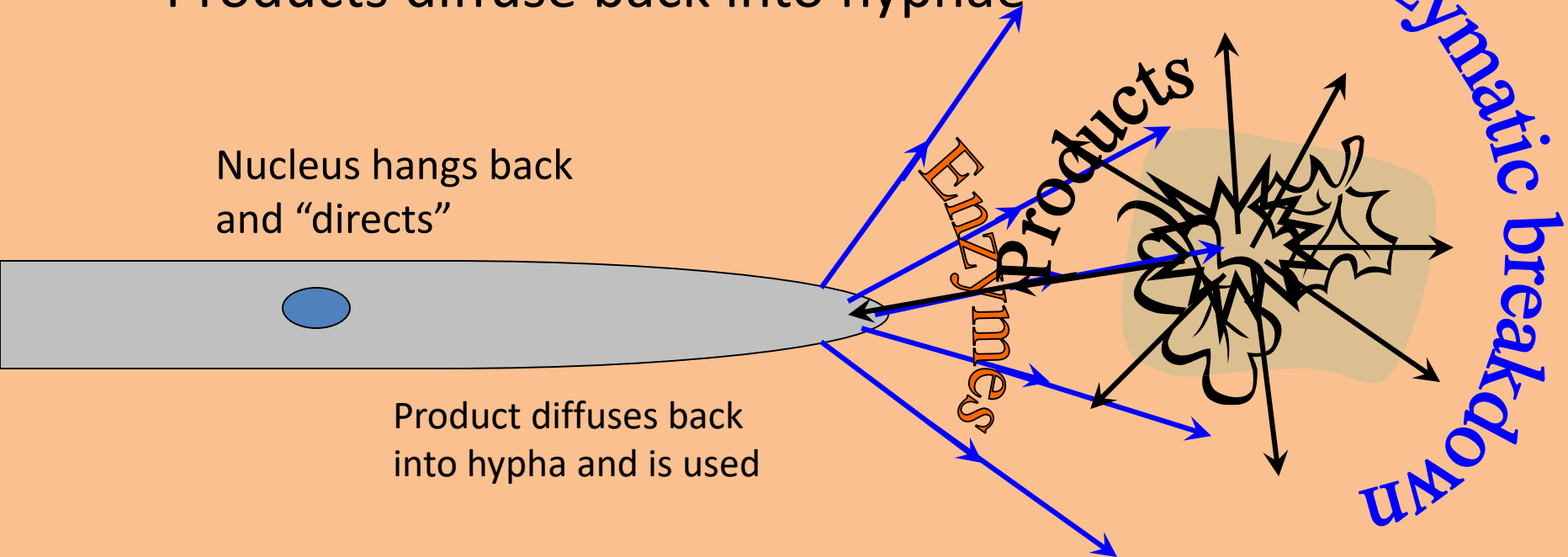
- **Chemo-organotrophic:** They utilise pre-existing organic sources of carbon from their environment and the energy from chemical reactions to synthesis the organic compounds they require for growth and energy .
- Some fungi obtain their nutrients from a living host (plant or animal) and are called biotrophs; others obtain their nutrients from dead plants or animals and are called saprotrophs (saprophytes, saprobes). Some fungi infect a living host, but kill host cells in order to obtain their nutrients; these are called necrotrophs.

- **Heterotrophic** - 'other food'
  - Saprophytes or saprobes - feed on dead tissues or organic waste (decomposers), e.g. *Penicillum* sp, *Pleurotus* sp, *Rhizopus* sp
  - Symbionts - mutually beneficial relationship between a fungus and another organism e. g. VAM, Lichen
  - Parasites - feeding on living tissue of a host.
    - Parasites that cause disease are called pathogens. *Phytophthora* sp, *Helminthosporium* sp.

Nutrition takes up

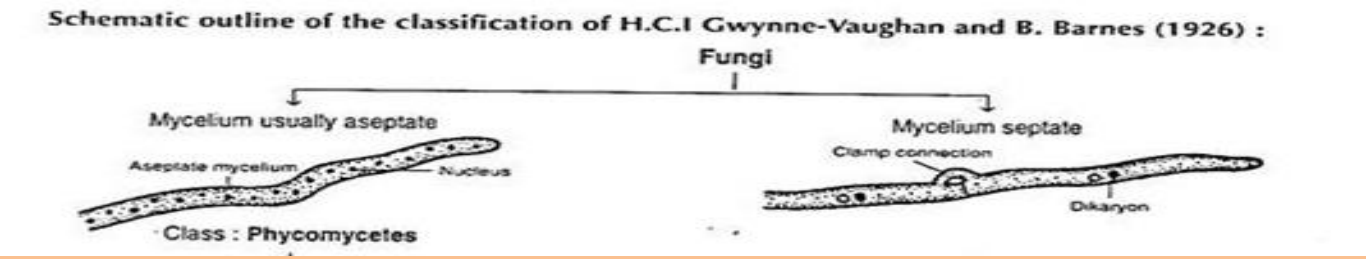
Fungal cells imbibe or absorb, rather than ingest nutrients

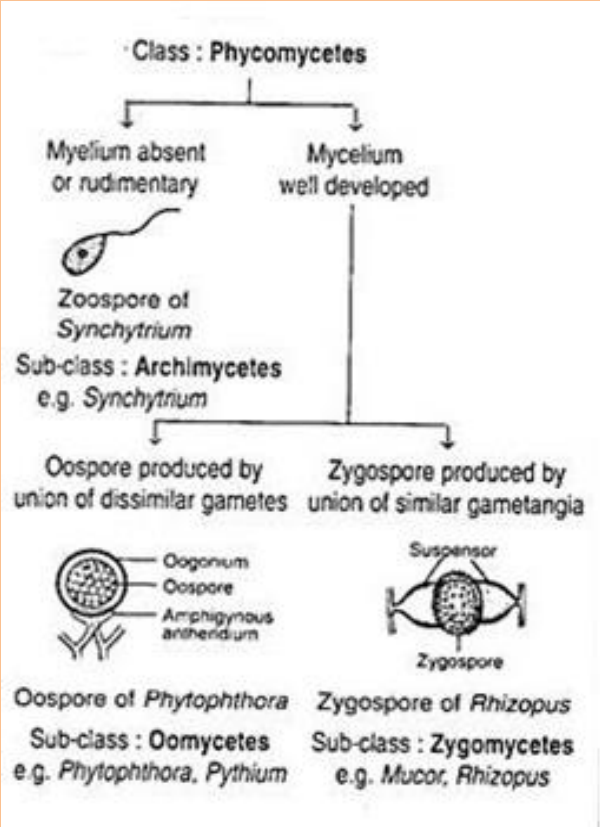
- Fungi get carbon from organic sources
- Hyphal tips release enzymes
- Enzymatic breakdown of substrate
- Products diffuse back into hyphae

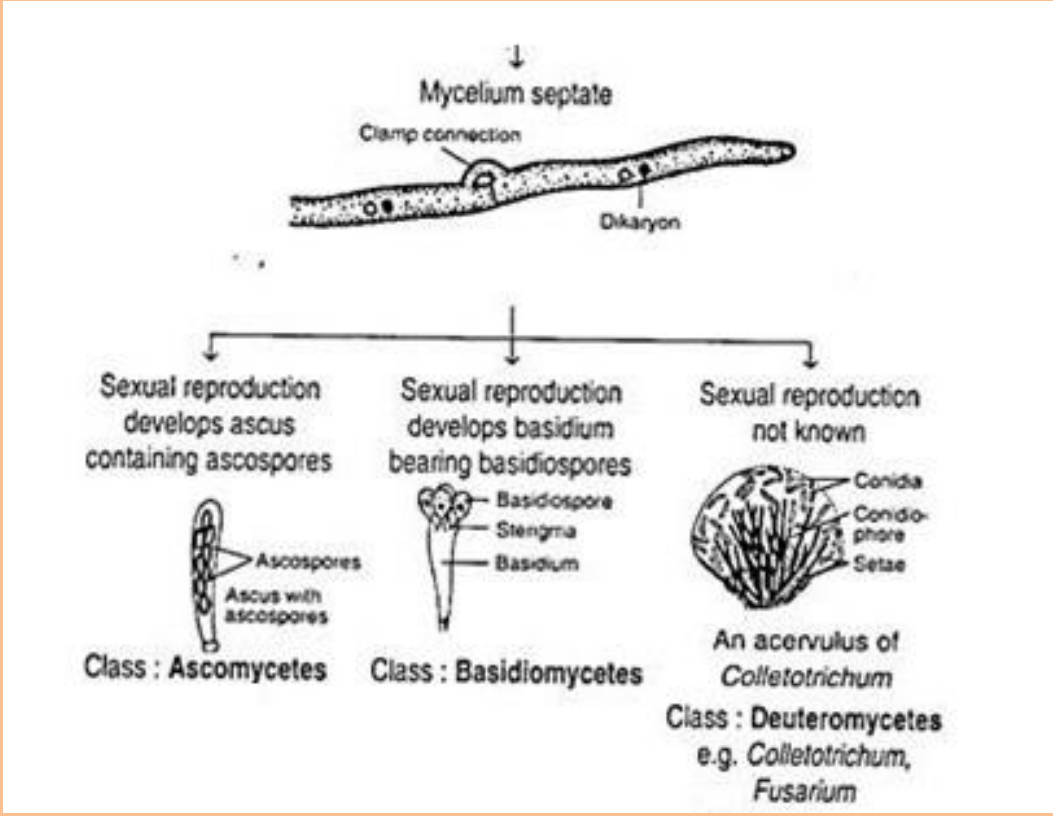


- Fungi obtain their nutrients by the process of **ABSORPTION**.
- **SMALL MOLECULES** (e.g. simple sugars, amino acids) in solution can be absorbed directly across the fungal wall and plasma membrane.
- **LARGER, MORE COMPLEX MOLECULES** (e.g. polymers such as polysaccharides and proteins) must be first broken down into smaller molecules, which can then be absorbed. This degradation takes place outside the fungal cell or hypha and is achieved by enzymes which are either released through or are bound to the fungal wall. Because these enzymes act outside the cell they are called **EXTRACELLULAR ENZYMES**.
- Since water is essential for the diffusion of extracellular enzymes and nutrients across the fungal wall and plasma membrane, actively growing fungi are usually restricted to relatively moist (or humid) environments.

Classification of Fungi

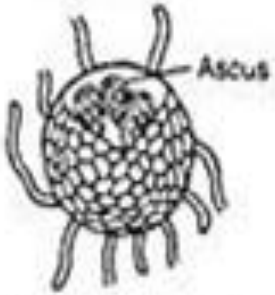






Class : **Ascomycetes**

Round ascocarp contains asci arranged irregularly

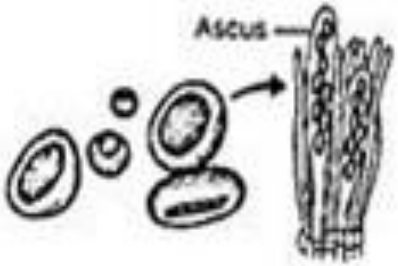


Cleistothecial ascocarp of *Erysiphe*

Sub-class : **Plectomycetes**

e.g. *Erysiphae, Penicillium*

Cup-shaped ascocarp contains asci arranged parallel



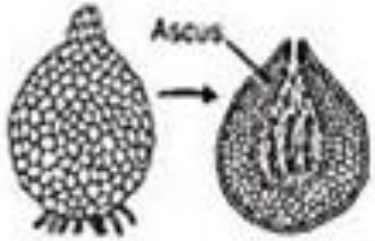
Apothecial ascocarps of *Ascobolus*

Asci and paraphyses in v. section (portion)

Sub-class : **Discomycetes**

e.g. *Ascobolus, Peziza*

Flask-shaped ascocarp contains asci arranged parallel



Perithecial ascocarp of *Neurospora*

Perithecium in section

Sub-class : **Pyrenomycetes**

e.g. *Neurospora, Daldenia*

Class : **Basidiomycetes**

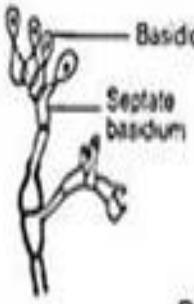
No. of basidiospores per basidium are indefinite

Germinated teliospore of *Ustilago avenae*

Sub-class :
Hemibasidiomyccetes
e.g. *Ustilago, Tilletia*

No. of basidiospores per basidium are definite

Basidium septate



Germinated teleutospore of *Puccinia graminis*

Sub-class :
Protobasidiomycetes
e.g. *Puccinia*

Basidium continuous

Basidium of *Coprinus*

Sub-class :
Autobasidiomycetes
e.g. *Agaricus, Coprinus*

Sexual reproduction not known

An acervulus of *Colletotrichum*

Class : **Deuteromycetes**
e.g. *Colletotrichum, Fusarium*

Unit 2: Chytridiomycota and Zygomycota

Characteristic features;
Ecology and significance;
Thallus organisation;
Reproduction;
Life cycle with reference to *Synchytrium, Rhizopus* .

Chytridiomycota features

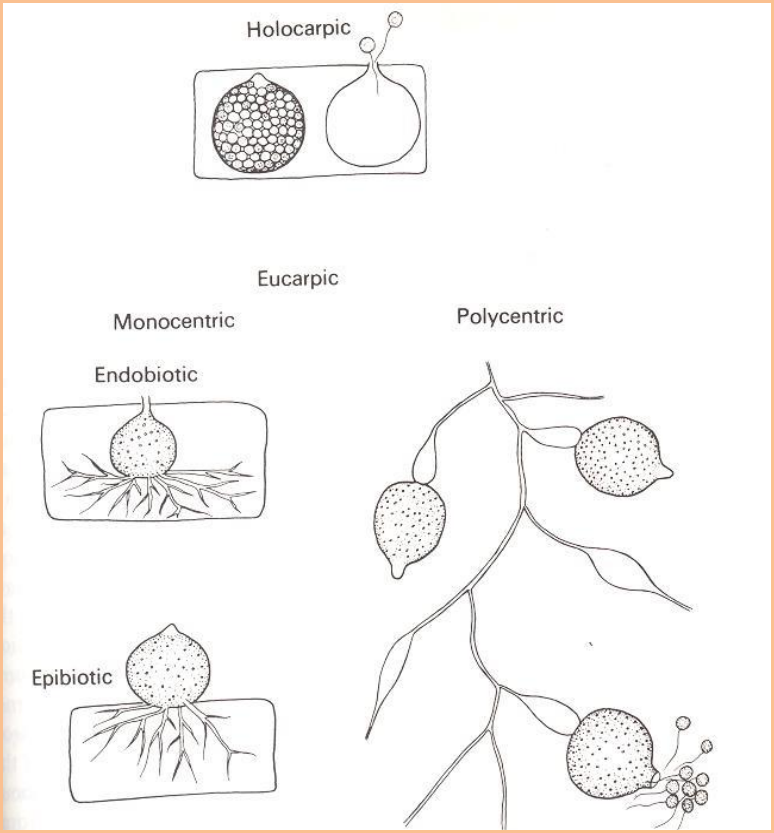
- Coenocytic hyphae (no cross walls) or may be unicellular.
- These fungi have uniflagellated cells (Protist characteristic).
- Cell Wall made of Chitin(Fungi characteristic).
- Absorptive mode of eating.
- Example: Chytrid

Ecology

i. Primarily aquatic
ii. Habitats – zoospores require free water in which to swim – many occur in aquatic habitats, also found in soil water
iii. Many species are saprotrophic – grow on a variety of substrates, most are aerobic, some anaerobic
iv. Some are parasitic on algae, other fungi, aquatic animals, some parasitic on higher plants (crops).
v. Saprotrophs grow on variety of substrates – "baiting"
vi. Parasites of algae, fungi, animals, higher plants – "black wart of potato" caused by ***Synchytrium endobioticum***.
vii. *Olpidium brassicae* is a cabbage parasite that is a vector for a plant virus.
viii. One species is parasitic on amphibians – mentioned in decline of frog populations - ***Batrachochytrium dendrobatidis***

Thallus Types

•Single multinucleate thallus with no appendages.
•If grows within host cell-endobiotic or outside – **epibiotic**.
•If entire thallus is converted to zoosporangium-**holocarpic**.
•During differentiation, the entire thallus is not converted into a zoosporangium – **eucarpic**.
•Many species form rhizoids – tapering structures that anchor thallus and increase surface area for absorption of nutrients.
•Some chytrids produce only one zoosporangia per thallus – **monocentric.**
•Others produce multiple zoosporangia – **polycentric**
Produce rhizomycelium



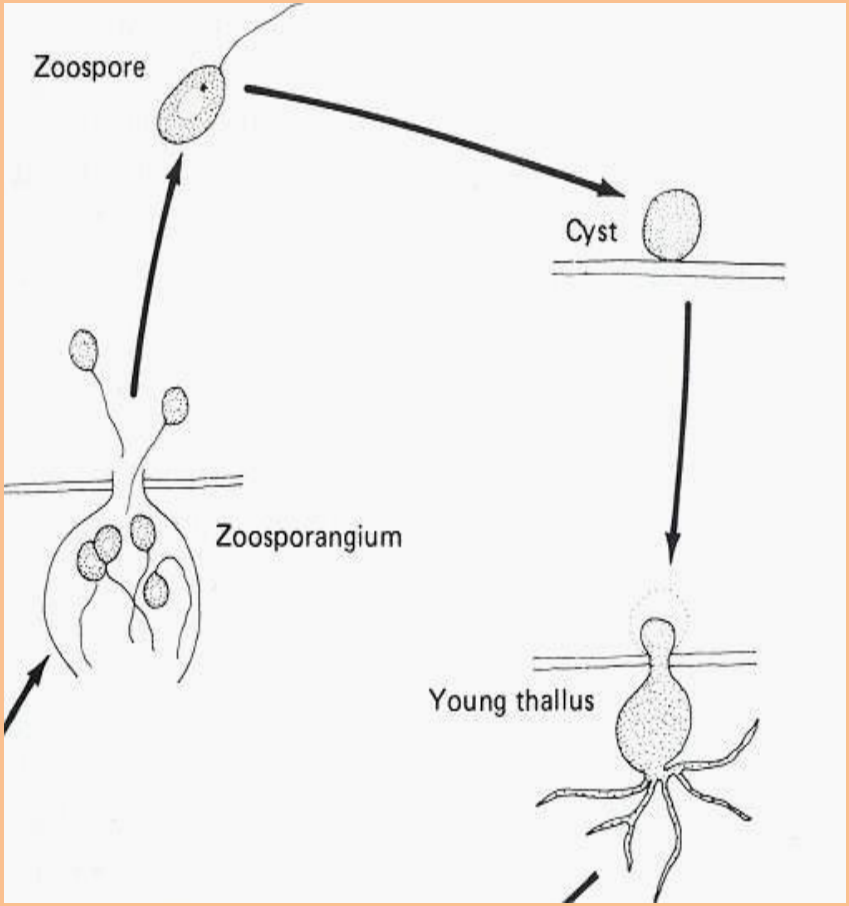
Asexual Reproduction

Asexual reproduction by zoospores produced in zoosporangia.

Zoospores have one posterior flagellum.

Initially zoospores encyst – withdraw or lose flagellum, rapidly form a cell wall.

Cyst then germinates to form young thallus



Sexual reproduction

Great deal of variation, but nuclear events, e.g. meiosis, not clearly determined

Fusions have been seen between zoospores, gametangia, rhizoids

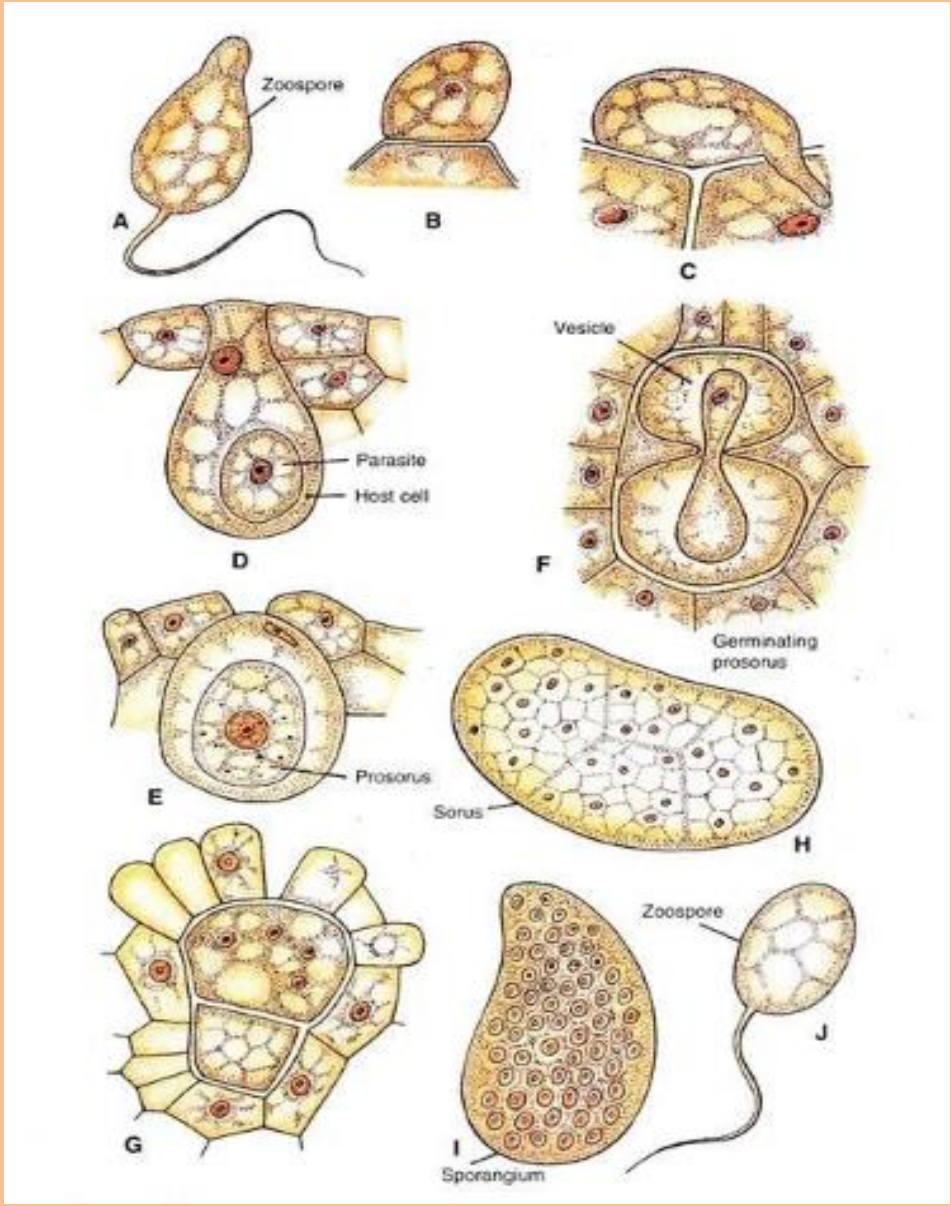
Synchytrium endobioticum

- *Synchytrium endobioticum* causes the black wart or wart disease of potato (Solanum tuberosum). According to Karling (1964), it has a broad spectrum of Solanaceous sp. in its host range. The potato wart disease is widely distributed in the potato growing regions of the world.
- It is prevalent in areas with a cool moist climate. In India, it has been reported from the Darjeeling district (West Bengal) and areas of Nepal contiguous to the former. The fungal parasite cannot survive in hot places

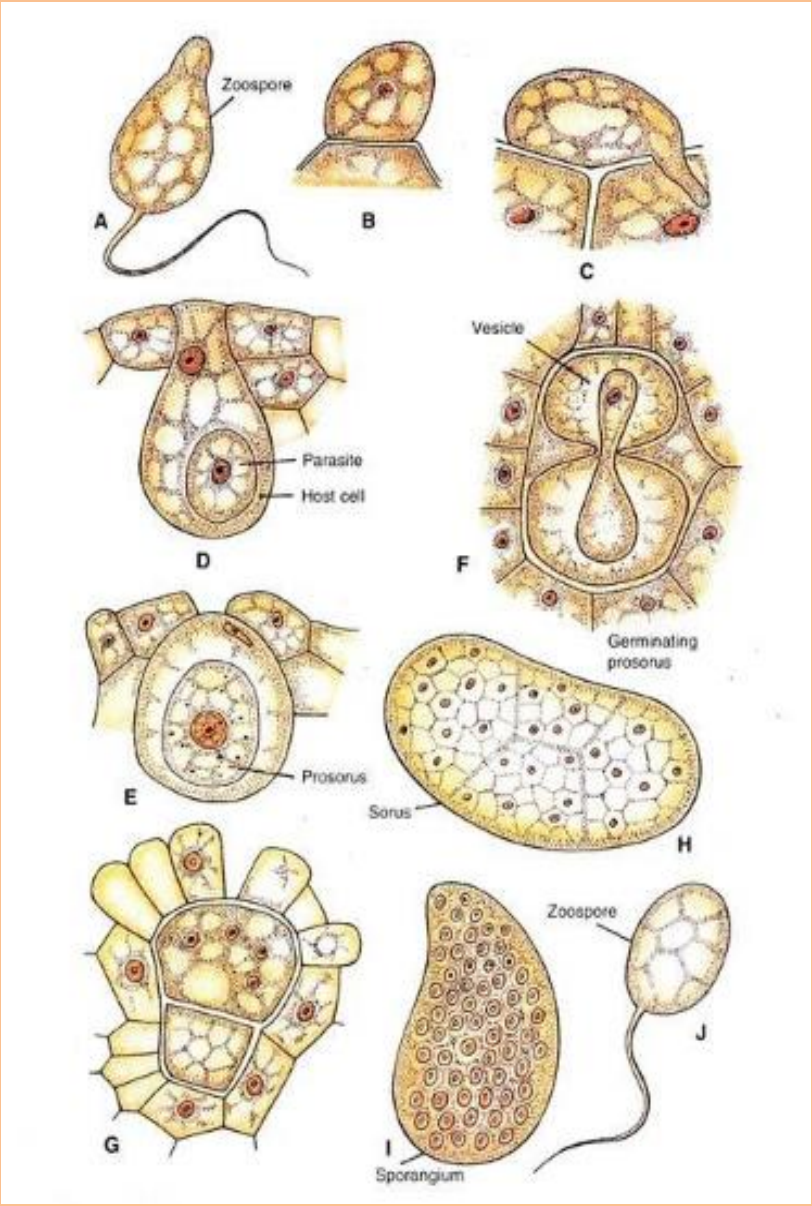
Life Cycle of *Synchytrium Endobioticum*

- *Synchytrium endobioticum* is a holocarpic endoparasite.
- The life cycle of S.endobioticum has been studied by Curtis (1921) and Kohler (1923, 1931).
- **Asexual Phase:** The asexual phase of the life cycle of this parasitic fungus starts with the infection of the host by the parasite.
- The causal organism (*S. endobioticum*) is present in the wart tissue of potato tuber or in soil in the form of resting sporangia.

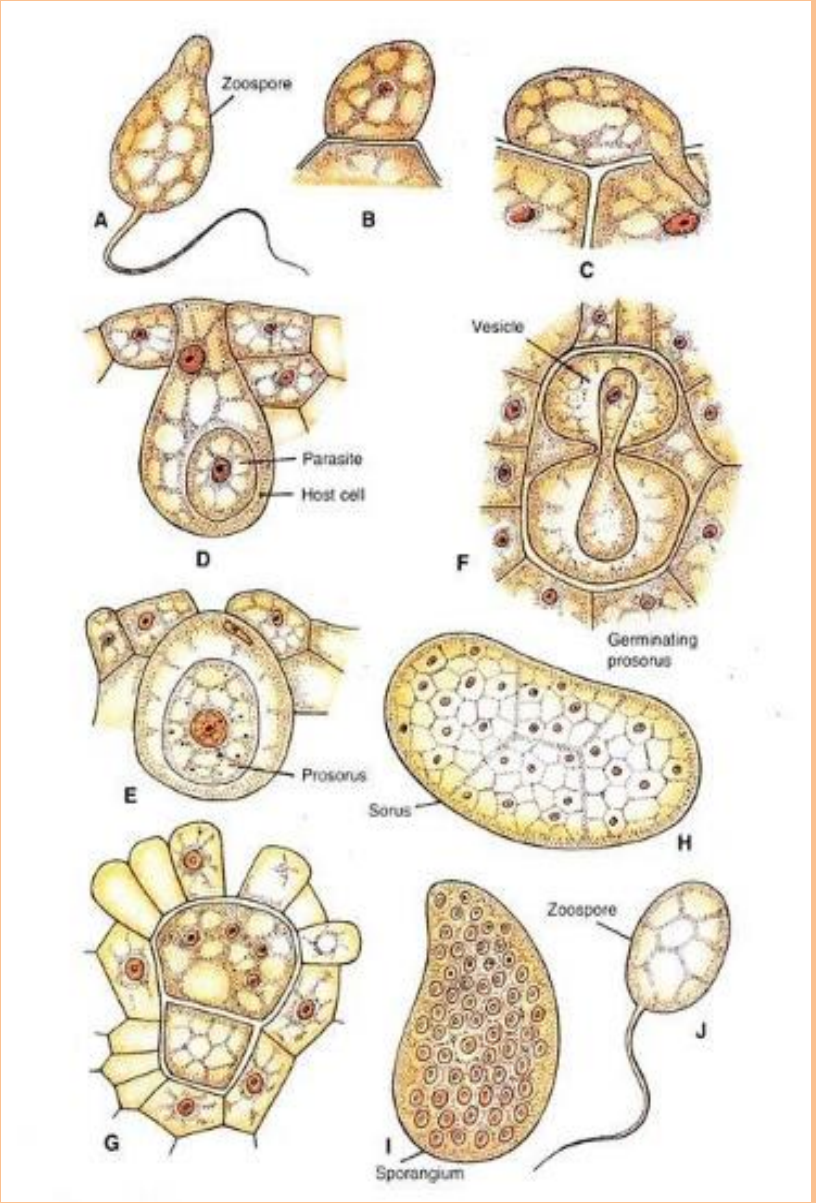
- Under suitable conditions (presence of potato seedlings in the field, moist soil and suitable temperature), the resting sporangium or spore germinates releasing posteriorly uniflagellate, naked haloid zoospores which are liberated by the rupture of the enclosing membrane.
- The liberated zoospore (A) swims in a film of water in the contaminated soil. It may finally reach a potato plant and come to rest on the host surface (tuber or stolon). The zoospore (B) then withdraw its flagellum and germinates by putting out a small, thin, naked, peg-like germ tube called the infection peg or penetration tube (C).
- Subsequently the uninucleate protoplast of the zoospore enters the host as a naked mass.



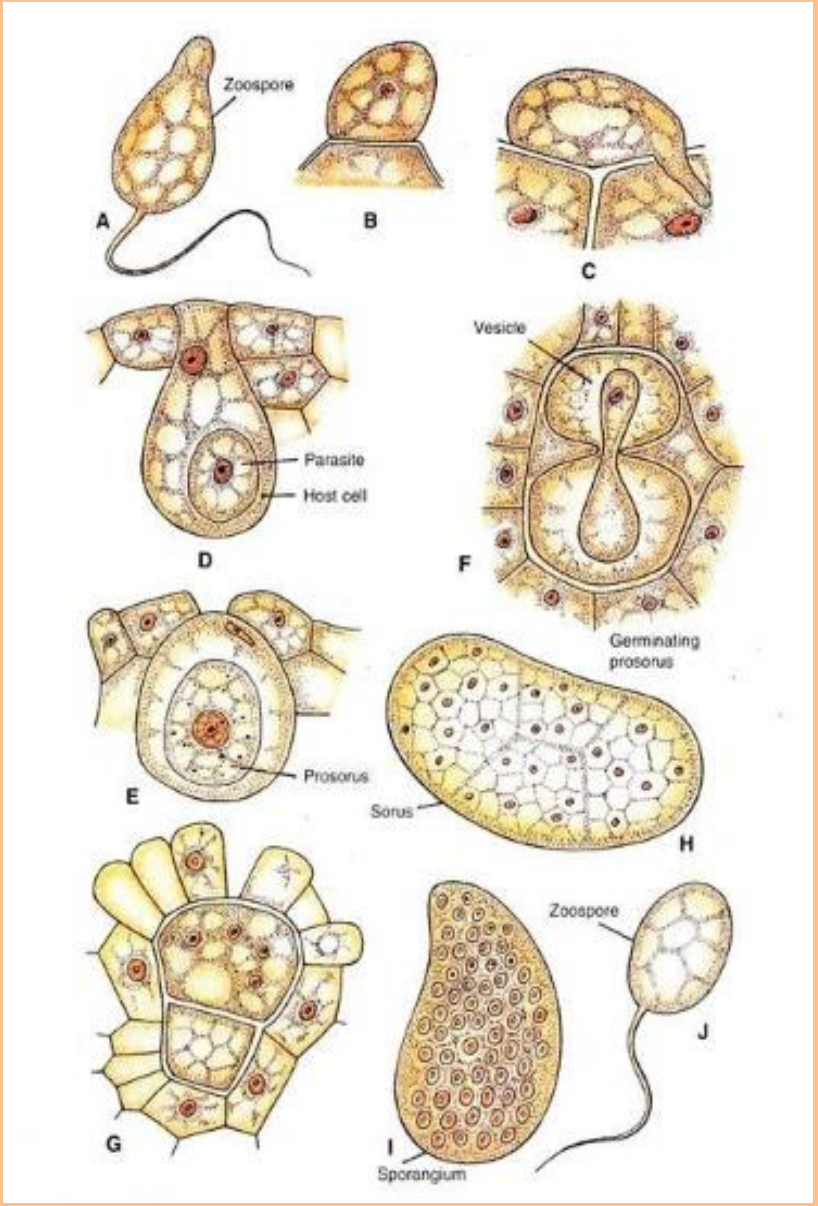
- **Prosorus Stage:** Once within the epidermal cell of the host it promptly sinks to its lower part (D) where it develops into a uninucleate intracellular thallus with a comparatively large nucleus (D) at the expense of the food material absorbed from the host cell. The unicellular parasite rounds off and secretes a thin wall around it. It increases in size as the infected host cell is induced to enlarge and become pear-shaped.
- Reaching a certain size, the unicellular pathogen thallus secretes a wall around it which is differentiated into an outer, thick, golden yellow **exospore** and an inner, thin, hyaline **endospore** (E). The nucleus also increases in size. The mature thallus with a heavy golden wall around it is called the **prosorus** (pi. prosori).
- Meanwhile the adjacent epidermal cells and the surrounding cortical cells divide rapidly and repeatedly to form a minute gall or tumor or a wart-like tissue. The infected hypertrophied cell containing the prosorus in its lower part by now is dead. It is in the centre of a rosette of more or less hardened epidermal cells.



- **Germination of Prosorus-** The mature prosorus germinates within the dead host cell. A pore is formed in the thick exospore layer. The thin, hyaline endospore layer extrudes throuth the pore in the form of vesicle (F). The contents, of the prosorus migrate into the vesicle which extends into the upper half of the host cell. During migration, prosorus nucleus divides (G) repeatedly to form about 32 daughter nuclei.
- The multinucleate protoplast of the vesicle is now partitioned by newly formed thin, hyaline walls into four to nine multinucleate polygonal compartments (H) or segments. Each segment has a wall of its own and functions as a zoosporangium. The whole mass of 4 to 9 sporangia compose a **sorus**.

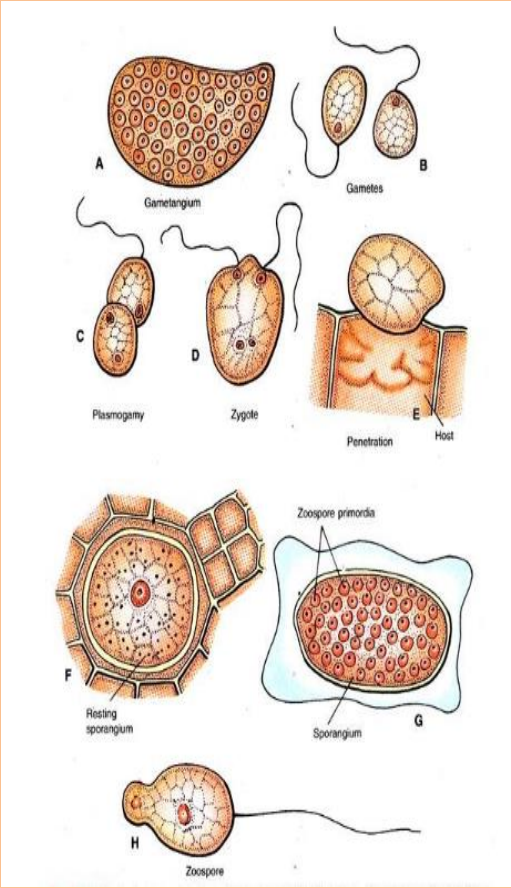


- **Sporangia-** The nuclei in each sporangium undergo further division to form 200 to 300 daughter nuclei. The multinucleate protoplast is finally organised into uninucleate daughter protoplasts by aggregation and rounding off of the cytoplasm round the nuclei (H).
- Each daughter protoplast becomes metamorphosed into a posteriorly uniflagellate zoospore. In this way about 1500 zoospores are produced from the single, original zoospore which initiated the infection of the host.
- The mature sporangia in the sorus absorb water and swell.
- The zoospores escape through an opening (a slit) in the sporangial wall, or upon the rupture of hyaline projections in the sporangial wall which are termed papillae. The released zoospores (J) swim in a film of water in the soil.
- Some of these may reinfect the host and repeat the sequence of events outlined above. This completes the asexual phase in the life cycle of *Synchytrium*.



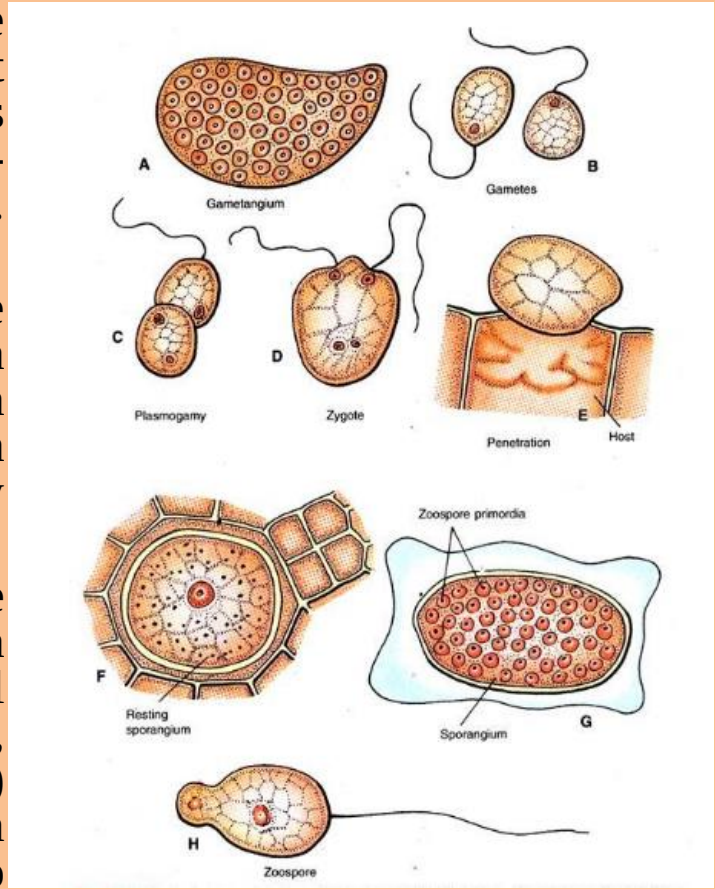
Sexual Phase

- **Gametangia:** Under conditions of scarcity of water (dry weather), which means the end of growing season, the segments of the prosorus function as gametangia (A) which are in no way different from sporangia. The gametangia produce planogametes (B) similar to zoospores in every respect except size. The gametes are smaller than the zoospores and fuse in pairs (C).
- Fusion occurs after liberation in a film of water on the surface of the host or in the soil, between planogametes from different gametangia in the same sorus. Plasmogamy (fusion of the gametes) is followed by karyogamy which probably takes place at the time of host penetration.



- **Zygote :** The diploid zygote formed by the fusion of the planogametes is biflagellate. It swims about in a film of water in the soil. Finally it comes to rest on the surface of the host (tubers) and penetrates the epidermal cell (E) in much the same way as the haploid zoospore.
- The flagella are removed and absorbed before entry into the host. Within the host the zygote sinks to the bottom of the infected hypertrophying epidermal cell of the host and grows in size.

- **Resting Sporangium :** The presence of the parasite (zygote) in the host causes hypertrophy and hyperplasia of the surrounding cells. They are stimulated to divide repeatedly. Consequently the infected cell is soon buried deep within the host tissue. The diploid zygote (parasite) enlarges and is enclosed in a thick, reticulately ornamented, two-layered wall to become a resting sporangium. Some authors call it a resting or winter spore.
- The resting spores are released into the soil by the decay of the infected tubers. In the soil they remain dormant through winter. It has, however, been reported that resting spores can remain viable in the warty tubers in soil for five years and air dry soil for fifteen months.
- Sharma and Commack (1976) reported that the resting spores of S. endobioticum may remain dormant in the soil for 25-30 years. Several investigators such as Curtis (1921), Glynne (1926), Karling (1967) and Sharma and Commack (1976) reported that the resting spores of S. endobioticum function as sporangia giving rise directly to zoospores



- **Germin-** At the onset of conditions favourable for growth (following spring when the host is available), the resting sporangium germinates. A number of granule-like structures make their appearance in the cytoplasm.
- These are zoospore primordia. Further, each zoospore primordium extrudes chromatin. This is suggestive of meiosis. The multinucleate protoplast undergoes cleavage to form numerous uninucleate, dauthter protoplasts.
- Each daughter protoplast gets metamorphosed into a posteriorly uniflagellate zoospore. The outer layer of the sporangial wall ruptures. The zoospores (H) escape throuth the exit tube. They are larger in size than the zoospores released from the sporangium of the asexual cycle. They, however, function in the same way and may infect the host to repeat the asexual phase.
- The effect of zygote infection on tuber is more serious and destructive as compared with zoospore infection. The zygote infection induces excessive rate of division (hyperplasia) not only of the adjacent host cells but also of the cells some distance away from the site of infection.
- Hyperplasia is followed by excessive enlargement of the resultant cells (hypertrophy). Hypertrophy and hyperplasia of the surface cell layers of the infected potato tuber and the resultant abnormal growth activity leads to the formation of large, unsightly and useless masses of crinkled black warty tissue (4.3) known as the wart or tumour.
- The wart is soft and pulpy and thus invaded by bacteria which cause rot. The warty tubers become useless and a source of infection.

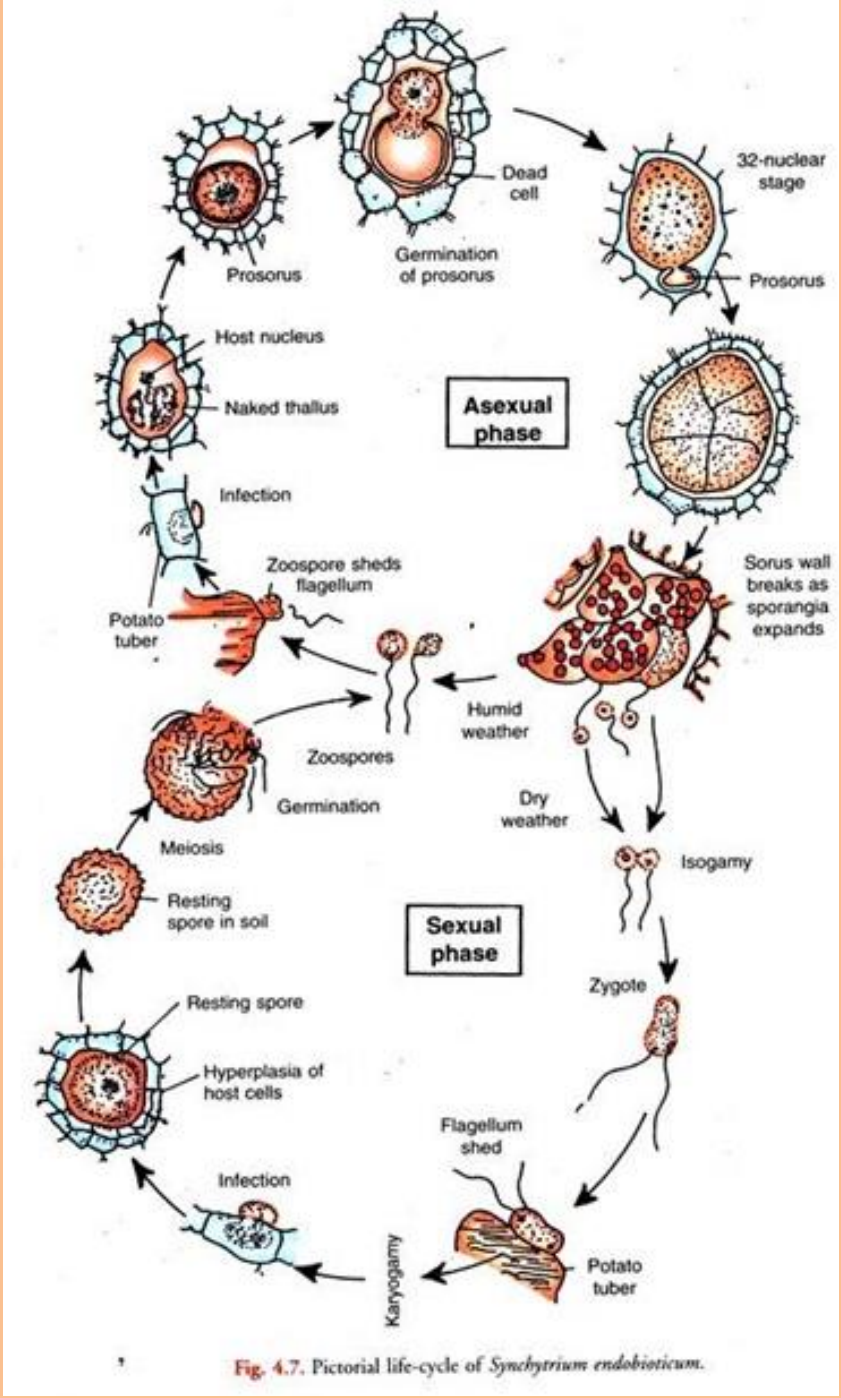


Fig. 4.7. Pictorial life-cycle of *Synchytrium endobioticum*.

Unit 3: Zygomycota

General features

- Zygomycota, like all true fungi, produce cell walls containing chitin.
- Somatic phase as mycelia, hyphae which are generally coenocytic because they lack cross walls or septa.. Unlike higher fungi comprising the Ascomycota and Basidiomycota which produce regularly septate mycelia.
- ***Gametangial Copulation*** is a type of sexual reproduction in zygomycota in general *the gametangia fuse with each other, lose their identity and develop into a* ***zygospore.***

General features

- Most Zygomycota are thought to have a ***zygotic or haplontic life cycle***.Thus; the only diploid phase takes place within the zygospore. Nuclei within the zygospore undergoes meiosis during germination,
- Asexual reproduction take place in specialized structures called ***Mitosporangia or sporangia.*** Mitosporangia that contain few to several thousand of sporangiospores (spores) depending on the species. Mitosporangia are carried by specialized hyphae is known (sporangiophores).

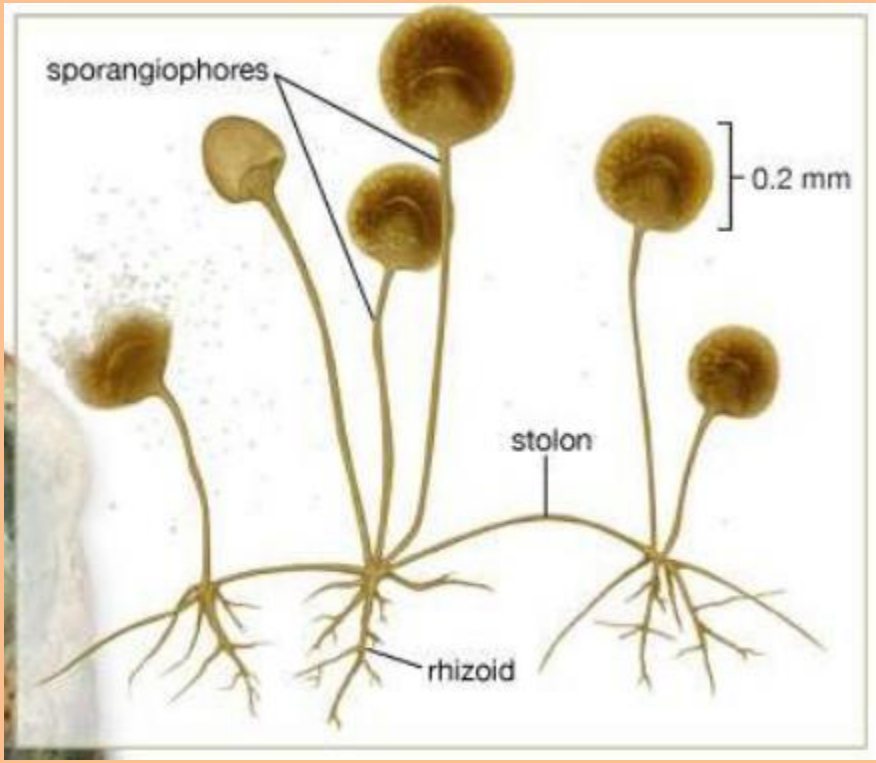
General features

- Chlamydospores are another type of asexual spores different from sporangiospores.
- It is naked not produce inside fruiting body (sporangium) and forming by dividing of hyphae into many parts by cross wall with thick cell wall in order to resist the severe environmental conditions .
- Chlamydospores have no mechanism for dispersal.
- In zygomycetes the formation of chlamydospores is usually intercalary. However, it may also be terminal.
- Each chlamydospore germinate to form primary mycelium like the germination of spore .

General features

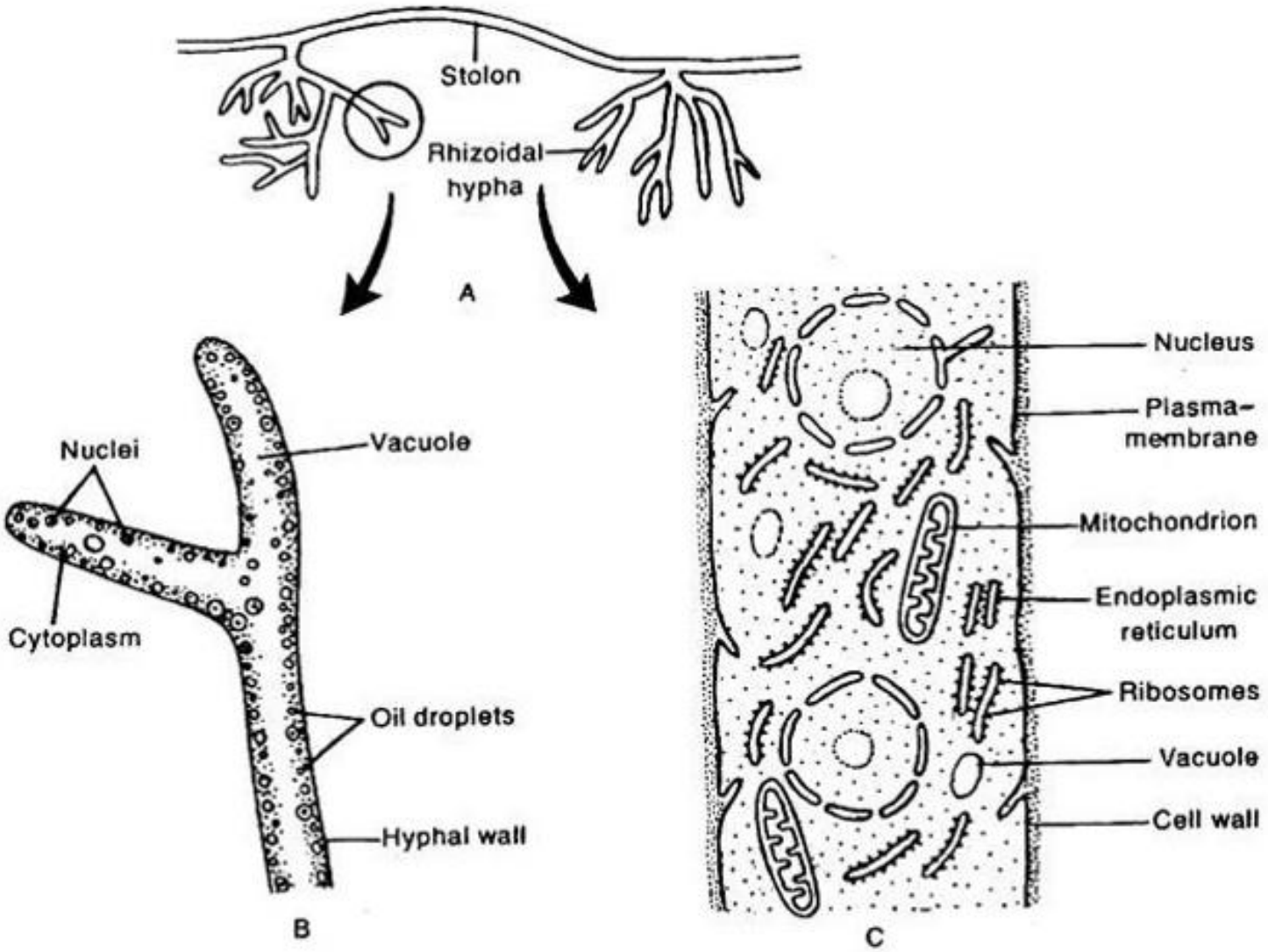
- They are primarily decomposers
- Asexual spores may be produced in sporangia
- Sexual reproduction occurs between + and – strains forming a 2n **zygote**;
- -a z**ygospore** develops and may lie dormant for a long period of time;
- -meiosis occurs just before germination
- -only the **zygote is diploid**; all hyphae and asexual spores are haploid
- The fungal mass of hyphae, known as the MYCELIUM penetrates the bread and produces the fruiting bodies on top of the stalks.
- Mycelia = a mass of hyphae or filaments
- Rhizoids = root-like hyphae The zhizoids meet underground and mating occurs between hyphae of different molds (SEXUAL REPRODUCTION)

Rhizopus stolonifer



Morphology and reproduction of black bread mold

- *Rhizopus stolonifer* is also known as black bread mold.
- Thallus is white cottony, much branched mycelium.
- Mycelium is differentiated into nodes and internodes. The nodal region bears much branched rhizoid grows downward, inside the substratum for anchorage and absorption of food.
- The internodal region is the aerial and arching hyphae, known as stolon, which when touches the substratum forms the nodal region



Rhizopus stolonifer : A. Vegetative mycelium, B. Portion of hypha under light microscope, C. Portion of hypha under electron microscope

Reproduction in Rhizopus: life cycle

1. Fragmentation
2. Asexual method: Sporangiospore formation and chalmydospore formation
3. Sexual method: gamentagial copulation

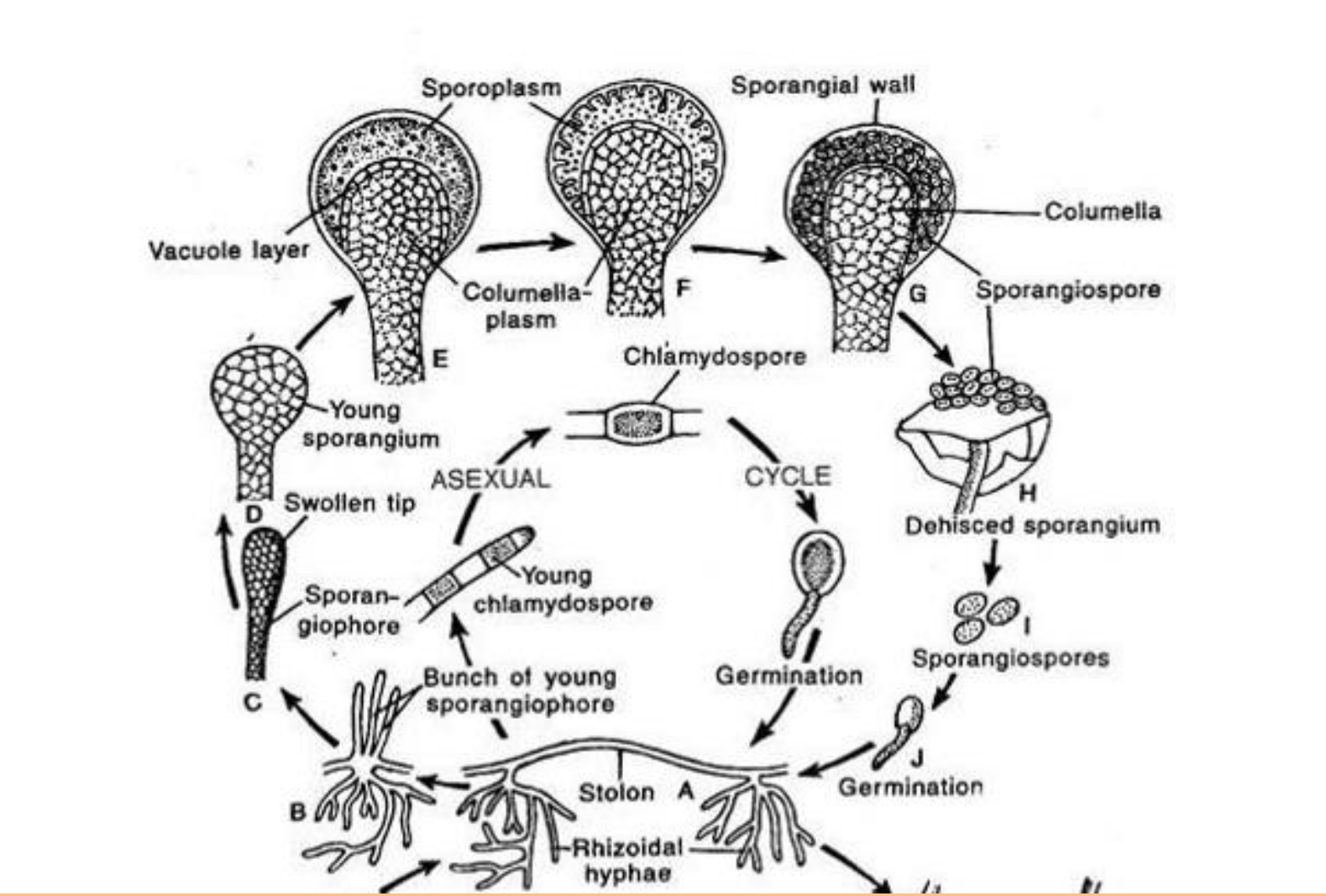
Fragmentation

- Disjoining of hyphae gives new organism.
- It is one of the common mode of reproduction in *Rhizopus*

Asexual reproduction in Rhizopus:

- It occurs during favorable condition
- Aerial hyphae develop from internode and arise to certain height
- The nuclei and cytoplasm push more and more towards the apical side, consequently the apex of the aerial hyphae swells up.
- The swollen part enlarges and develops into a large round **sporangium**
- **Sporangium** differentiates into two region; multinucleated **sporoplasm** and **vaculated columellaplasm**
- Nucleus in sporoplasm divides rapidly, and each nuclei gather some cytoplasm and transform into **spongiospore**
- After maturity columella collapsed releasing sporangiospore in atmosphere
- Sporangiospore attached to substratum and germinates to give mycellium
- During unfavorable condition, septum formation occurs in mycelium and each intercalary mycelium give rise to thick resting spore known as chlamydospore

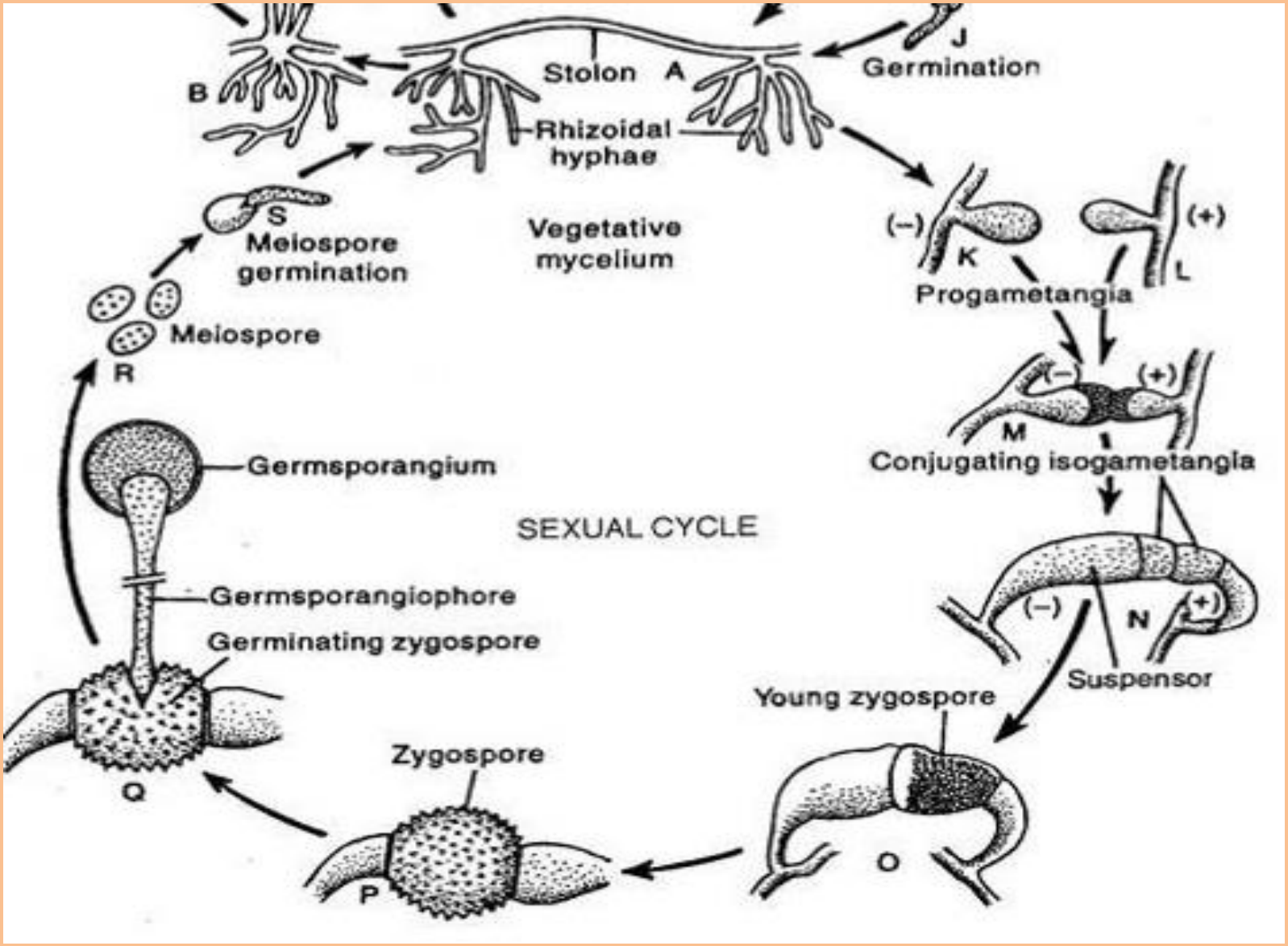
Asexual reproduction in Rhizopus:

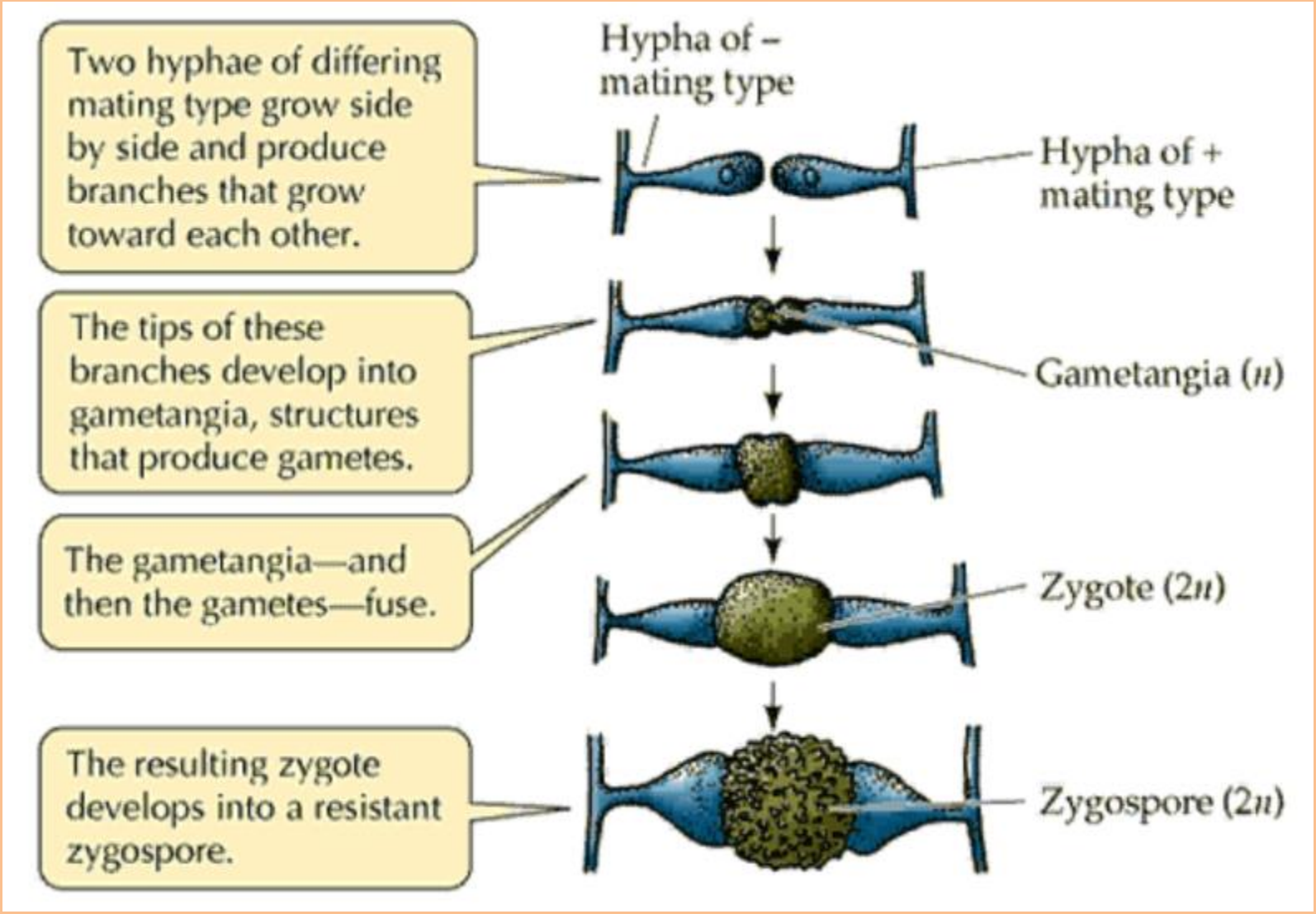


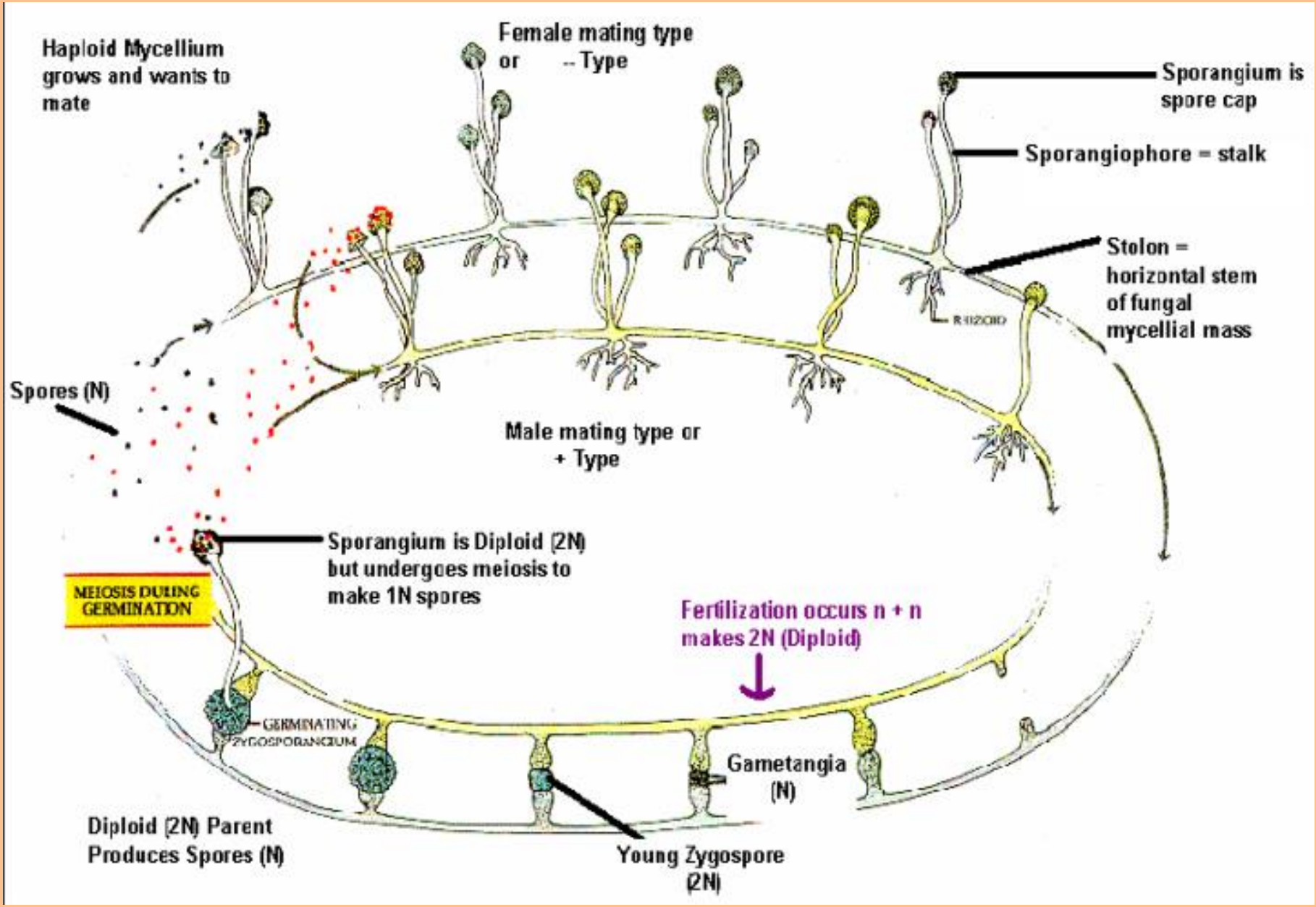
Sexual reproduction in Rhizopus:

- Sexual reproduction takes place during unfavourable condition by means of **gametangial copulation**.
- Most Rhizopus are **heterothallic**
- When two mycelium of opposite strain come close to each other, each mycelium produce small outgrowth, called **progametangia**
- The apical region of the two progametangia come in close contact and cytoplasm of each progametangium push more and more towards the apical region which swell up with dense protoplasm.
- The apical region is known as **gametangia** and basal region is known as **suspensor**
- The protoplasm in gametangia fuses to from **zygospore**
- **Zygospore** is a resting spore
- During favorable condition, spore wall rupture and form **germ tube** which elongates to form **promycellium**
- Promycellium have two region; **germsporangiophore** and **germsporangium**
- Nucleus in germsporanium divides by meiosis forming haploid nuclei, which gather cytoplasm and behaves as spore.
- The haploid spore are released and germinates to give mycellium

Sexual reproduction in Rhizopus:




Two hyphae of differing mating type grow side by side and produce branches that grow toward each other.
The tips of these branches develop into gametangia, structures that produce gametes.
The gametangia—and then the gametes—fuse.
The resulting zygote develops into a resistant zygospore.
Hypha of – mating type
Hypha of + mating type
Gametangia (n)
Zygote (2n)
Zygospore (2n)


Haploid Mycellium grows and wants to mate
Female mating type or -- Type
Sporangium is spore cap
Sporangiophore = stalk
Stolon = horizontal stem of fungal mycellial mass
RHIZOID
Spores (N)
Male mating type or + Type
Sporangium is Diploid (2N) but undergoes meiosis to make 1N spores
MEIOSIS DURING GERMINATION
Fertilization occurs n + n makes 2N (Diploid)
GERMINATING ZYGOSPORANGIUM
Gametangia (N)
Diploid (2N) Parent Produces Spores (N)
Young Zygospore (2N)

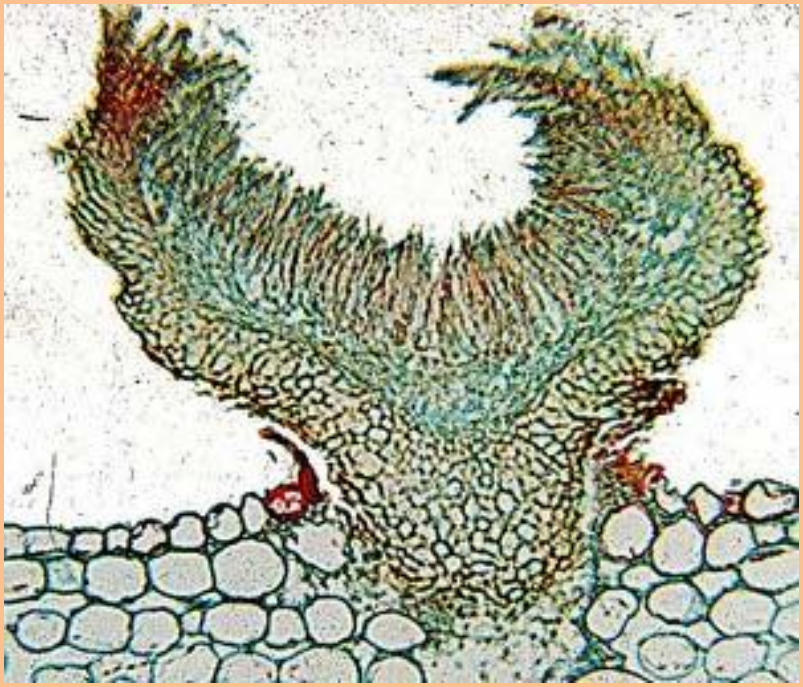
Unit 4: Ascomycota

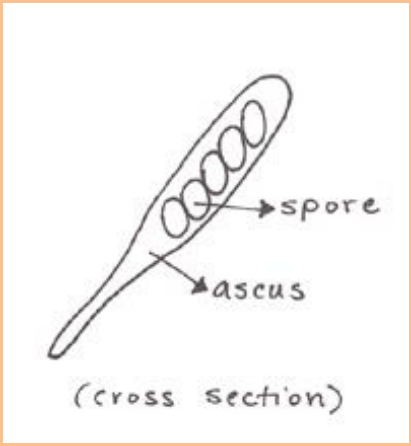
General characteristics (asexual and sexual fruiting bodies); Ecology; Life cycle, Heterokaryosis and parasexuality; Life cycle and classification with reference to *Saccharomyces, Aspergillus*, *Penicillium, Alternaria, Neurospora* and *Peziza.*

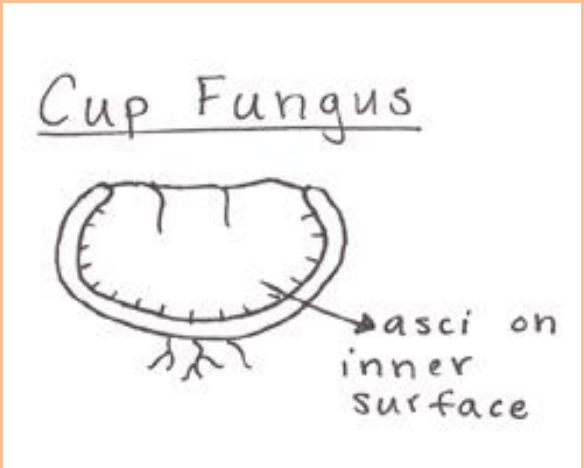

Ascomycetes: Phylum Ascomycota

“Cup fungus”

- Group of fungi characterized by their production of sexual spores in a sac-like structure called an ascus.

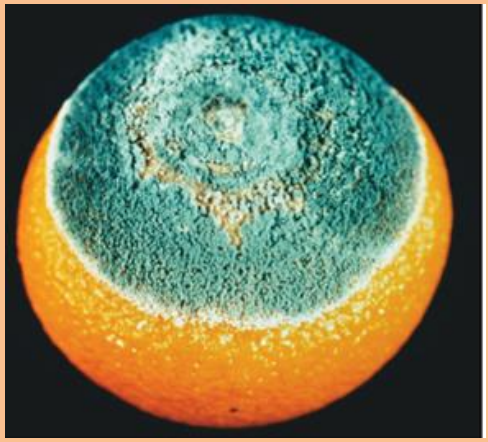






The Ascomycota

- Most are blue-green, red and brown molds that cause food spoilage
- Form non-motile ascospores internally with sac like structure (Ascus) eg –*Penicillium, Aspergillus*



Salient Features of Ascomycetes:

- Most of the members are terrestrial.
- The majority of ascomycetes are saprophytic, some are parasite on insects and other animals, and some are responsible for causing destructive plant diseases.
- Some ascomycetes characteristically grow on dung and are popularly called **coprophilous fungi (Peziza).**

Salient Features of Ascomycetes:

- The members vary in their form and structure. Yeasts and other a few members (e.g. *Taphrina*) are unicellular, but almost all other members of this group have a well-developed, profusely branched, and septate mycelium with uni- or multinucleate cells and perforated septa.
- In unicellular forms, the cell wall is composed of **glucans and mannans**, whereas in septate forms it consists of **chitin and glucans.**
- Asexual reproduction takes place by various types of non-motile spores, such as oidia, chlamydospores, and conidia.
- In unicellular forms, fission, fragmentation, and budding are the most common methods of propagation.

Salient Features of Ascomycetes:

- They are homothallic or heterothallic. In some heterothallic species, male (antheridium) and female (ascogonium) sex organs develop on the thallus of the same strain, they are **self-incompatible**. In these species, male gamete of one mating type fertilises ascogonium of other mating type. This process is known as **physiological heterothallism**.
- Sexual reproduction takes place by gametangial copulation (e.g., yeast), gametangial contact (e.g., *Aspergillus, Penicillium, Erysiphe*), somatogamy (e.g., *Peziza, Morchella*) or spermatization (e.g., *Polystigma*).

Salient Features of Ascomycetes:

- The sexual spore is haploid called **ascospore**, which is formed endogenously by free cell formation after karyogamy and meiosis within a sac-like or cylindrical structure referred to as an **ascus**. If the sexual spore of a fungus is an ascospore, the fungus is an Ascomycete regardless of any other character. This one character distinguishes Ascomycetes from all other fungi.
- They show the phenomenon of **heterokaryosis**, i.e., the nuclei of two different genotypes are present in the same mycelium.
- The fruiting bodies are known as ascomata (sing. ascoma; earlier called ascocarp). The ascomata are of four types cleistothecium (cleistothecial ascoma), perithecium (perithecial ascoma), apothecium (apothecial ascoma), and ascostroma (stromatic stroma) or pseudothecium.

Salient Features of Ascomycetes:

- Some Ascomycetes cause destructive plant diseases such as Dutch elm disease (*Ceratocystis ulmi*), ergot of rye (*Claviceps purpurea*), apple scab (*Venturia inaequalis*), powdery mildews of various crop plants (*Erysiphe*, *Phyllactinia*, *Uncinula*, etc.), and many others.
- The most interesting Ascomycetes are the yeasts which are variously significant because they are involved in the production of many products of bakery and brewing industry.
- *Claviceps purpurea* causes ergot disease. Ergot contains a variety of alkaloids including LSD (lysergic acid diethylamide), the well-known hellucinogenic drug of the day.
- *Penicillium* spp. are involved in production of **penicillin**, the wonder drug.
- Many ascomycetous fungi are used in production of **cheese**.

Significance of Ascomycetes:

- *Penicillium* spp. are involved in production of penicillin, the wonder drug.
- Many ascomycetous fungi are used in production of cheese. The Japanese and Chinese often use the members of '*Aspergillus flavus-oryzae* group' to produce foods and important industrial alcohol.
- *Neurospora* genetics laid down by Dodge provides a new approach of haploid genetics and biochemical genetics. This became possible only because the fungus *Neurospora* opened up a new way in the study of heredity.

What is the difference between Homothallic and Heterothallic Fungi?

Homothallic	Heterothallic
Homothallic fungi are the fungal strains which are able to produce both male and female mating types for sexual reproduction from the same thallus.	Heterothallic fungi are the fungal strains which have only one type of mating and depend on a compatible mating partner for sexual reproduction.
Mycelium of the homothallic fungi is bisexual.	Mycelium of the heterothallic fungi is unisexual.
Homothallic fungi perform self-fertilization.	Heterothallic fungi perform outcrossing.
Homothallic fungal sexual reproduction reduces genetic variation.	Heterothallic fungal sexual reproduction increases genetic variation.
Homothallic fungi do not depend on a mating partner from another thallus.	Heterothallic fungi need a different but compatible mating partner.
Homothallic mating types are genetically more or less similar	Heterothallic mating types are genetically different
Examples of homothallic fungi examples include Aspergillus nidulans, Neurospora galapagoensis, etc.	*Examples of heterothallic fungi include Neurospora Crassa, Saccharomyces cerevisiae, Aspergillus fumigatus, Aspergillus flavus, etc.*

ASEXUAL REPRODUCTION

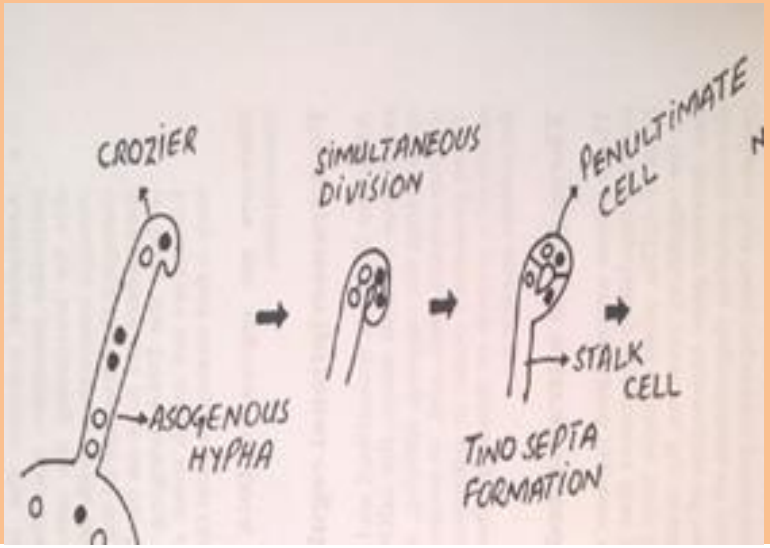
- Spores produced by mitosis
- Spores called conidia (also called mitospores)
- Formed by (1) fragmentation, (2) fission, (3) budding, or (4) blastic development.
- Chlamydospores - thick-walled resistant cells

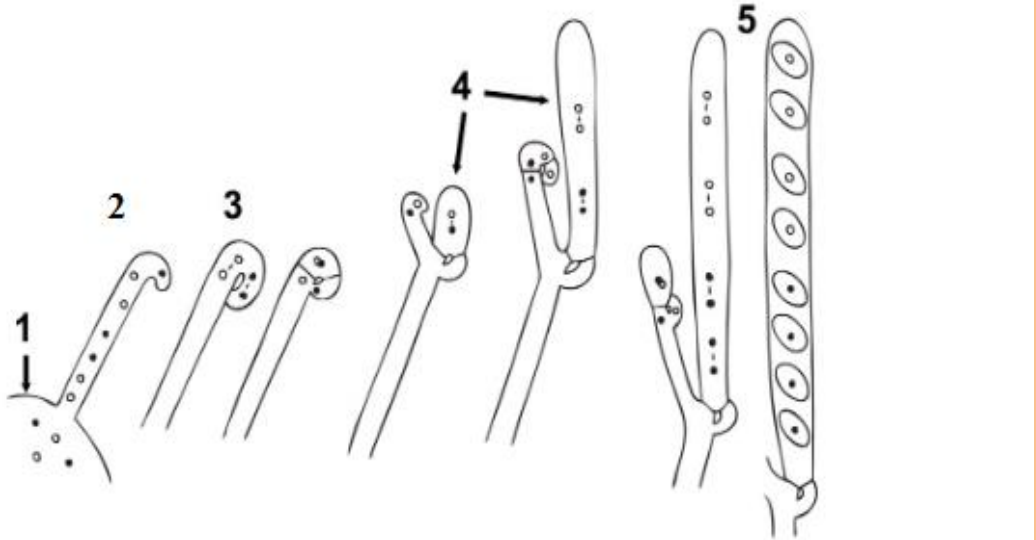
Sexual reproduction in Ascomycetes

- Always involves the formation of an ascus (pl. asci)- saclike structure within which a haploid ascospores are formed following meiosis.
- Because the ascus resembles as sac, commonly referred to as “sac fungi”
- Both the asci and ascospores are unique structures that distinguish the ascomycetes from all other fungi
- Ascus formation usually occurs within a complex structure composed of tightly interwoven hyphae- the ascoma (pl. ascomata) or ascocarp.

Ascus development in Ascomycota

- In **yeasts** and related fungi, the **ascus** arises directly from a **single cell,** but in most other ascomycetes it develops from a **specialized hyp** the **ascogenous** h ha, which in turn develops from an **ascogonium.**





1: ascogonium, 2: ascogenous hyphae; 3: crozier; 4: ascus initial; 5: ascus with ascospores.

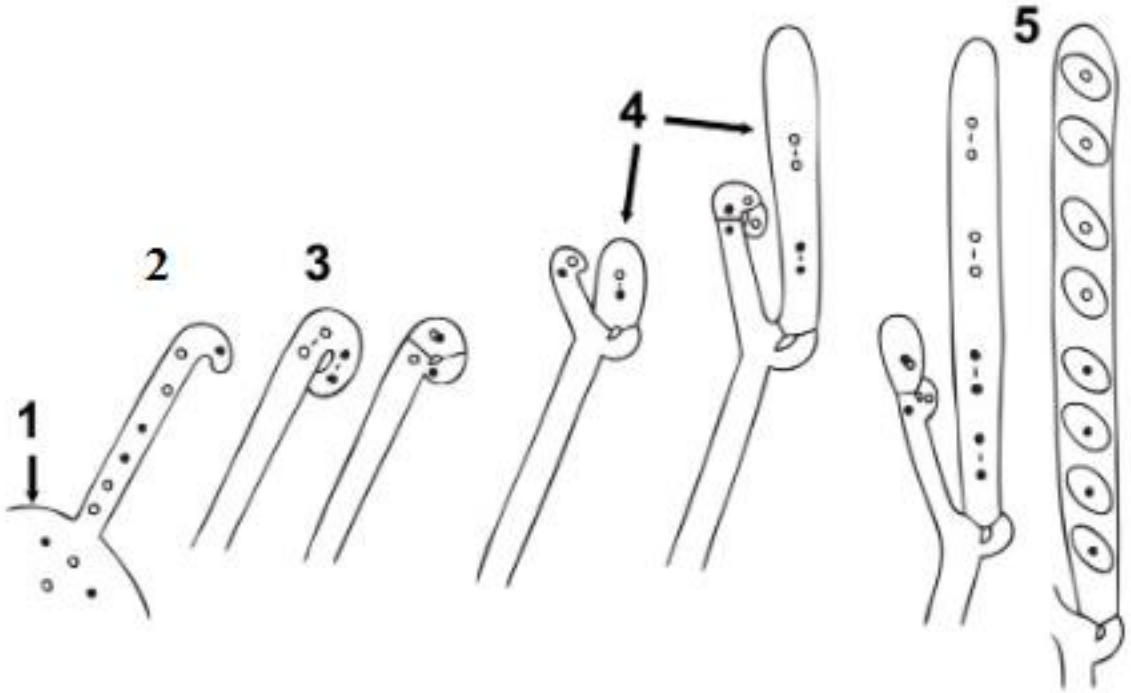
Ascus development

•The ascogenous hypha of many ascomycetes is **multinucleate,** and its tip is recurved to form a **crozier** (shepherd's crook). Within the ascogenous hypha, **nuclear division** occurs simultaneously. **Two septa** at the tip of the crozier cut off a terminal uninucleate cell and a **penultimate** binucleate cell destined to become an ascus.

•The **ante-penultimate cell** beneath the penultimate cell is termed the **stalk cell**. The terminal cell of the crozier curves round and fuses with the stalk cell, and this region of the ascogenous hypha may grow on to form a **new crozier** in which the same sequence of events is repeated. Repeated proliferation of the tip of the crozier can result in a tight cluster of **asci** in many ascomycetes or a succession of well-separated asci as in *Daldinia concentrica*.

- Specialized septal **plugs,** more elaborate than normal **Woronin bodies**, block the pores in the septa at the base of the ascus.
- In the ascus initial the **two nuclei fuse** and the **diploid** fusion nucleus undergoes **meiosis** to form four haploid daughter nuclei.
- These nuclei then undergo a **mitotic** division so that **eight** haploid nuclei result which form 8 Ascospores.
- Later, a series of **four or more synchronous mitoses** occur after the spores have become **pigmented** so that they contain **32 or more nuclei** when they are mature.
- The eight nuclei **may divide further mitotically so that each ascospore is binucleate**, or, if still more mitoses follow, the ascospore becomes **multinucleate**.
- Where the ascospores are **multicellular**, there are repeated nuclear divisions accompanied by the formation of **septa** which divide up the spore.
- In some ascomycetes **more than eight ascospores are formed** e.g. coprophilous genera *Podospora* and *Thelebolus.*
- Asci with **fewer than eight spores** are also known, e.g. in *Neurospora tetrasperma* where the four ascospores are binucleate,
- In *Phyllactinia guttata* where there are **two ascospores** , or
- In *Monosporascus cannonballus* which has a **single ascospore**.

Development of an ascus



1: ascogonium, 2: ascogenous hyphae; 3: crozier; 4: ascus initial; 5: ascus with ascospores.

FRUITING BODIES

- General term is ascoma (pl. ascomata).
- Cleistothecium - completely closed, no preformed opening.
- Perithecium - often flask-shaped, with an apical opening.
- Apothecium - ascomata open and saucer-shaped at maturity.
- Pseudothecium - asci formed in a stromatal cavity.

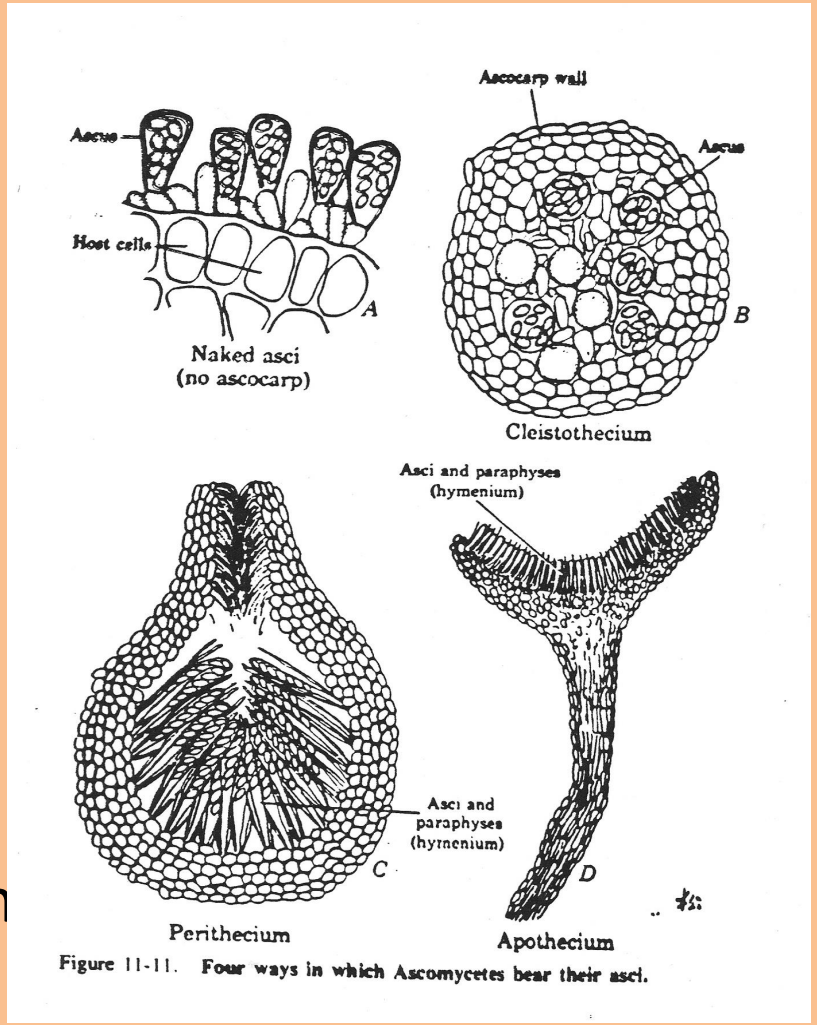


Figure 11-11. Four ways in which Ascomycetes bear their asci.

Types of ascomata.

- The asci are surrounded by a loose hyphal net in **gymnothecia**

- In **cleistithecia** the asci develop in a closed spherical ascoma with no definite operculum.

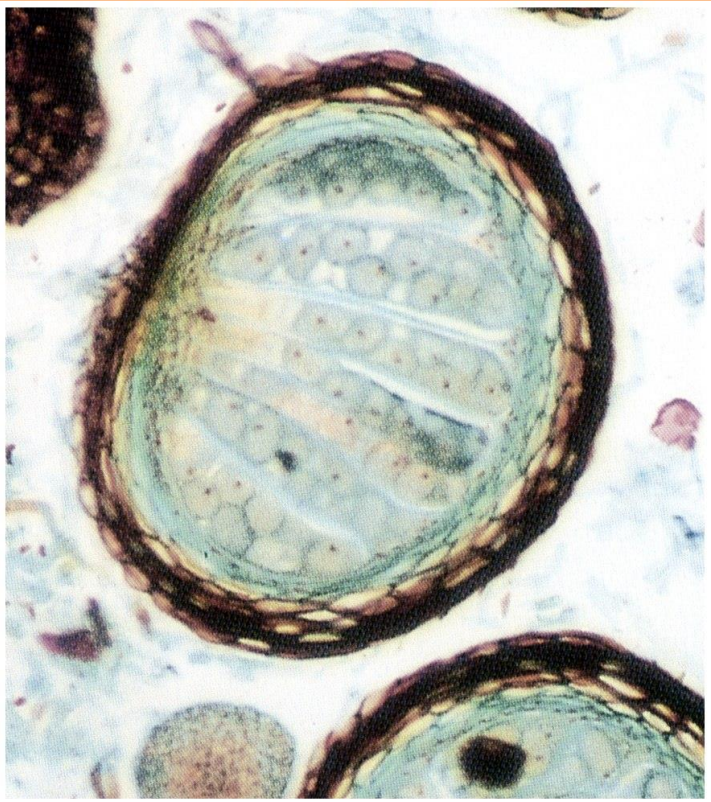


Figure 14-16b
Biology of Plants, Seventh Edition

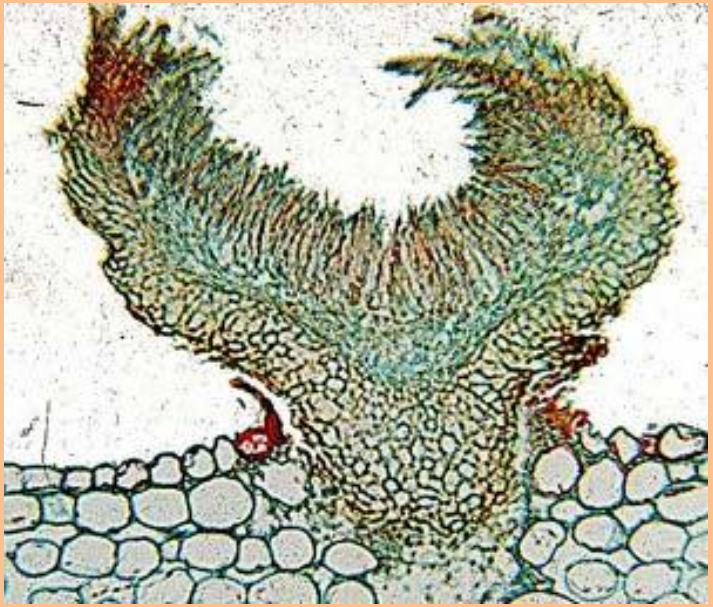
Types of ascomata.

- The **perithecium** is a flask-shaped ascoma in which the asci form in a palisade termed a hymenium. The perithecium has an aperture (ostiolum) where the spores can emerge. Perithecia can develop singly (e.g. *Sordaria*) or sometimes are embedded in a compact mycelial structure called a perithecial stroma (e.g. ergot, *Claviceps pupurea*).
- In a pseudothecium the asci develop in cavities of a compact hyphal aggregate (ascostroma).

Figure 14-16c
Biology of Plants, Seventh Edition

Types of ascomata.

- The apothecium is a cup-like open ascomata and the asci with sterile cells (parahpyses) among them develop in a layer (hymenium) on the open side. The apothecia could have stipes as do the mushroom-form morels or can form closed hypogeous ascomata characteristic of the truffles.



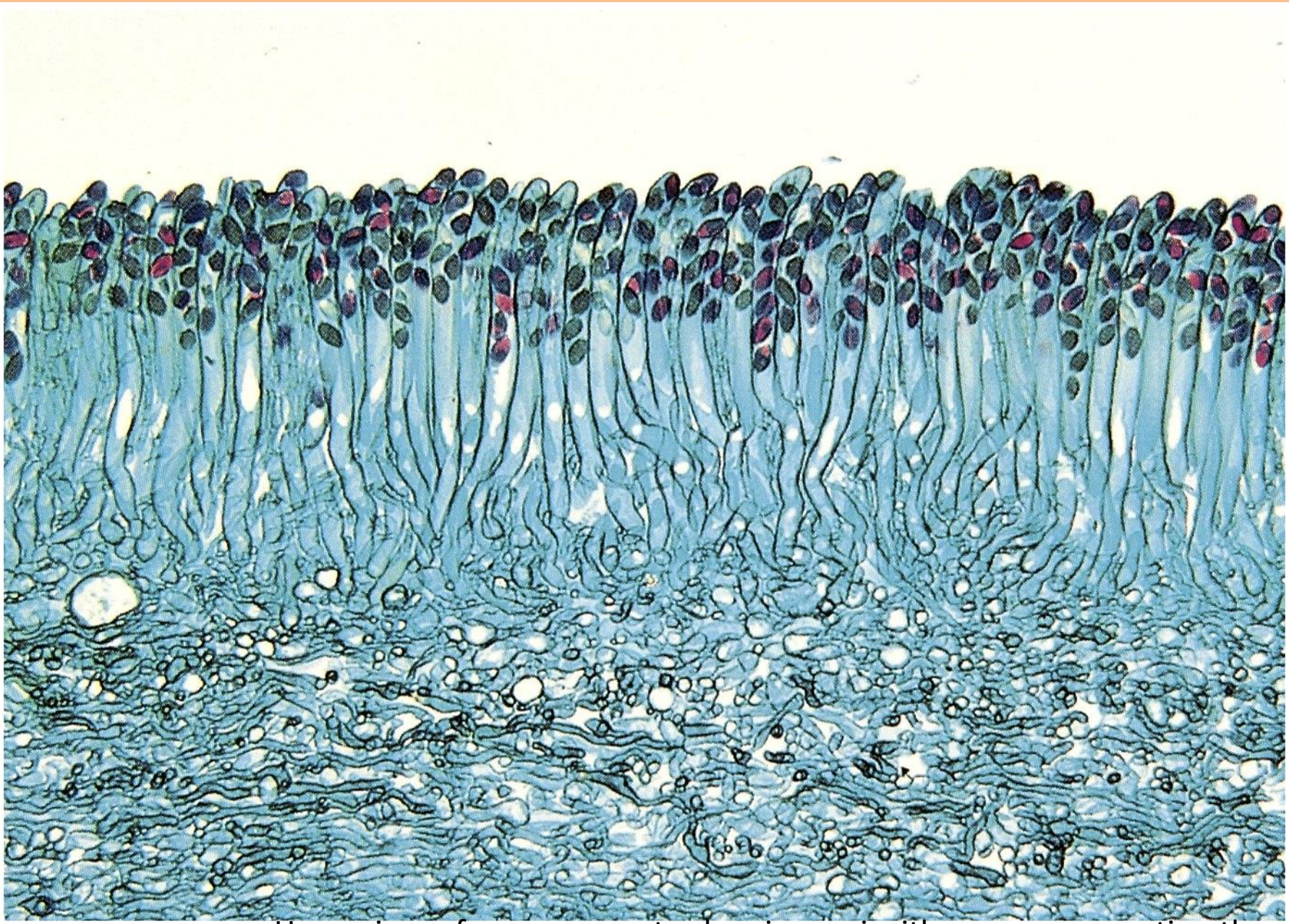
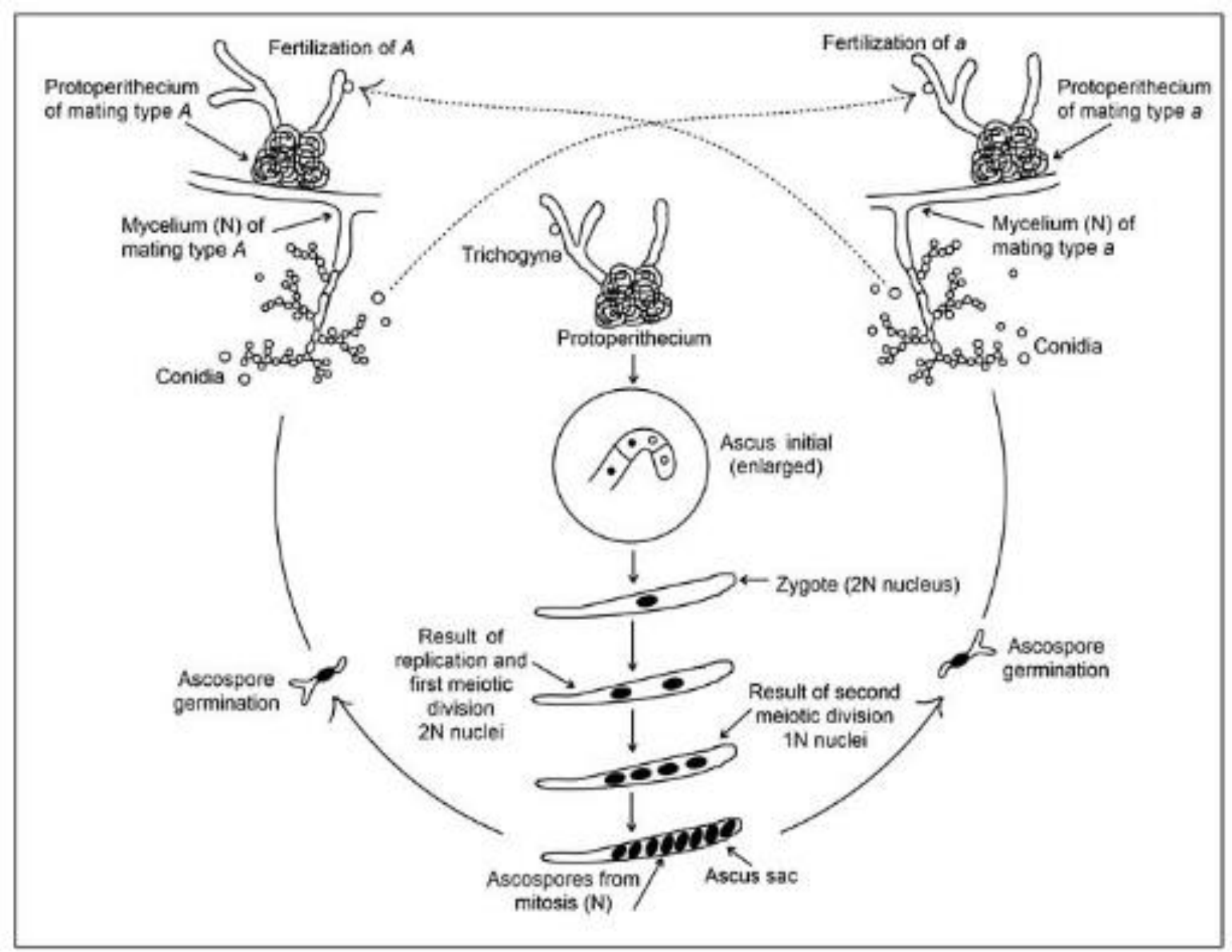


Figure 14-17
Biology of Plants, Seventh Edition

Hymenium of an ascomycete showing asci with ascospores section thru the hymenial layer of Morela

Neurospora crassa is considered as the most analyzed heterothallic fungal species.



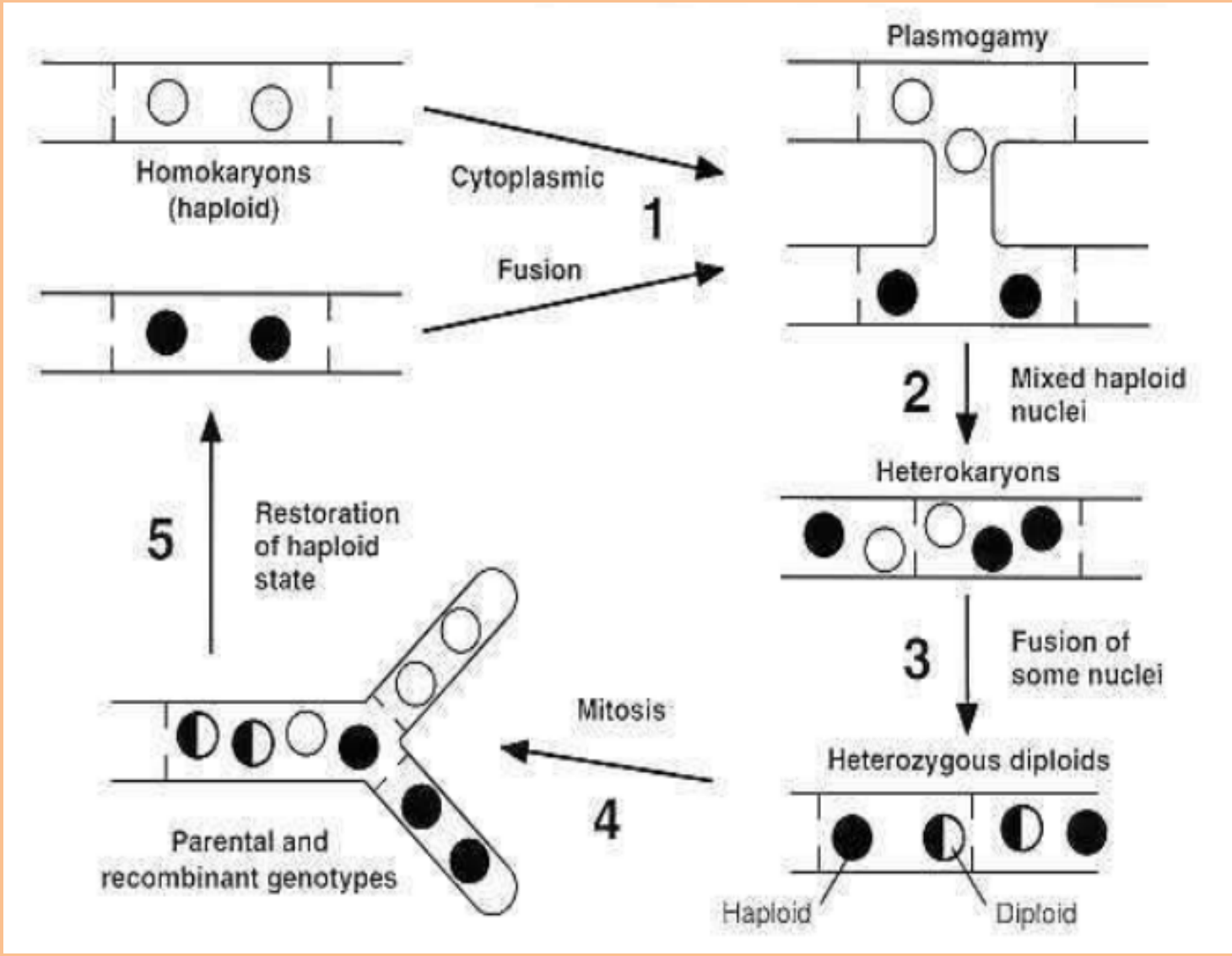
HETEROKARYOSIS

- Heterokaryosis - co-existence of genetically different nuclei in cytoplasm continuity with one another.
- Discovered by Hansen and Smith (1932) in Botrytis cinerea.
- plays major role - variability and sexuality in fungi.

FORMATION OF HETEROKARYOSIS

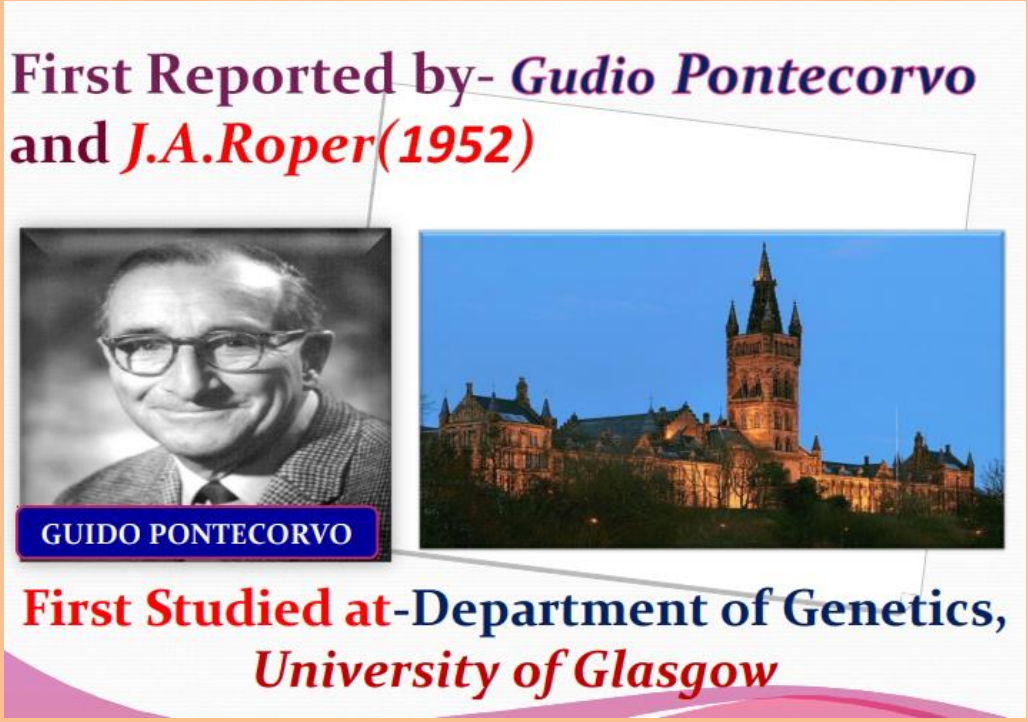
- Heterokaryotic condition arises by-
  - **Mutation-** A high frequency of mutation is characteristic of fungi - main source of variability.
  - **Anastomosis** (fusion of hyphae)- Fusion is mostly intra-specific. Nuclear migration from the point of fusion to the remainder of the mycelium takes place - heterokaryotic mycelium. eg- development of heterokaryon in basidiomycota
  - **Inclusion of dissimilar nuclei in spores after meiosis**, in heterothallic fungi- Meiosis results in the production of genetically different nuclei sharing common cytoplasm. e.g. *Neurospora tetrasperma*, Podospora anserine. on germination - give rise to a heterokaryotic thallus.

HETEROKARYOSIS



ParasexuaL cycle

- In some fungi ,true sexual cycle comprising of nuclear fusion and meiosis is absent. These fungi derive the benefits of sexuality through a cycle know as parasexuaL cycle.



DEFINETION

- Parasexuality is defined as a cycle in which Plasmogamy, Karyogamy and Meiosis [Haploidization] take place in sequence but not at a specified time or at specified points in the life cycle of an organism.
- Generally parasexual cycle occurs in those fungi in which true sexual cycle does not take place.
- Parasexualcycle also know as Somatic recombination.
- PASEXUALITY REPORTED in
- *Aspergillus niger, Aspergillus fumigatus, Aspergillus oryzae, Aspergillus sojae, Penicillium chrysogenum, Penicillium expansum, Penicillium italicum, Ustilago maydis, Ustilago violacea*

Yeast: morphology and life cycle

- They are single celled fungi
- **Size:** generally larger than most bacteria; (1-5) um wide and (5-30)um length
- **Shape:** cell is egg shaped, some are elongated or spherical
- Size and shape varies among species
- Yeast cell lacks flagella and other organ of locomotion.

Morphology of yeast cell

- **Cell wall:** composed of thin chitinous cell wall
- The protoplasm is surrounded by cell membrane which contains all the usual cell organelles like ribosomes, mitochondria, ER, nucleus and other granules
- Vacuole is single, large and centrally located.

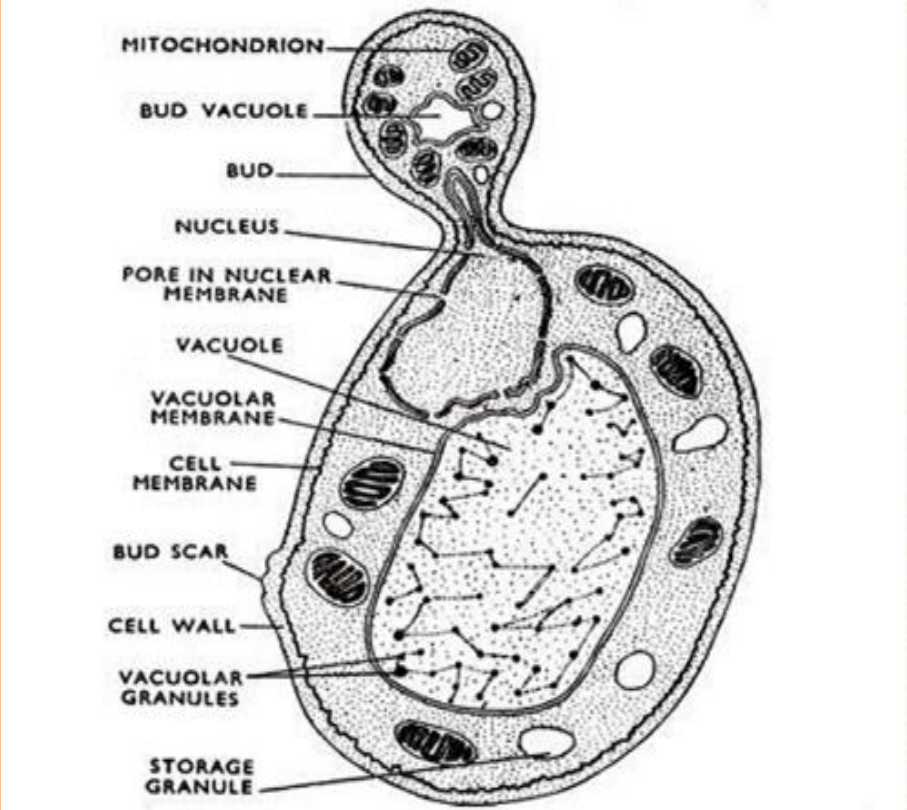


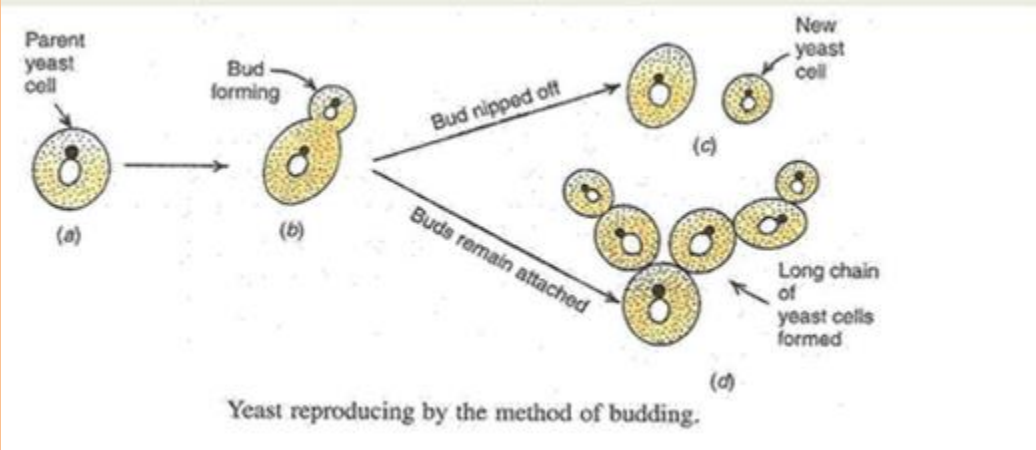
Fig. 215. *Saccharomyces cerevisiae*. Sectional view of a budding cell.

Reproduction in yeast cell

- Yeasts generally reproduce by Asexual method such as Budding or fission,
- Yeasts lacks sex organs (anthridium and oogonium)
- Sexual reproduction in yeast is highly variable

Budding

- It Occurs during abundant supply of nutrition
- Parent nucleus divides and moves toward daughter cell
- Enzymatic activities increases,
- Increased turger pressure acts on weaker part of cell wall and bud erupts
- Septum formation and bud separates into individual cell



Yeast reproducing by the method of budding.

Sexual reproduction

- Sexual reproduction is highly variable in yeasts
- Three different pattern of life cycle found in different genus
  - i. Haplodiplobiontic life cycle
  - ii. Haplobiontic life cycle
  - iii. Diplobiontic life cycle

Haplobiontic life cycle

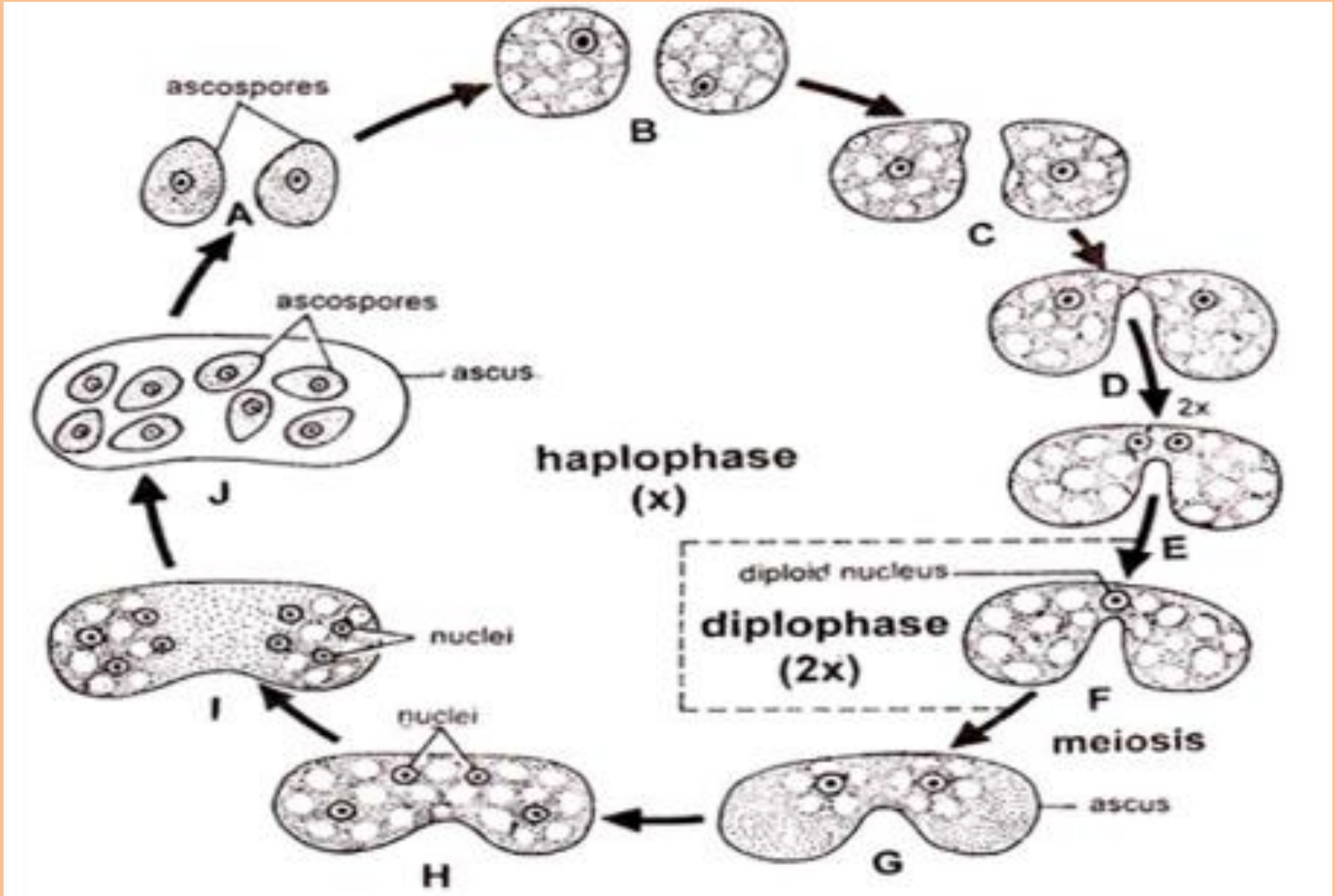


Fig. 5. (A–I). *Schizosaccharomyces octosporus* : Haplobiontic life cycle

Haplobiontic life cycle

This life cycle occur in *Schizosaccharomyces.*

In haplobiontic cycle, somatic haploid cell multiply by fission producing number of haploid cell.

During sexual reproduction, two sister haploid cell behaves as gamatangia and produce beak like structure

The beaks of two gamatangia fused and wall at the point of contac dissolve to form canal called conjugation tube.

Nucleus of two cell moves and fused to form diploid zygote

The zygote directly function as ascus mother cell

Nucleus of ascus mother cell divides by meiosis forming 4-haploid nuclei which themselves divides by mitosis to form 8- haploid cells

Each 8- nuclei gather some cytoplasm and become ascospore

Ascospore released by rapture of ascus

Ascospore germinates to give haploid cell and continue life cycle

Haplodiplobiontic life cycle

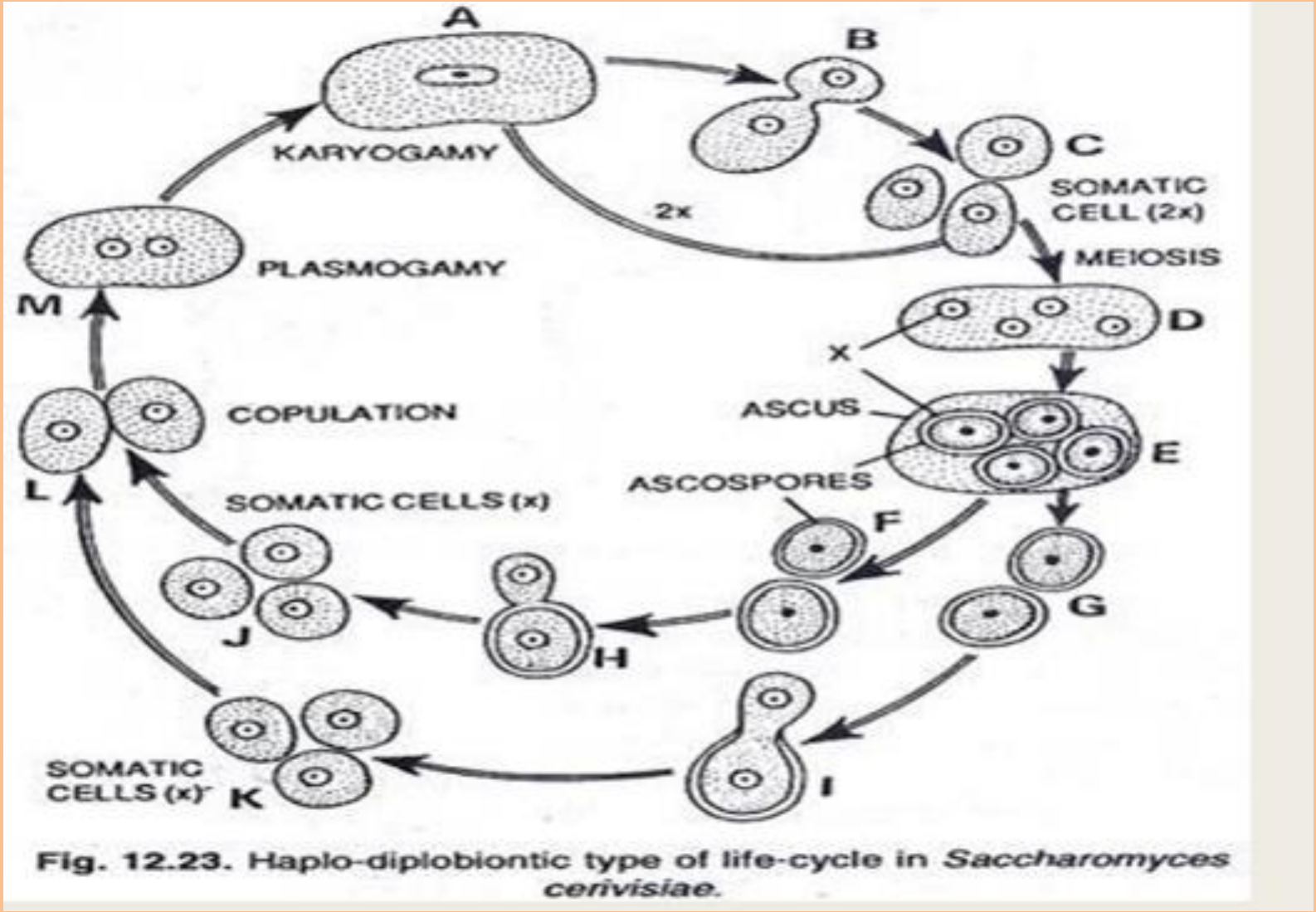
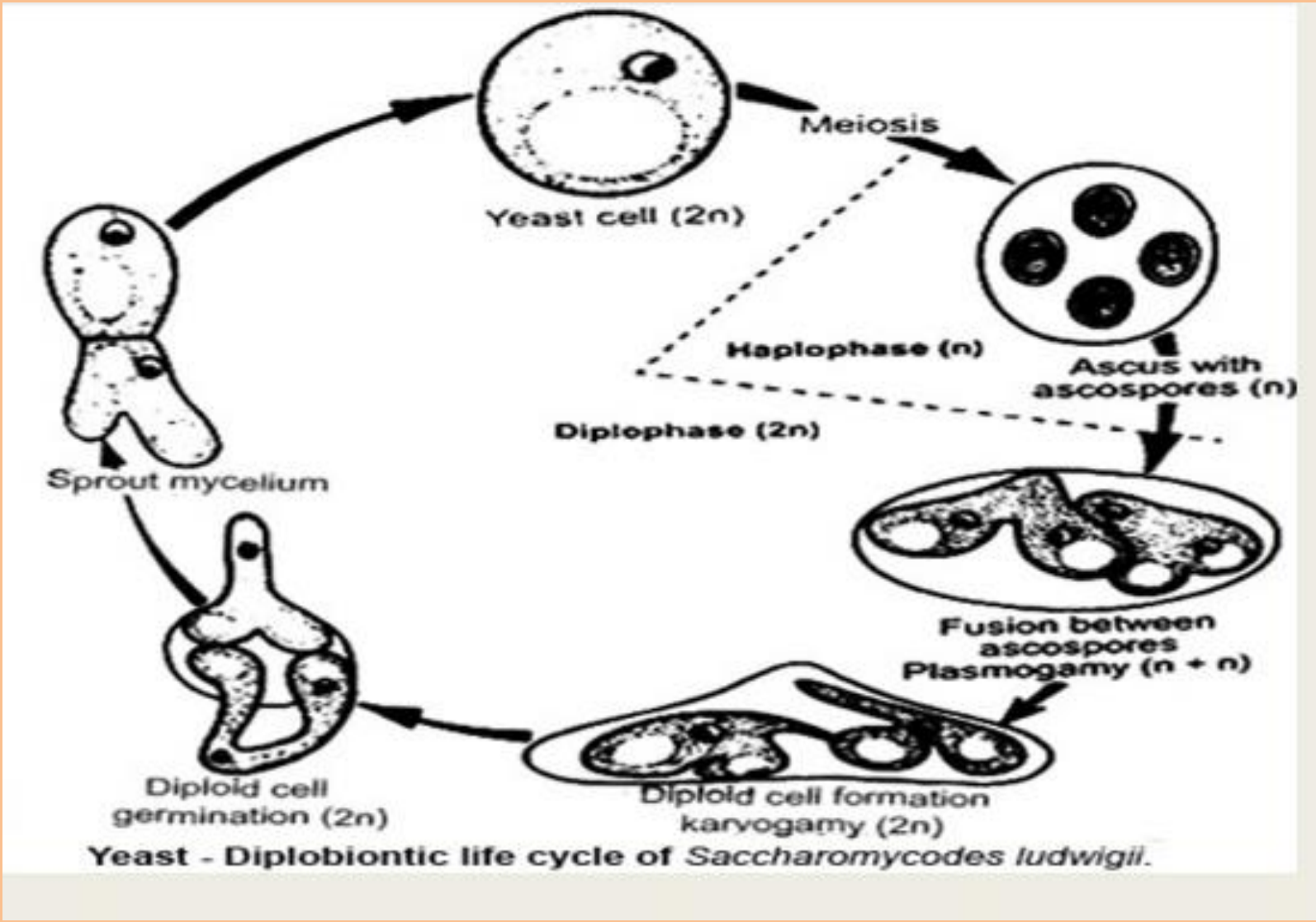


Fig. 12.23. Haplo-diplobiontic type of life-cycle in *Saccharomyces cerivisiae*.

Haplodiplobiontic life cycle

- This cycle occurs in *Saccharomyces cerevisiae*
- In this life cycle somatic cell of yeast exists in two form (Haploid dwarf cell and Diploid large cell)
- Haploid cell contains two mating types “a” and “α”
- During favorable condition each of the haploid cell multiply by budding only
- If these mating types comes in contact with each other, they form gametangia and starts sexual reproduction
- Fusion of these two haploid cell form large fusion cell called Plasmogamy
- Nucleus also fused by karyogamy to form zygote
- Zygote multiply by budding and forms several diploid cells
- these diploid cells are larger than haploid cells
- Like haploid cell, these large diploid cells also live independent life and reproduce by budding
- Under unfavourable condition, diploid large cell become spherical and directly behaves as ascus mother cell
- Nucleus of ascus mother cell divides by meiosis to form 4- haploid nuclei
- Out of 4-nuclei, 2 belongs to mating type “a” and t2 belongs to “α”
- Each nuclei gather some cytoplasm and becomes ascospore
- Each ascospore is globular and thick walled structure and relased by rapture of ascus wall.
- Ascospore germinates to give haploid dwarf cell.

Diplobiontic life cycle



Yeast - Diplobiontic life cycle of *Saccharomycodes ludwigii*.

Diplobiontic life cycle

- This life cycle is found in *Saccharomyces ludwigii*
- In diplobiontic life cyle, diploid somatic cell multiply by budding and fission
- Under certain condition, these somatic cell directly functions as ascus mother cell and nucleus of ascus mother cell divides by meiosis to form 4-haploid nuclei
- These haploid nulceii gather cytoplasm and transform into ascospore4 ascospore,
- Out of 4-ascospore, 2 are mating type “A1” and 2 mating type “A2”
- These two mating ascospore fused within ascus to form diploid zygote.
- The diploid zygote gerinates within ascus producing a germ tube
- The germ tube breaks the ascus wall and function as diploid sprout mycelium.
- The sprout mycelium on budding gives sprout diploid cell which give diploid somatic cells.

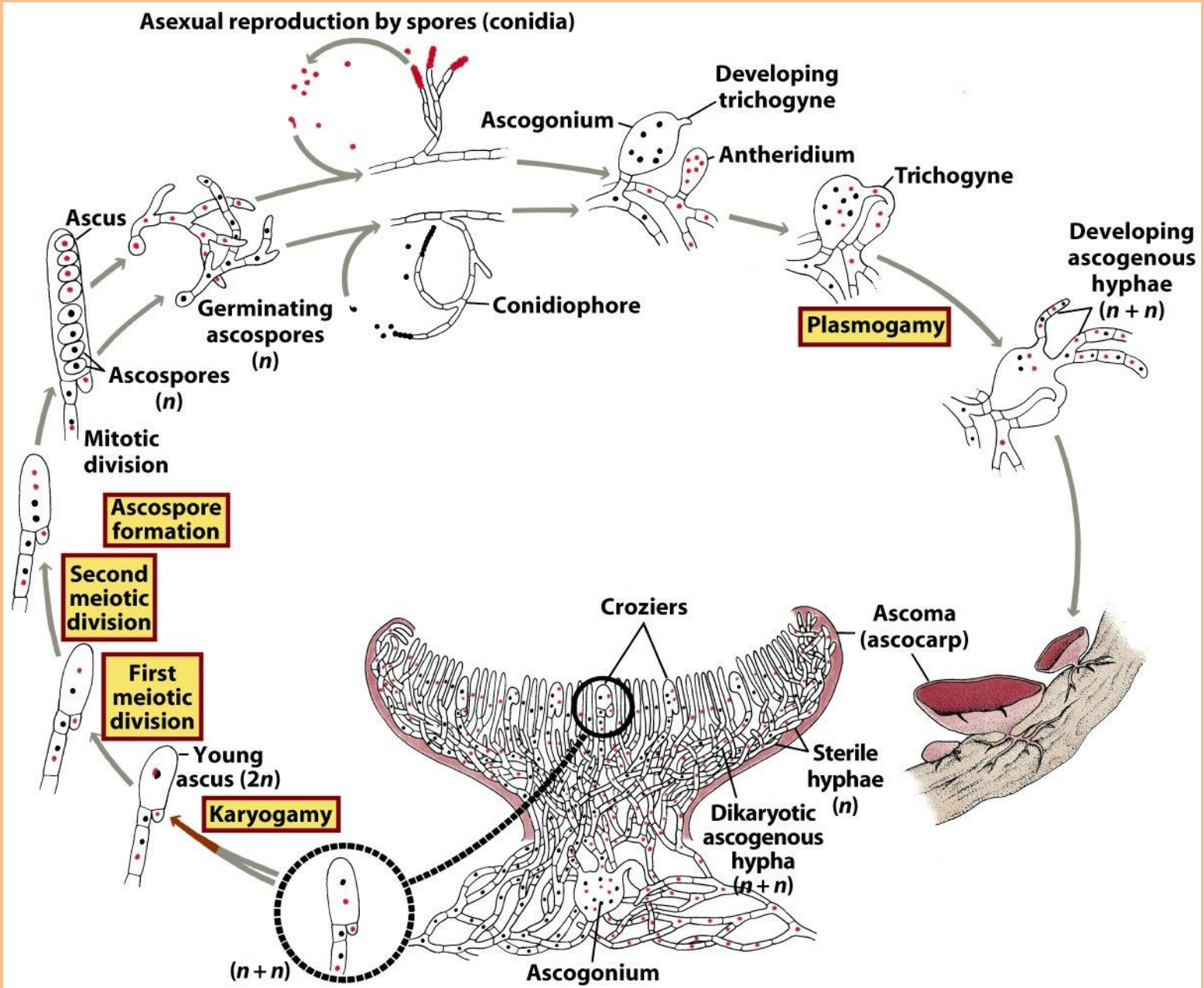
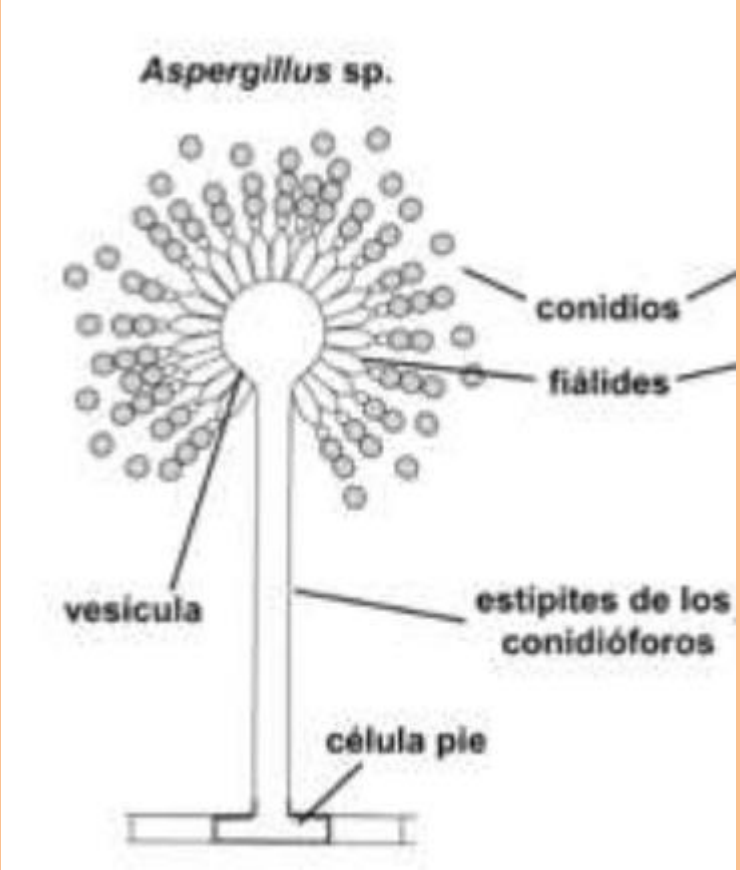


Figure 14-14
Biology of Plants, Seventh Edition

Classification of Aspergillus

- Division : Mycota
- Sub division : Eumycotina
- Class : Ascomycetes
- sub-class : Euascomycetidae
- Order : Aspergillales
- Family : Aspergillaceae
- Genus : Aspergillus

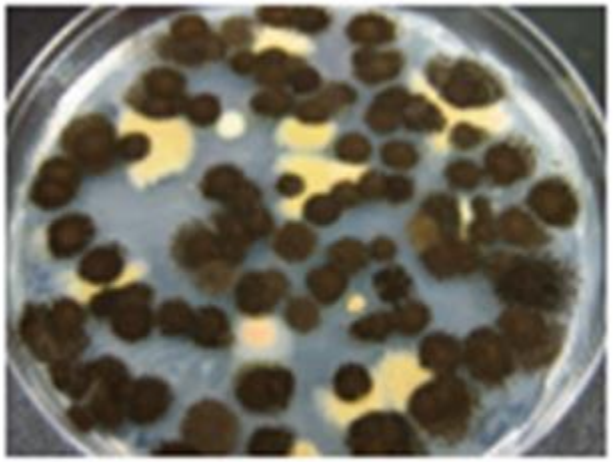


Morphology of Aspergillus

Aspergillus Fumigatus

Aspergillus Flavus

Aspergillus Nidulans



Aspergillus Niger

Occurrence of *Aspergillus*

- Saprophytic fungus.
- There are 200 species of Aspergillus.
- Grows on
  - decaying vegetable.
  - fatty media such as butter and ghee.
  - starchy media such as bread and rice.
  - preserved food such as jams and jellies.
  - Also found on rotting oranges and other fruits.

Appearance of *Aspergillus*

- Greenish and Smoky Patches along with *Mucor, Rhizopus* and *Penicillium* on moist bread.
- Other common shades are Yellow, Black, and Blue.
- Mostly appear in the conidial stage (imperfect stage).
- Very few produce cleistothecia (perfect stage).

Economic importance of *Aspergillus*

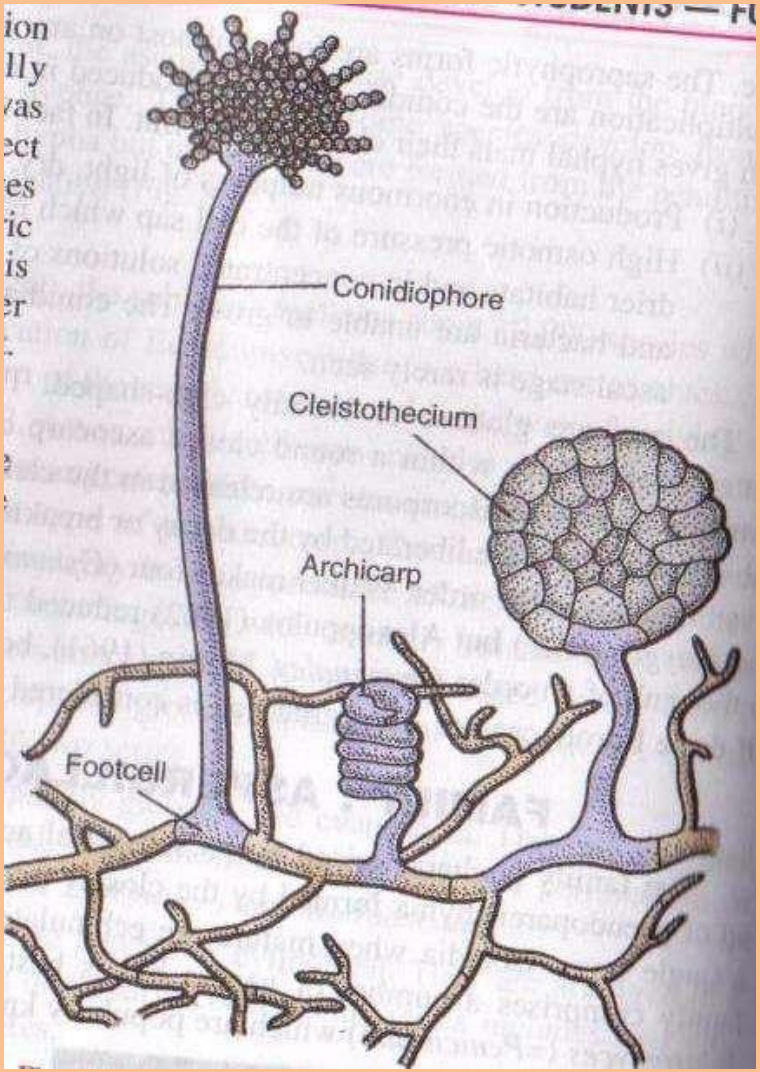
- 33 species are reported in India, many of them are used for pharmaceuticals.
  - *Aspergillus oryzae* is utilized to make alcohol.
  - *Aspergillus niger* is utilized in production of citric acid and other organic acid.
  - Some species yield antibiotics.
  - Culture of A. *niger* and *A. oryzae* yield awide range of enzymes. Which are used for industrial fermentation.

Major diseases caused by *Aspergillus*

- Aspergillosis is the disease caused by infection by the fungi of the genus *Aspergillus.*
  - Occurs in people with underlying illness such as tuberculosis or Chronic Obstructive Pulmonary Disease (COPD).
  - People with deficient immune systems - such as patients undergoing hematopoietic stem cell transplantation, Chemotherapy for leukaemia or AIDS - are at the risk of more disseminated diseases.
- The most frequently identified pathogen is *Aspergillus fumigatus - a ubiquitous organism that is* capable of living under extreme environmental stress.

General Characteristics of *Aspergillus*

- Well developed structures.
- Made up of interwoven mass, branched and septate hyphae.
- Hyphae are branched and form mat on the substratum.
- Some of the hyphae lie superficially upon the substratum and other penetrate deeply to absorb food and for mycelium.



Asexual reproduction

- Cells vigorously grow and mycelium become thick walled.
- Thick walled T-shaped cells called **foot cell**.
- Each T-cell produce erect branch called conidiophores. Lenth of conidiopores is around 2.5mm.
- Swells at the tip and form globose called vesicle.
- Lumen of vesicle is continuous with upper part of conidiopores.
- From the surface of vesicle tubular cells grows outwords called **strigmata or phialides**.
- Phialides cover the whole surface of vesicle.
- Cytoplasm, nucleus, mitochondria and other organelles migrate from vesicle to phialides.
- In maturity stage phialides cut off from vesicle from basal septum.

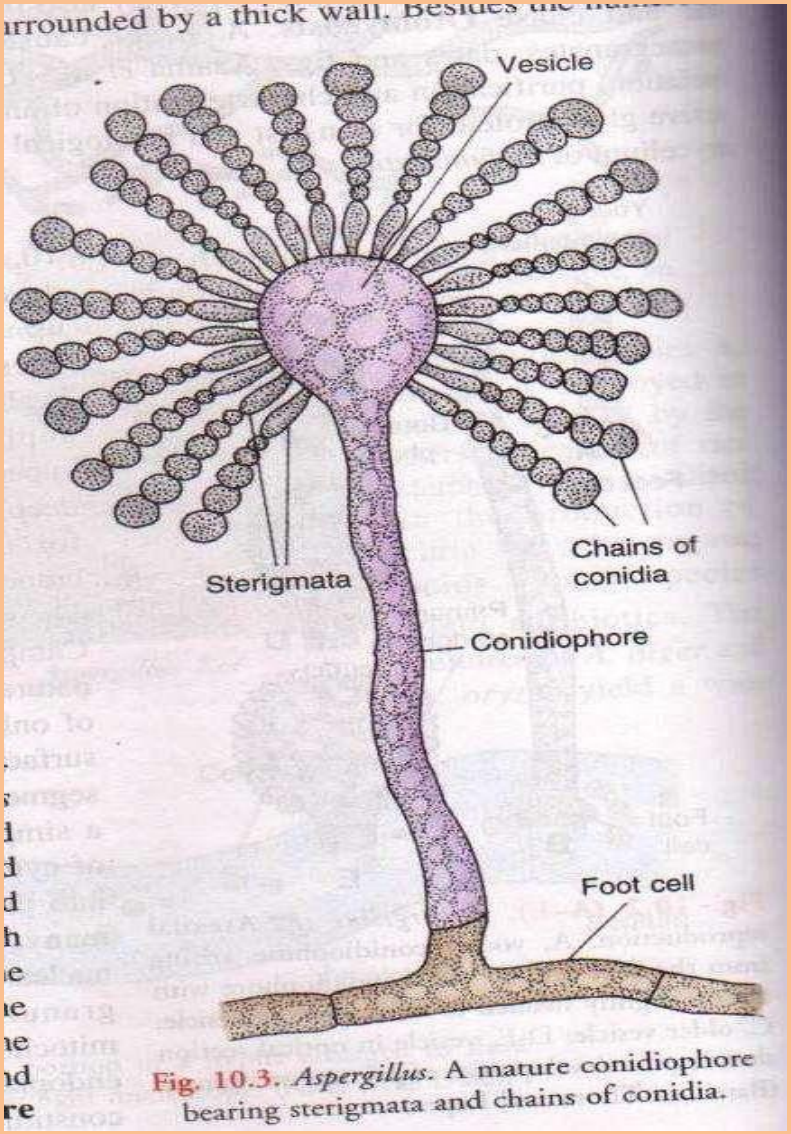
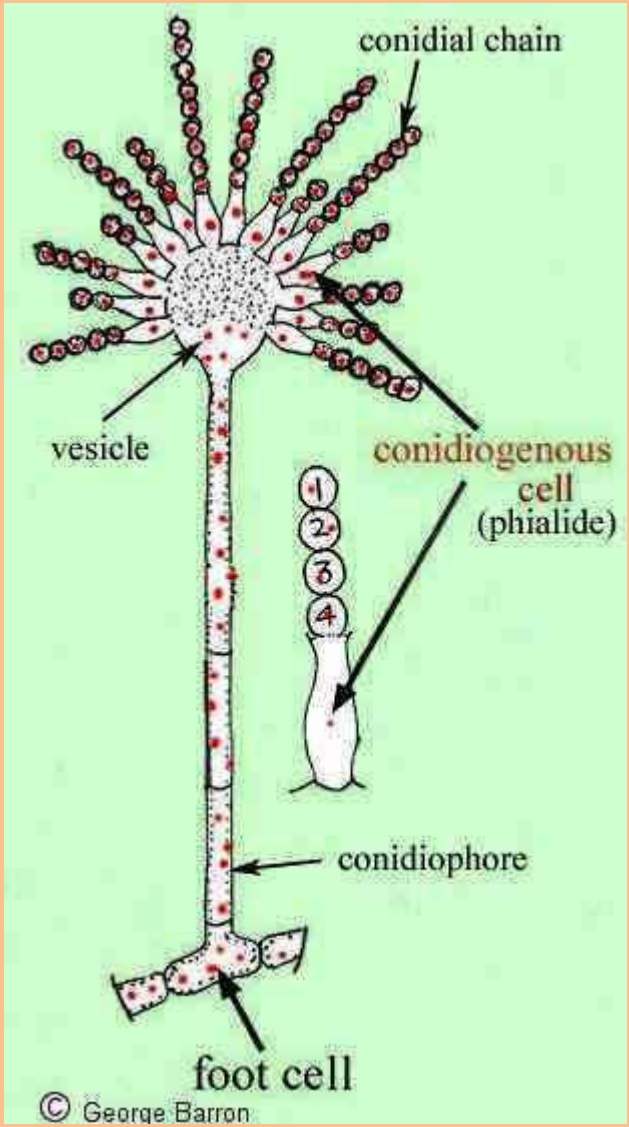


Fig. 10.3. *Aspergillus*. A mature conidiophore bearing sterigmata and chains of conidia.

Asexual reproduction

- Phialides are uninucleate. Nucleus divide by mitosis to form two daughter nuclei.
- From two one migrates to tip of the phialides to form first conidium by cutting off by basal septum at the phialide apex.
- Later develop second conidium in same manner.
- This series of events repeated.
- Thus phialide continue to grow conidia one below to another.
- Consequently chain of conidia is formed at the tip of the phialides.
- The youngest is at the base and oldest is at the top.



Asexual reproduction

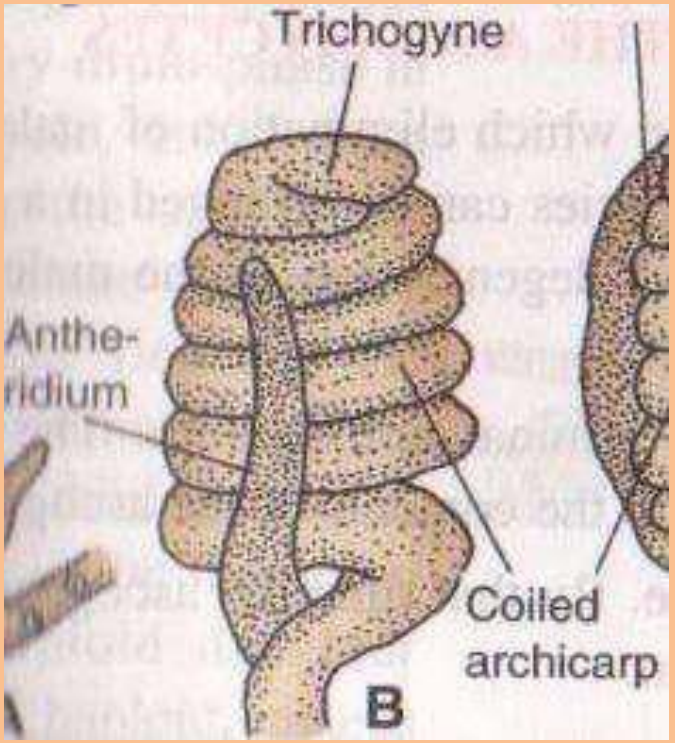
- Conidia are black, green, brown, blue or yellow in colour according to their species
- Conidial wall is thick consist of two layers outer **epispore** and inner **endospore**
- On falling of suitable substratum each conidium germinates
- First produce germ tube which grows into mycelium

Sexual reproduction

- Sexual reproduction is rare.
  - Feamle sex organ is called ascogonium or archicarp.
  - Male sex organ is called pollonidium or anthridium.

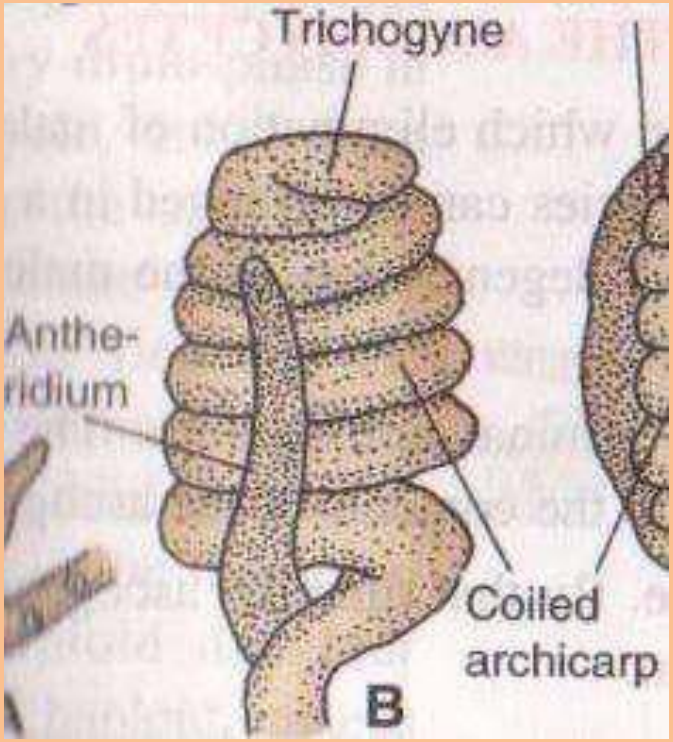
Ascogonium (female sex organ)

- Small, coiled, septate branch.
- Terminal segment is longest and single celled called trigogyne contain 20 nuclei.
- Trigogyne function as a receptive part of female sex organ.



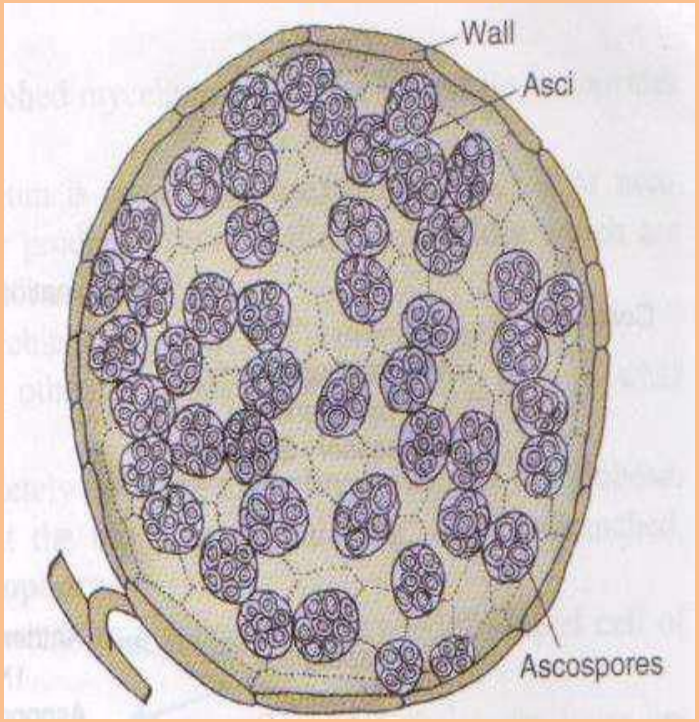
Anthredium (male sex organ)

- Male branch grows beside the ascogonium from the same hyphae.
- Anthredium is multi nucleate.



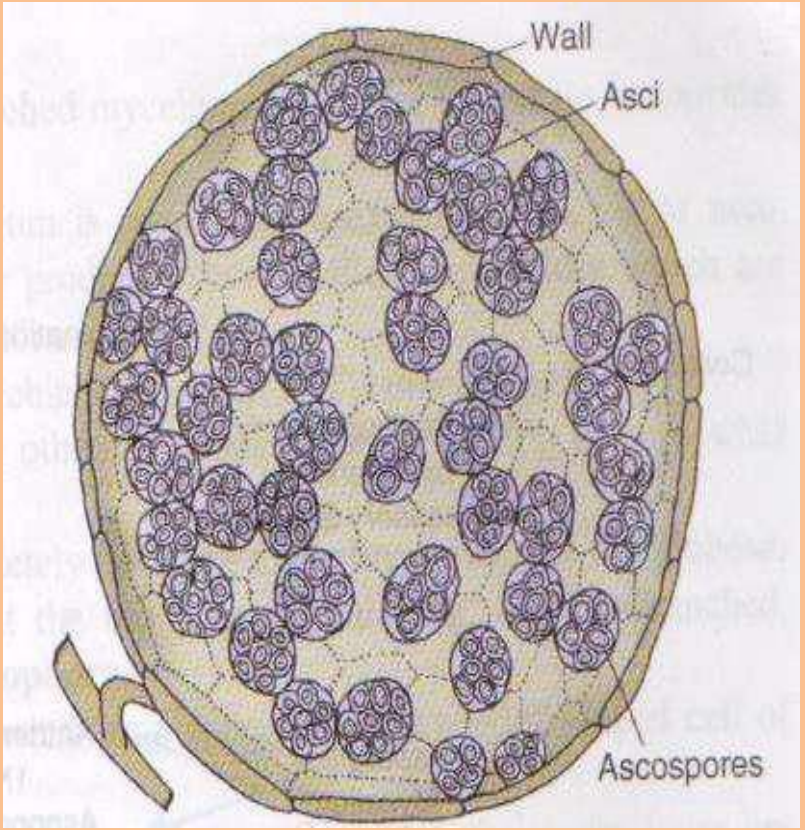
Plasmogamy

- Fusion of ascogonium and anthredium is called plasmogamy.
- Tip of anthredium fuse with trochogyne. Then intervening wall is dissolved. Content of anthredium pass into the trochogyne. Here haplophase ends.
- Male nuclei pair with female nuclei. Each pair is called dikaryon and phase is called **dikaryotic phase**. Dikaryon undergo fusion and form diploid nucleus.
- Diploid nucleus undergoes three successive division.
  - 1st and 2nd division are meiosis.
  - 3rd division is mitotic. As a result 8 haploid daughter nucei form.
- Each haploid nucleus is surrounded by cytoplasm.
- Then formation of wall occur called ascopores. So 8 ascospores are formed

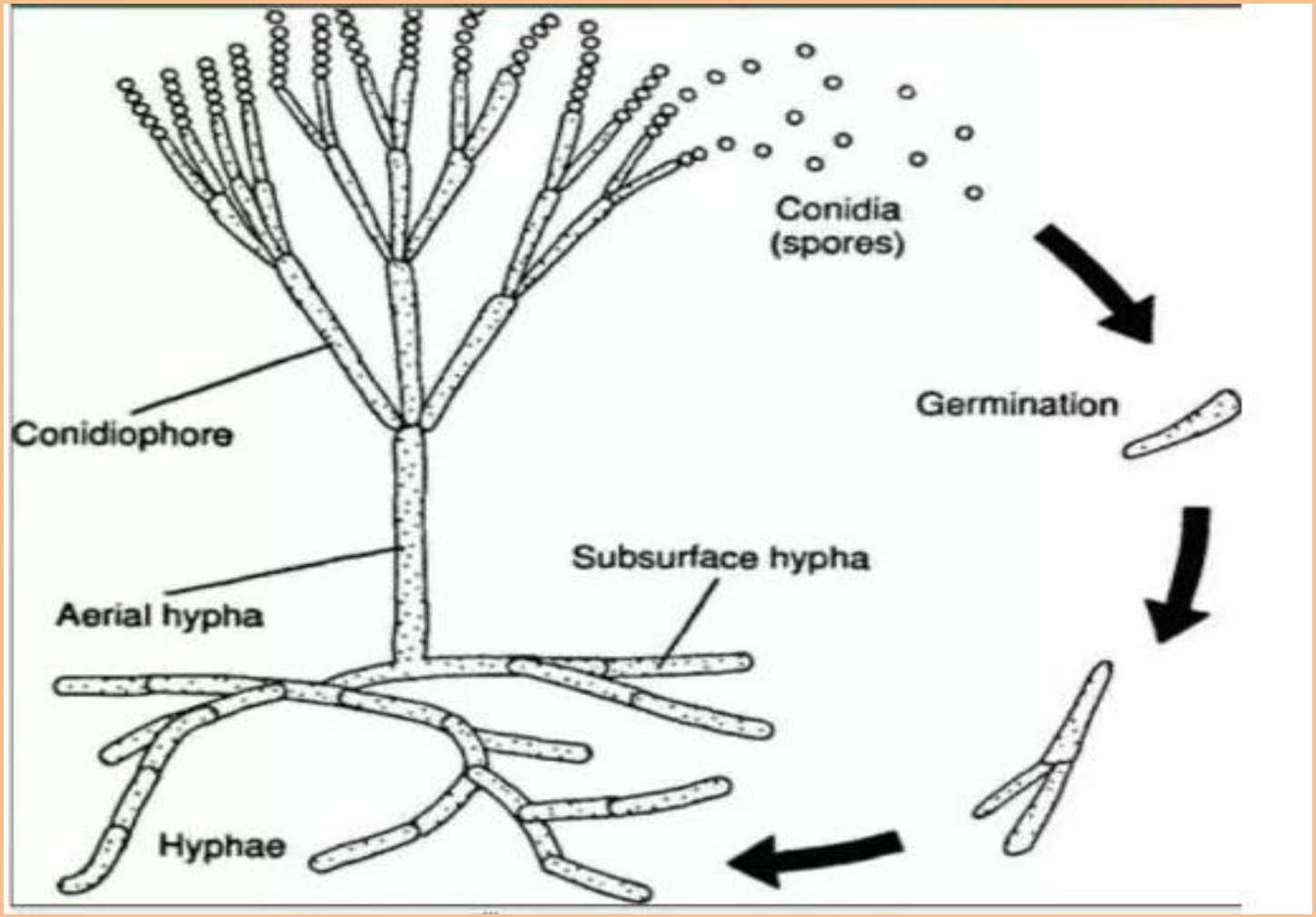


Cleistothesium

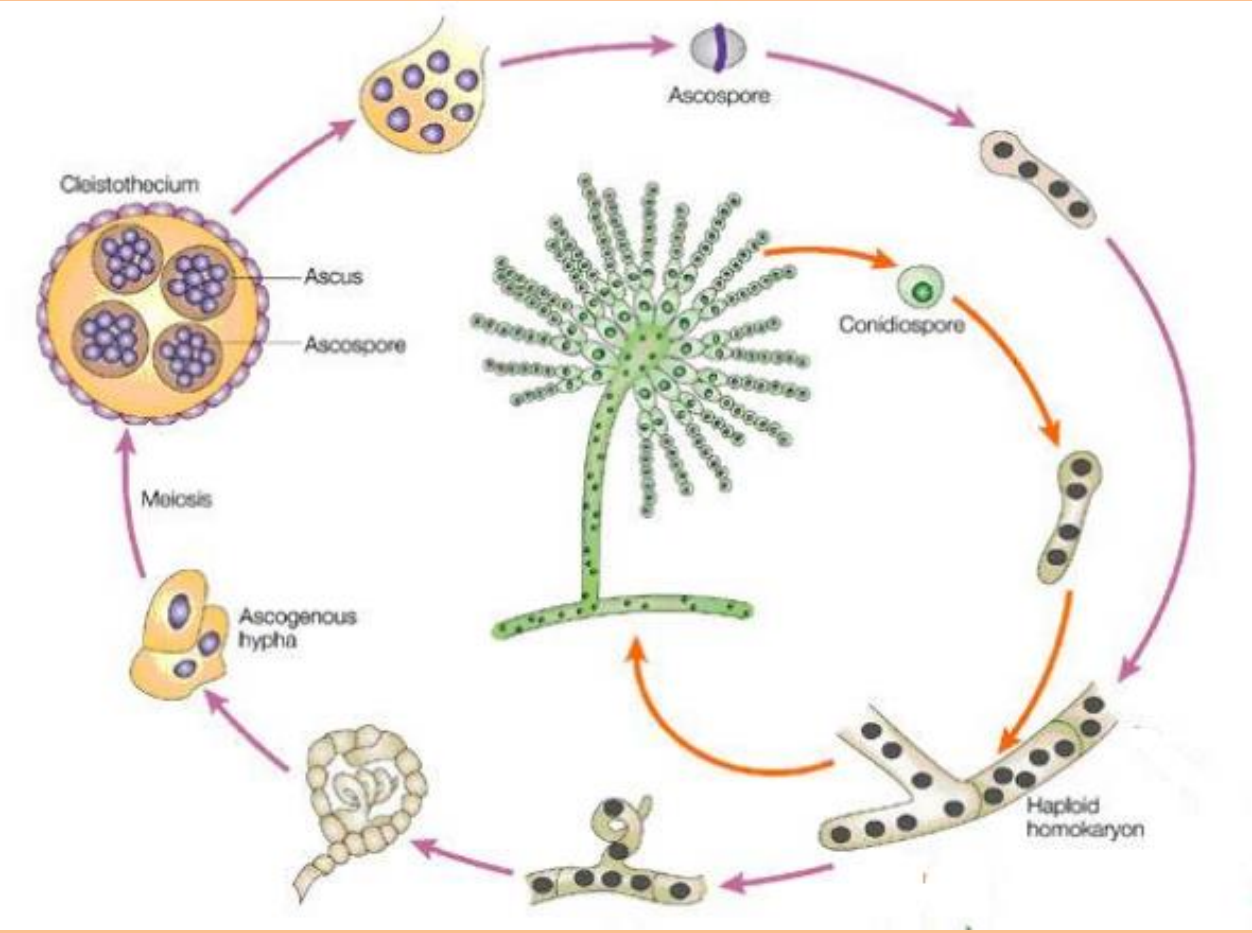
- The wall of asci is dissolved.
- Ascopores are released into **cleistothesium**.
- Then wall of cleistothesium decays to released ascopores into atmosphere.
- Each ascopores germinate to form mycelium.



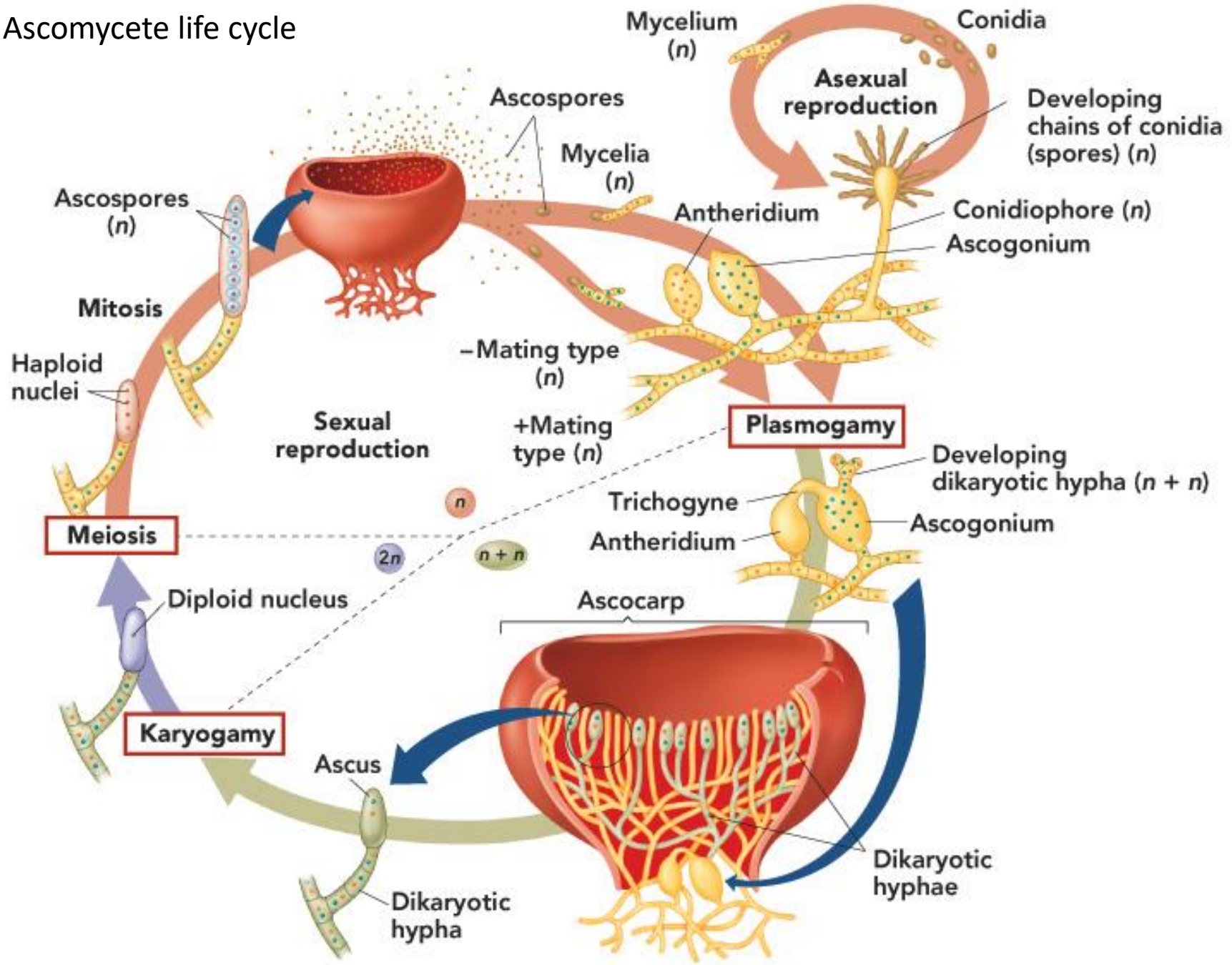
Aspergillus



Aspergillus



Ascomycete life cycle



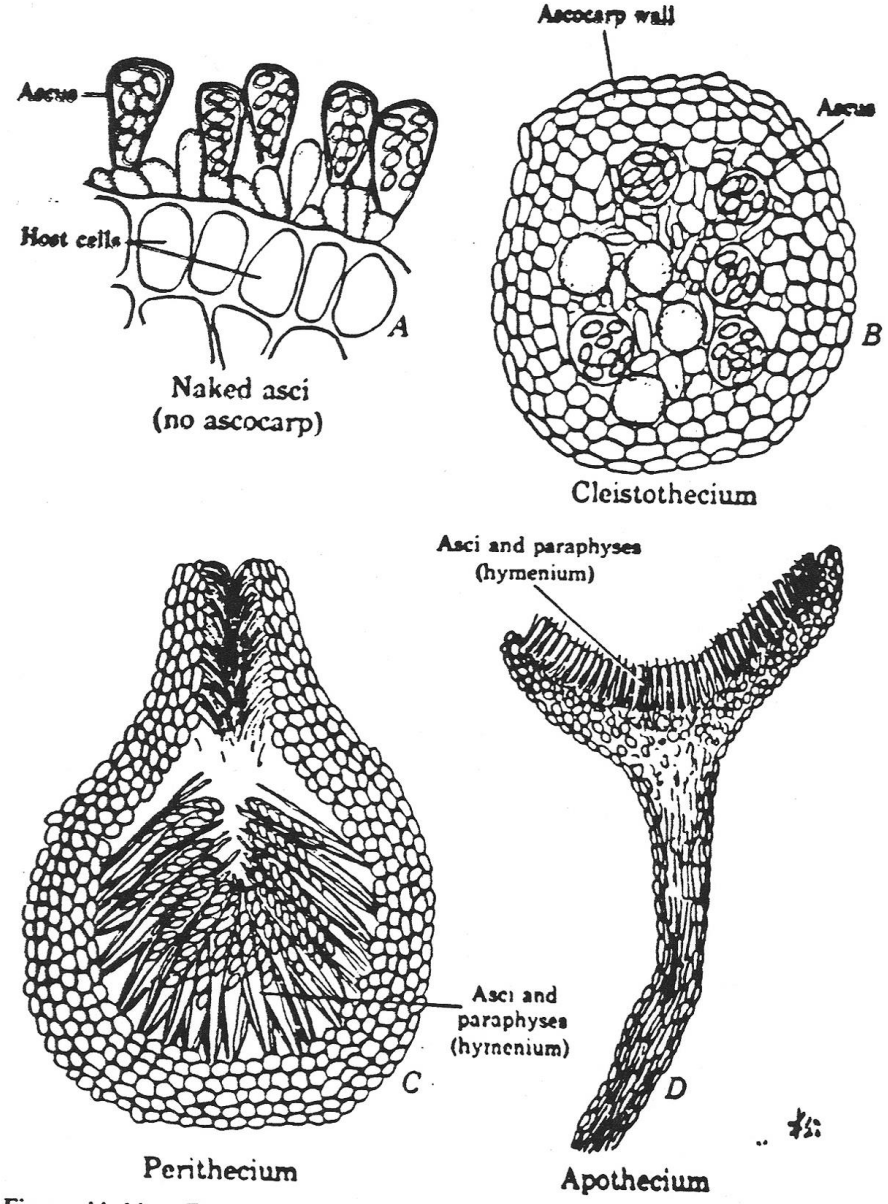
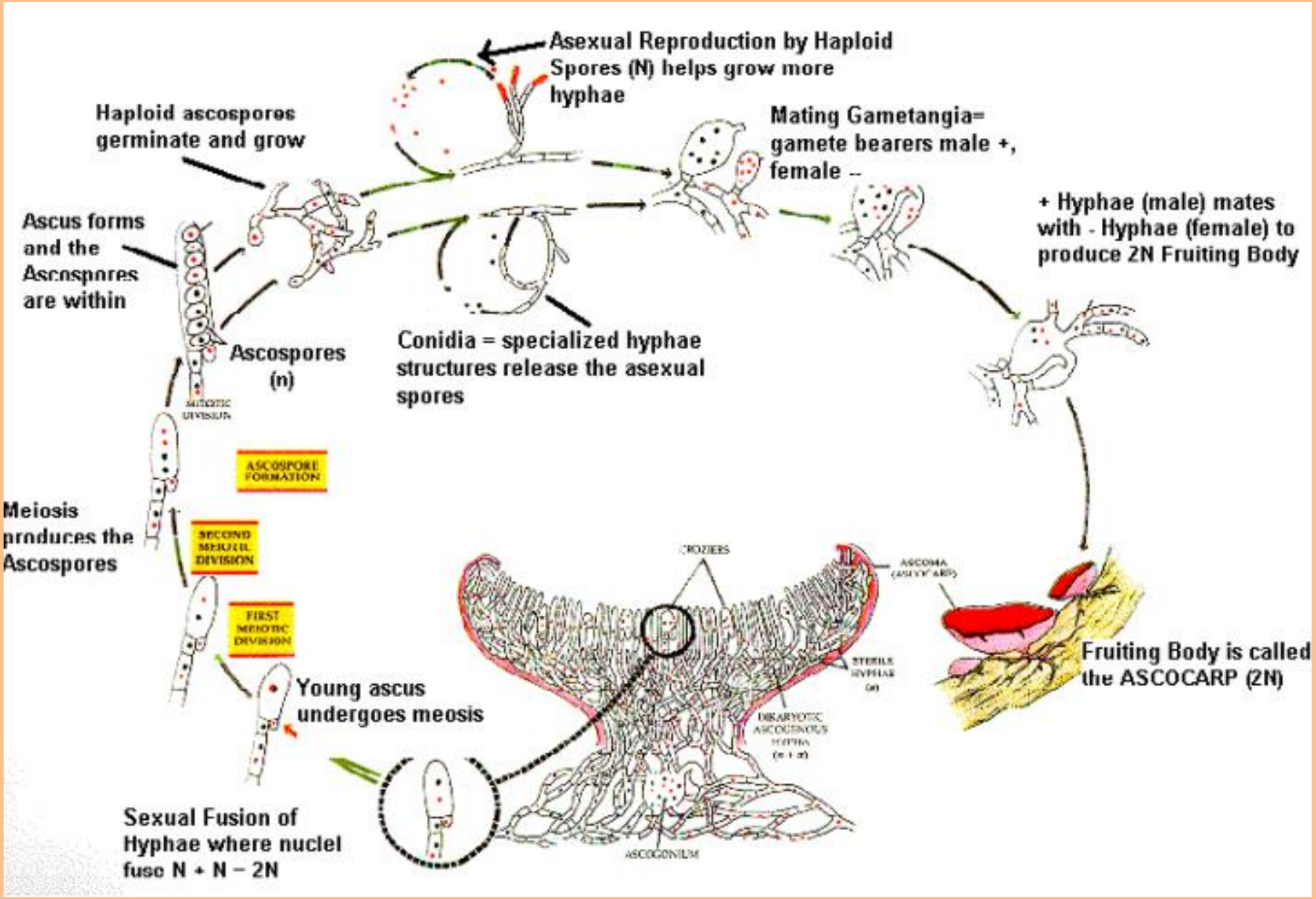
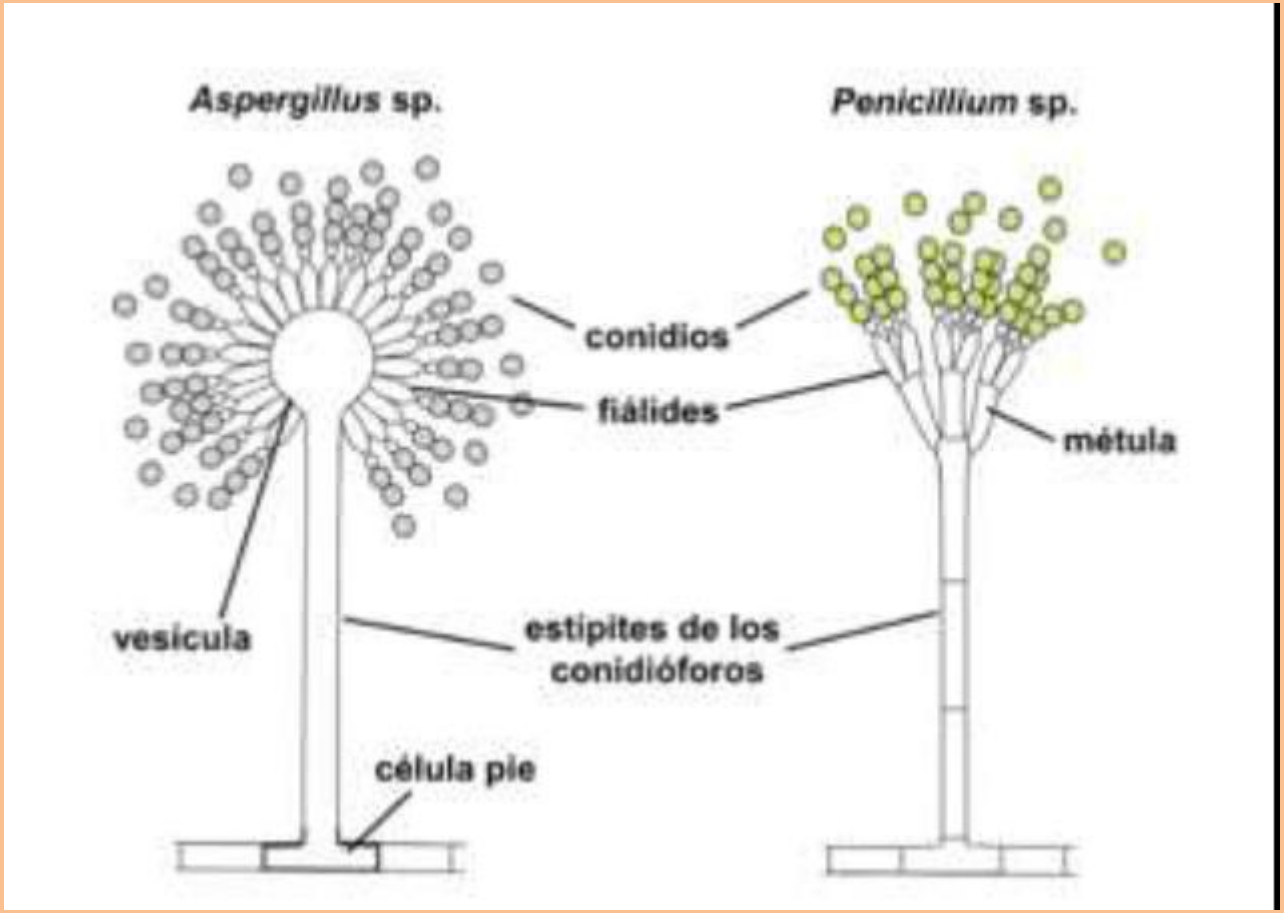


Figure 11-11. **Four ways in which Ascomycetes bear their asci.**


Asexual Reproduction by Haploid Spores (N) helps grow more hyphae
Haploid ascospores germinate and grow
Mating Gametangia= gamete bearers male +, female –
+ Hyphae (male) mates with - Hyphae (female) to produce 2N Fruiting Body
Ascus forms and the Ascospores are within
Ascospores (n)
Conidia = specialized hyphae structures release the asexual spores
ASCOSPORE FORMATION
Meiosis produces the Ascospores
SECOND MEIOTIC DIVISION
FIRST MEIOTIC DIVISION
Young ascus undergoes meosis
Sexual Fusion of Hyphae where nuclei fuse N + N – 2N
Fruiting Body is called the ASCOCARP (2N)
CROZIERS
ASCOGONIUM

Differentiate between Aspergillus and Penicillium

Aspergillus and Penicillium



Aspergillus	*Penicillium*
❑ The conidiophore is aseptate and unbranched.	❑ Conidiophore is long slender septate and branched.
❑ Conidiophore arises from a specialized T shaped thick walled foot cell.	❑ Conidiophore arises from any vegetative cell of the mycelium. ❑ There are no foot cell.
❑ Conidiophore enlarges into a vesicle at its tip bears the finger like sterigmata. The structure forms a spherical head.	❑ The conidiophore ends in a whorl of branches which gives a broom like appearance.

Aspergillus	*Penicillium*
❑ The peridium is quite soft.	❑ The peridium of cleistothecium is thicker and generally consists of loosely interwoven hyphae.
❑ Ascogonium: A small loosely coiled septate hyphal branch (latter becomes tight and close). The archicarp arises from the vegetative hyphae.	❑ A long erect, multinucleate (32-64) aseptate tubular structures. At times the upper end of the ascogonium may be curved like the handle of the umbrella.
❑ Many *Aspergillus* sp. causes disease known as Aspergillosis which affects lungs.	❑ *Penicillium* produces antibiotics that are effective against gram positive bacteria.

Unit 5: Basidiomycota

- General characteristics; Ecology; Life cycle and Classification with reference to black stem rust on wheat *Puccinia* (Physiological Specialization), loose and covered smut (symptoms only), *Agaricus*; Bioluminescence, Fairy Rings and Mushroom Cultivation.

- The third phylum of fungi, the **basidiomycetes** has about 22,000 named species.
- The majority of edible fungi belong to the Phylum-Basidiomycota.
- Among the basidiomycetes are not only the
- mushrooms, toadstools, puffballs, jelly fungi, and shelf fungi, but also many important plant pathogens including rusts and smuts.
- These mushroom-producing basidiomycetes are sometimes referred to as "gill fungi" because of the presence of gill-like structures on the underside of the cap. The "gills" are actually compacted hyphae on which the basidia are borne.

Ecosystem

- Basidiomycota are very important for the ecosystem and for humans.
- **Decomposition-**Many of the basidiomycota with the larger fruitbodies (toadstools etc.) are common and important agents of wood decay or decomposers of leaf litter, animal dung, etc.
- **Symbiotic relationships-** Some also form important symbiotic relationships, such as mycorrhizal associations with the roots of a plant, whereby the fungus receives carbohydrates from the plant’s photosynthesis and the plant gains the mycelium's very large surface area to absorb water and mineral nutrients from the soil.

- The basidia, which are the reproductive organs of these fungi, are often contained within the familiar mushroom, commonly seen in fields after rain, on the supermarket shelves, and growing on your lawn.
- The fungi in the Phylum Basidiomycota are easily recognizable under a light microscope by their club-shaped fruiting bodies called basidia (singular, basidium), which are the swollen terminal cell of a hypha.
- Basidiomycota are unicellular or multicellular, sexual or asexual, and terrestrial or aquatic.
- Basidiomycota are so variable that it is impossible to identify any morphological characteristics that are both unique to the group and constant in the group. The most diagnostic feature is the production of basidia which are the cells on which sexual spores are produced, and from which the group takes its name.

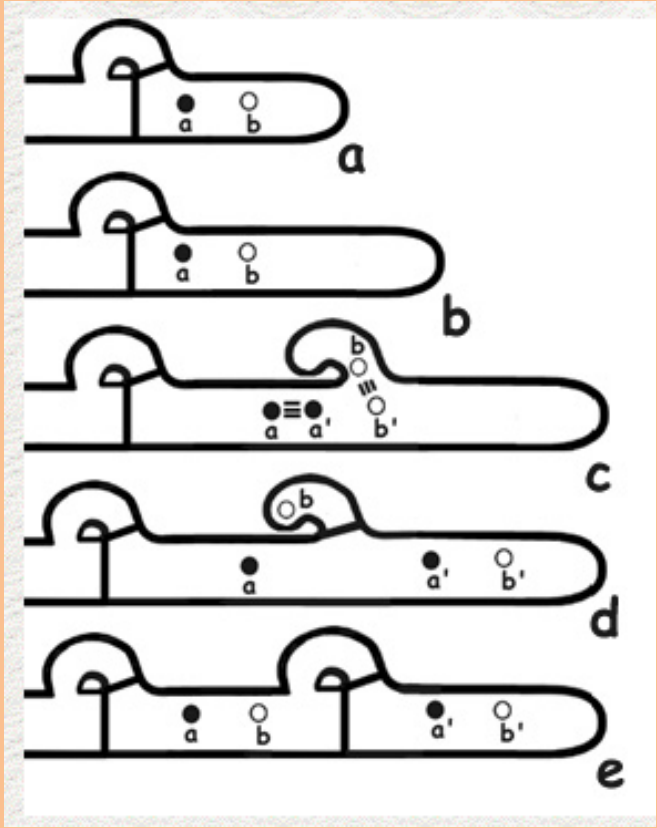
Ballistospores

- One of the most fascinating characteristics of Basidiomycota is the production of **ballistospores.**
- A **ballistospore/ballistoconida** is a spore that is discharged into the air from the tips of sterigmata in species of fungus. Ballistospores may be sexual or asexual.

Clamp connections

- Not all Basidiomycetes produce these, but when a fungus does it will always be a basidiomycete.
- A **clamp connection is a structure formed by** growing hyphal cells of certain fungi to ensure each cell, or segment of hypha separated by septa receives a set of different nuclei, which are obtained through mating of hyphae.
- It is used to create genetic variation within the hypha.

- Figure 1. Formation of Clamp Connections: a. Terminal cell of hypha. Growth only takes place at hyphal tips; b. Hyphal tip elongating. c. Synchronous division of nuclei and the beginning of hyphal branch that will become the clamp connection. One nucleus (b) migrates into the new clamp. d. Septum forms at base of the clamp trapping nucleus b. Nuclei a' and b' migrate to the hyphal tip, while nucleus a migrates *away* from the tip. e. Septum forms below clamp forming new cell at hyphal tip. Fusion of the clamp to the adjacent cell releases nucleus b to the adjacent cell. Now both the terminal and subterminal are binucleate, each with a compatible pair of nuclei.



Fruiting body

The Basidiomycota is **Holocarpic** in which the entire thallus/body is converted into a Fruiting body.

Eventually, the secondary mycelium generates a basidiocarp, which is a fruiting body that protrudes from the ground; this is what we think of as a mushroom.

The basidiocarp bears the developing basidia on the gills under its cap.

Fairy ring

- **Fairy ring**, a naturally occurring circular ring of mushrooms on a lawn or other location. A fairy ring starts when the mycelium (spawn) of a mushroom falls in a favourable spot and sends out a subterranean network of fine, tubular threads called hyphae. The hyphae grow out from the spore evenly in all directions, forming a circular mat of underground hyphal threads. The mushrooms that grow up from this circular underground mat form a similar pattern above ground. Gradually the underground mycelium at the centre of the circle dies out. Its living outer edges, however, keep growing year by year, and hence the diameter of the ring gradually increases. Over time the ring's underground segments die out, until the ring form on the surface can no longer be discerned.

Bioluminescence

When a living organism produces and emits light as a result of a chemical reaction, the process is known as Bioluminescence

Bio means 'living' in Greek while lumen means 'light' in Latin

During the process, chemical energy is converted into light energy

The process is caused by an enzyme-catalyzed chemoluminescence reaction

The light production from bioluminescence is “cold light” emission, wherein less than 20% of the light is thermal radiation.

How does bioluminescence work ?

- Bioluminescence is a product of a chemical reaction in an organism
- It involves a class of chemicals called luciferins ("light bringers“)
- The luciferin oxidizes in the presence of a catalytic enzyme (luciferase) to create light and an ineffective compound (oxyluciferin)

List of bioluminescent fungus specie

- *Armillaria gallica*
- *Mycena chlorophos*
- *Mycena haematopus*
- *Mycena epipterygia*
- *Mycena singeri*
- *Roridomyces roridus*

Gills of *O. olearius*

Life Cycle of *Puccinia*

- *Puccinia is a obligate parasite and pleomorphic* fungi. Which cause macrocyclic and heteroecious rust in wheat.
- It produce different types of spores in 5 stages in

wheat.

1. Stage ‘O’ – Spermagonia/Pycnia – Spermatium
2. Stage ‘1’ – Aecia/Aecidia – Aceospore/aecidiospore
3. Stage ‘2’ – Uridinia/Uredia – Uredospore/Uredinospore (conidia)
4. Stage ‘3’ – Telia/Teleutosori – Teliospore/Teleutospore
5. Stage ‘4’ – Basidia/Promycelia – Basidiospore/Sporodia

- It complete life cycle on wheat as main host and Barbery and Mohinia as Alternate host.

1. Uredinal Stage –II

Uredial stage is found on wheat. In this stage uredia are form from branched, septate, intracellular and dikaryotic mycelium.

Under the epidermis from mycelium sporophorus form which bear urediospores.

These urediospores put pressure on epidermis and rupture it.

Urediospores are unicellular, binuclear, brown in color and having tiny spines on surface.

These urediospores germinate in the presence of moisture on leaf surface by forming germ tube and enter in host by stomata.

In optimum conditions in 10-15 days new urediospores form.

These urediospores are also known as repeated conidia of rust.

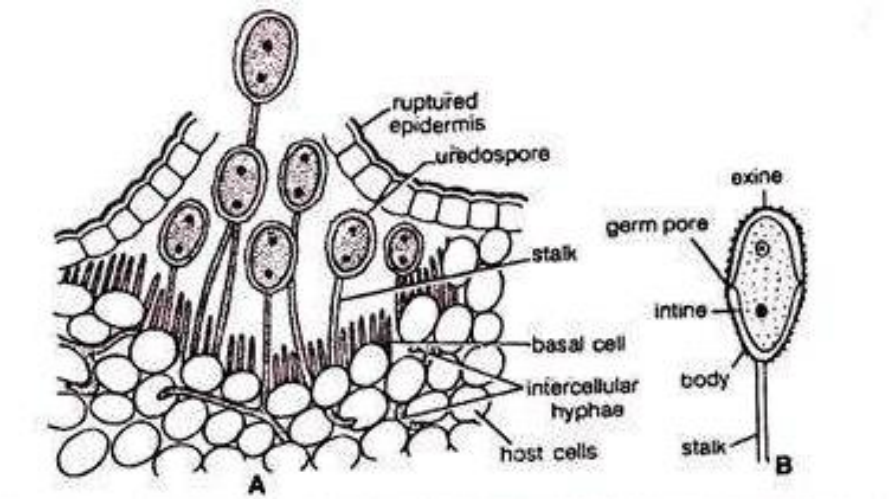


Fig. 4 (A–B). *Puccinia graminis* : T.S. wheat leaf passing through a uredosorus, (B) A uredospore

Telial Stage –III

- In the late of season at the time of crop maturity teliospores form in place of urediospores.
- Teliospores are stalked, bicellular, diploid, spindle shaped, thick wall celled and color is chestunt brown.
- Size of teliospore is 40-50 × 15-20µm.
- Teliospores not germinate like urediospores.
- In hilly areas teliospores remain in dormant stage on wheat residue but in plain area of India due to high temperature teliospore not survive.

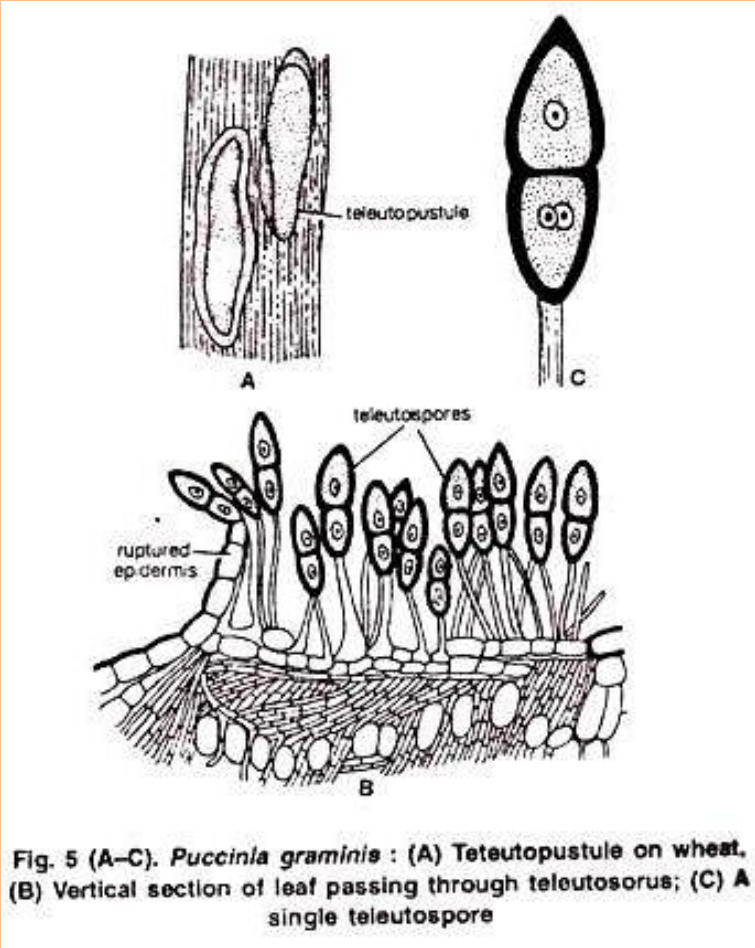


Fig. 5 (A–C). *Puccinia graminis* : (A) Teteutopustule on wheat. (B) Vertical section of leaf passing through teleutosorus; (C) A single teleutospore

Basidial Stage –IV:

After dormancy period each cell of teliospore germinate by forming promycelium or basidium.

Before germination of teliospore diploid nucleus by meiosis divided in four haploid nucleus.

Four basidiospores from 4 haploid nucleus form 4 basidiospores in which 2 act as + ve and 2 act as – ve factor.

These spores are unicellular, monokaryotic and haploid. These basidiospores by air reach on Barberry (Alternate host).

These spores can not infect to wheat.

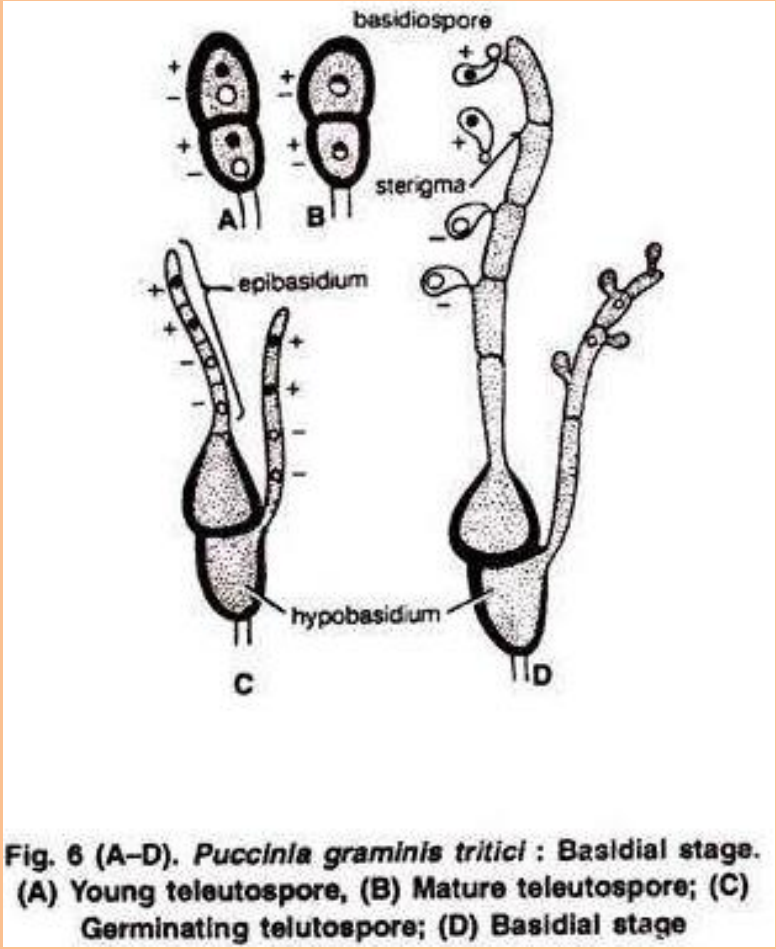


Fig. 6 (A–D). *Puccinia graminis tritici* : Basidial stage. (A) Young teleutospore, (B) Mature teleutospore; (C) Germinating telutospore; (D) Basidial stage

Spermogonial or Pycnial Stage –O

Basidiospores fall on alternate host (Barberry), in presence of moisture, germinate by germ tube and after entering into host mycelium grow intercellularly.

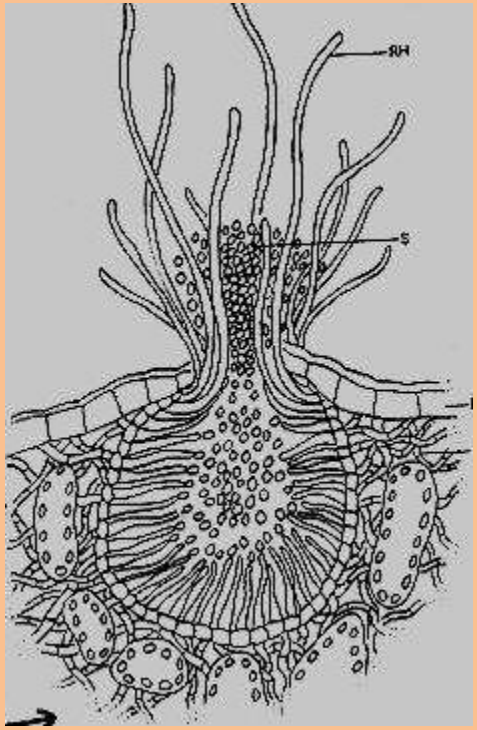
- After few days pycnia form which put pressure on epidermis and rupture it and open by ostiole.
- Flexuous receptive hyphae come out from ostiole.

Pycnospores form in pycnia and come out from pycnia.

- Sex of pycniospore depend upon the type of mycelium from which they are form (+ve or –ve factor)

Due to color, smell of sticky liquid and sweetness of pycnidia insects attract towards pycnidia and transfer the pycnospores to other receptive hypha.

When one opposite sex factor pycnospre reach to other sexfactor Dikaryotization take place resulting in dikaryotic mycelium form.



Aecial Stage –I

- After dikaryotization in pycnial stage this dikaryotic mycelium grow downside in leaves and form cup shaped aecia on lower side of barberry.
- Aeciospores form in these aecia.
- Aeciospores are unicellular, dikaryotic, spherical or hexagonal with 14-26 µm diameter.
- Aeciospores put pressure on epidermis and rupture it resulting in release of aeciospores in the air.
- These spores disseminate by air and reach on wheat leaves and in presence of moisture germinate by germ tube.
- Germ tube enter into plant through stomata and form dikaryotic, septate, intercellular mycelium which form urediospores.

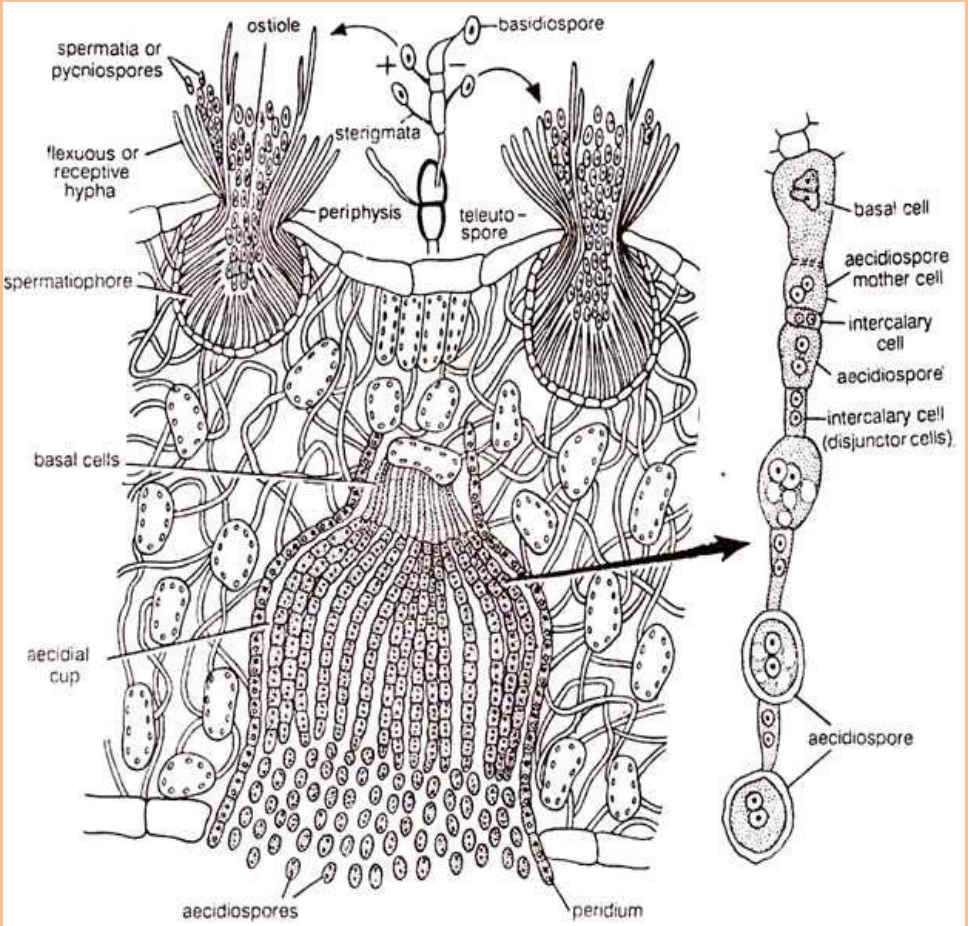
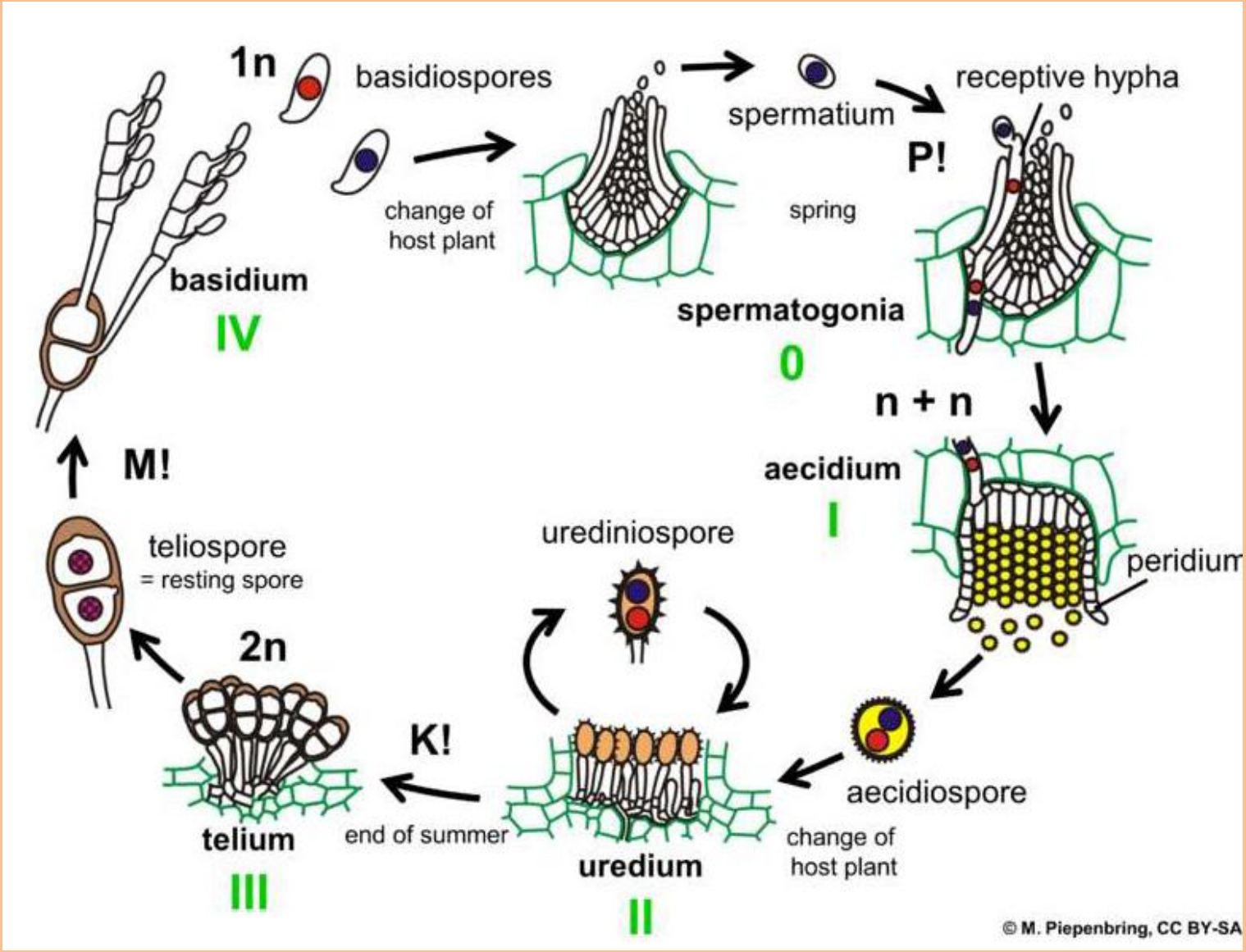
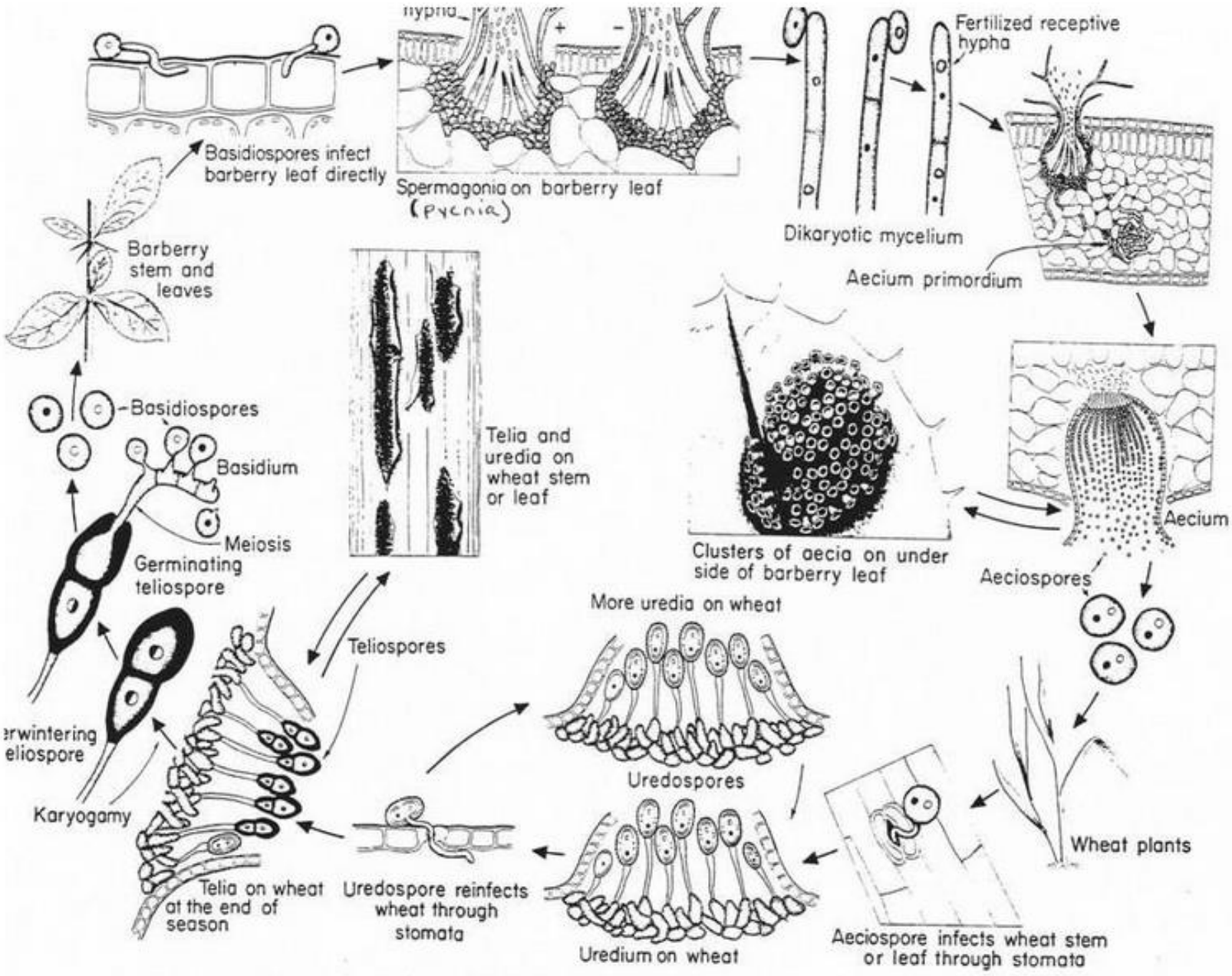


Fig. 7. Puccinia : Transverse section of barberry through pycnial and aecial cup

Life cycle of *Puccinia*



Wheat stem rust, caused by *Puccinia graminis tritici*



Unit 7: Oomycota

- General characteristics;
- Ecology;
- Life cycle and classification with reference to *Phytophthora, Albugo.*

1) **Biflagellate zoospores**
   - tinsel & whiplash flagella
   - Primary (anterior flagella) & Secondary (lateral flagella) zoospores

2) **Cell walls beta-glucans & cellulose; a few do have chitin**
   - beta-glucan: beta-1,3;1,6 D-glucose
   - chitin: beta-1,4 of N-acetylglucosamine

3) **Sex is oogamous by gametangial contact (gametangy)**
   - no flagellate gametes
   - female gamete (oospheres) produced by oogonium; one to many oospheres male gamete produced by antheridium
   - male gametes are donor nuclei that migrate from antheridium into oogonia and fertilize oospheres (=egg)

4) **Meiosis is gametangial (vs. zygotic); somatic nuclei diploid**
   - antheridia & oogonia are sites of meiosis
   - oosphere fertilized by male gamete
   - diploid zygote develops into oospore that germinates and give rise to vegatative diploid hyphae that reproduce asexually by production of zoospores.

5) Body plan

- thallus - single-celled or filamentous
- holocarpic - entire thallus may be converted into one or more reproductive structures
- eucarpic - reproductive organs arise from only a portion of the thallus, while the remainder continues as somatic; majority of species
- monocentric - any thallus that gives rise to only a single center of growth and reproduction
- polycentric - if thallus bears more than one center
- iso- or heterogametangic, usually later

6) Flagellar system:

- primary (Saproleginales & Leptomitales) & secondary zoospores (all orders)
- primary zoospores the flagella are located anteriorly
- secondary zoospores the flagella are located laterally

What is *Phytophthora*?

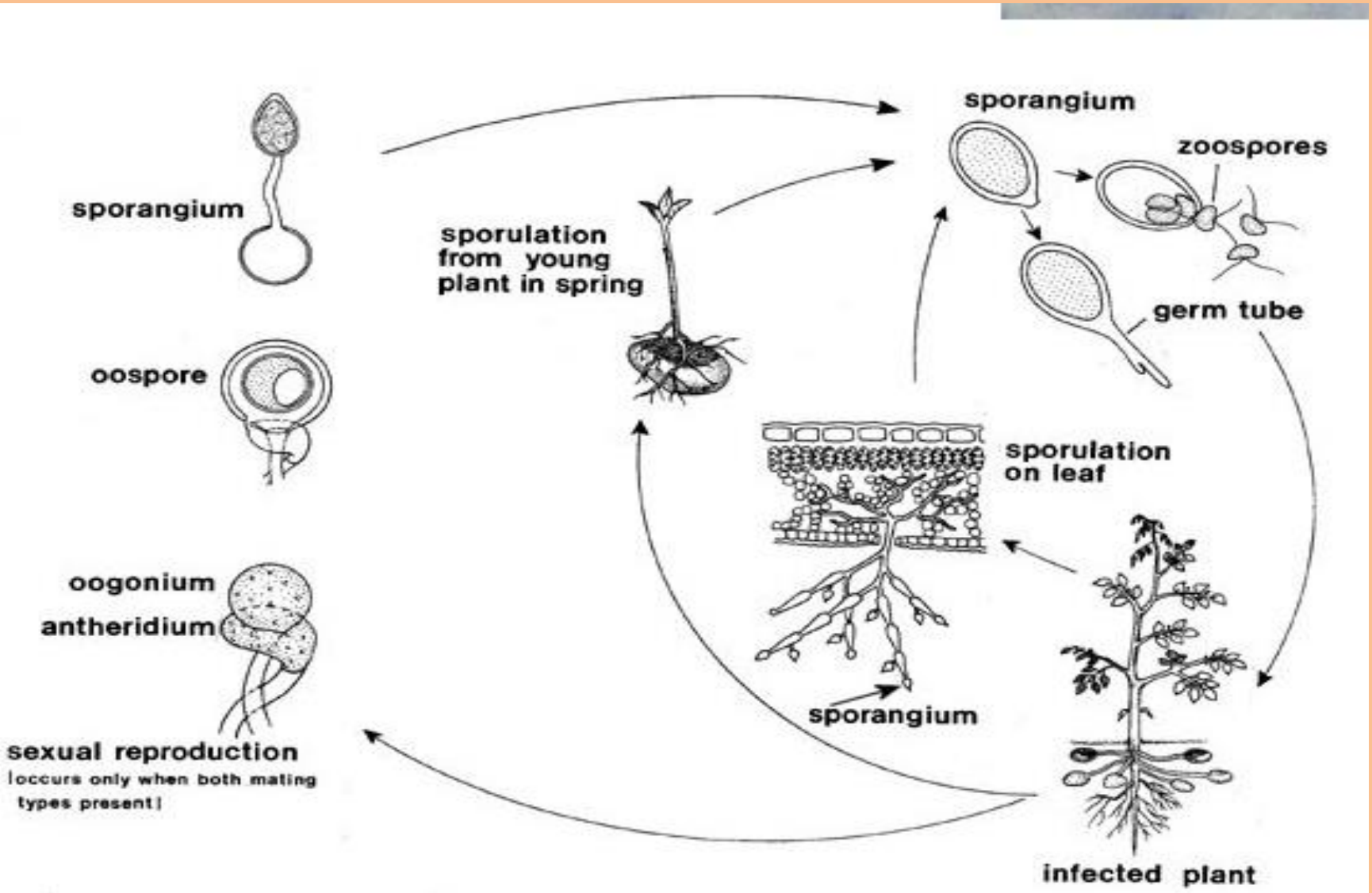
- *Phytophthora* is a genus of Oomycota (oomycetes or water molds), a phylogenetic group of fungus-like eukaryotes in the phylum Heterokonta, or stramenopiles. Many heterokonts are unicellular flagellates, and some, including *Phytophthora*, are multicellular with a flagellated single-celled stage in the life cycle called a zoospore. The name heterokont refers to the characteristic form of these cells, with differentiated flagella, one whiplash and one tinsel. The whiplash straminipilous flagellum is covered with tripartite (with three regions each) mastigonemes (lateral bristles).
- Much like fungi, oomycetes are filamentous, microscopic organisms that reproduce both sexually and asexually and absorb nutrients from their substrate either saprophytically or pathogenically. Oomycetes differ from fungi in that their cell walls are made of cellulose and beta glucans rather than chitin, their hyphae lack cross-walls (septations), and their life cycle is primarily diploid rather than haploid. Oomycetes include some of the most serious plant pathogens; almost all known *Phytophthora* species can cause disease symptoms in plants.
- *Phytophthora* has become one of the most studied genera of plant pathogens. The genus includes many species reported to cause root, crown, and collar rots, wilts, leaf and stem blights, fruit and tuber rots, cankers, bleeding cankers, and stem dieback, resulting in economic impacts to crops, ornamentals, and forest ecosystems around the world. Some species are particularly devastating plant pathogens that have a significant impact in agriculture or natural ecosystems; among them are *P. austrocedri*, *P. capsici*, *P. cinnamomi*, *P. infestans*, *P. kernoviae*, *P. quercina*, and *P. ramorum*.

Phytophthora life cycle

- Because *P. infestans* is a host-specific parasite, it needs plant tissue to grow in. Usually, as was the case in Ireland, *P. infestans* reproduces asexually. Its life cycle usually begins as the sporangia are carried by the wind, land on plant tissue, and release their zoospores (Judelson 1997). This will happen when the conditions are wet and cool and is called indirect germination. These spores are biflagellated—having both a tinsel and whiplash flagellum which is characteristic of oomycota and will swim until they encyst in the host. When conditions are warmer, *P. infestans* will infect the plant by direct germination—that is a germ tube will form from the sporangium and will penetrate the host tissue allowing it to gain nutrients from its host (Schumann and D'Arcy 2000).

- Sexual reproduction, can and does occur when both mating types are present. The antheridium and oogonium (the only haploid parts in the life cycle of *P. infestans*) nuclei will fuse together (karyogamy) when the antheridium enters the oogonium. They will form a diploid oospore, which will develop into a sporangium and the cycle will continue as is would asexually (Schumann and D'Arcy 2000).
- Infected plants show signs of small brown or black lesions on the leaves or stems, but soon spread and kill the plant. The growth of sporangia on the surface of the leaves or stems makes is white, which is another warning sign of infection.
- Tubers can also become infected when the sporangium are washed into the soil. The tubers will show signs by copper brown, reddish, or purplish color in the cracks, eyes, or lenticels. Soft rot (not to be confused with soft rock) bacteria will then invade causing the tuber to become smelly and rotten.
- Similar signs exist for the tomato plants (Schumann and D'Arcy 2000).

Phytophthora life cycle



This is a simplified disease cycle for late blight of potato. (2).