



BIOLOGY AND DIVERSITY OF VIRUSES, BACTERIA AND FUNGI (PAPER CODE: BOT 501)



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OBJECTIVES

The main objective of the present lecture is to cover the topic and make it easy to understand and interesting for our students/learners.

BLOCK – III : FUNGI – I

Unit –13 : Reproduction in Fungi

In this lecture, we will discuss about the various methods of reproduction adopted by the fungi.

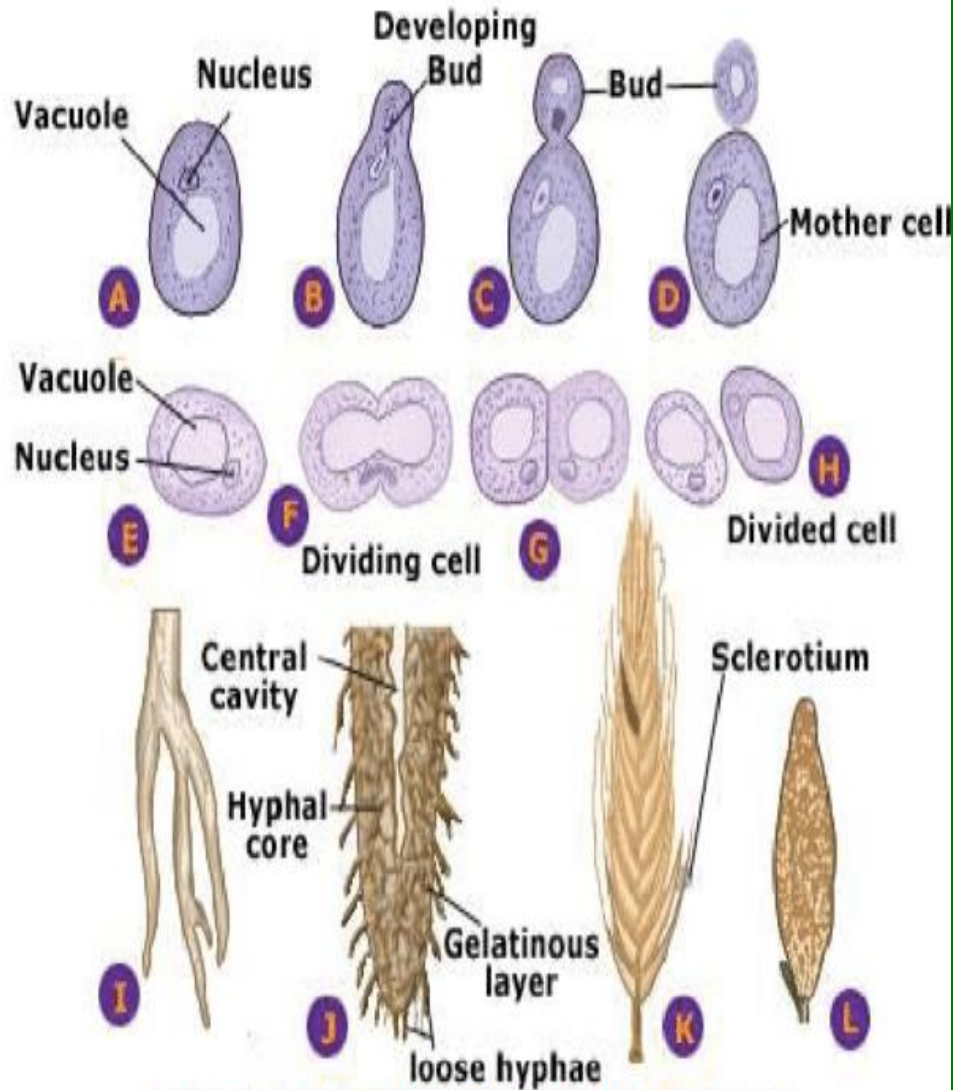
CONTENT

- ❑ Reproduction in fungi
 - ❖ Vegetative Reproduction
 - Fission
 - Budding
 - Fragmentation
 - Sclerotia
 - Rhizomorphs
 - ❖ Asexual Reproduction
 - Endogenous Spores
 - Exogenous Spores
 - ❖ Sexual Reproduction
 - Planogametic Copulation
 - Gametangial Contact
 - Gametangial Copulation
 - Spermatization:
 - Somatogamy
- ❑ Sexual Incompatibility
- ❑ Sexual Pheromones
- ❑ Key Points of The Lecture
- ❑ Terminology
- ❑ Some Assessment Questions

REPRODUCTION IN FUNGI

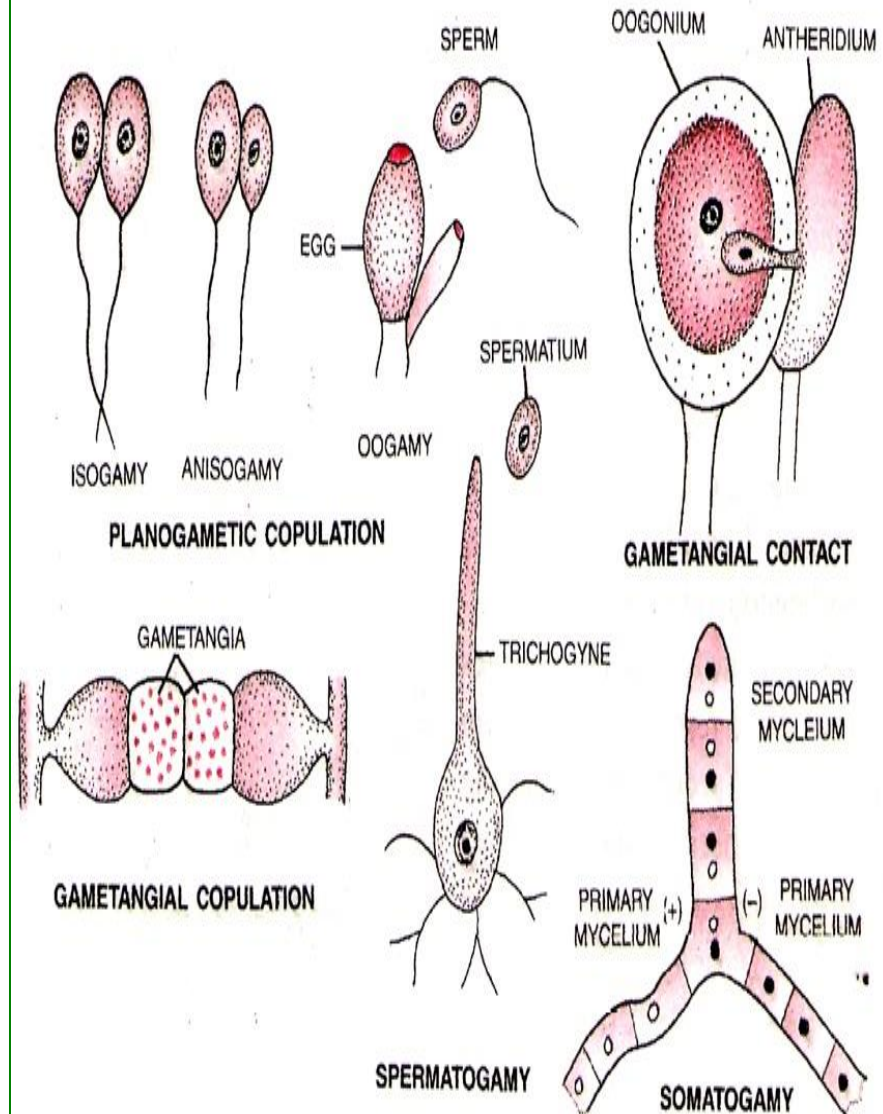
- ❖ Reproduction may be define as a process in which individual species increase their number by producing the progeny.
- ❖ Fungi are achlorophyllas, heterotrophic eukaryotic thallophytes, which adopted the various methods of reproduction.
- ❖ When the fungal mycelium has reached a certain stage of maturity and has accumulated reserve food material, it start reproduction.
- ❖ Reproduction involves the production of new individuals resembling the parent or parents.
- ❖ In fungi, reproduction is of three kinds;
 - Vegetative reproduction
 - Asexual reproduction
 - Sexual reproduction
- ❖ Many mycologist, however, included all methods of reproduction (vegetative and spore formation) which do not involve union of nucli or sex cell or sex organs under asexual or somatic reproduction.
- ❖ During asexual and sexual reproduction processes spores are the essential structures. The spores formed after meiosis are called meiospores (e.g., ascospores, basidiospores and sporangiospores) and those resulting from mitosis, called mitospores (e.g., mitospores, zoospores, aplanospores, conidia, uredospores).

REPRODUCTION IN FUNGI



Modes of vegetative reproduction in fungi.

A-D. Budding. E-H. Fission. I-J. Rhizomorph; K-L. Sclerotia



Types of sexual reproduction in fungi.

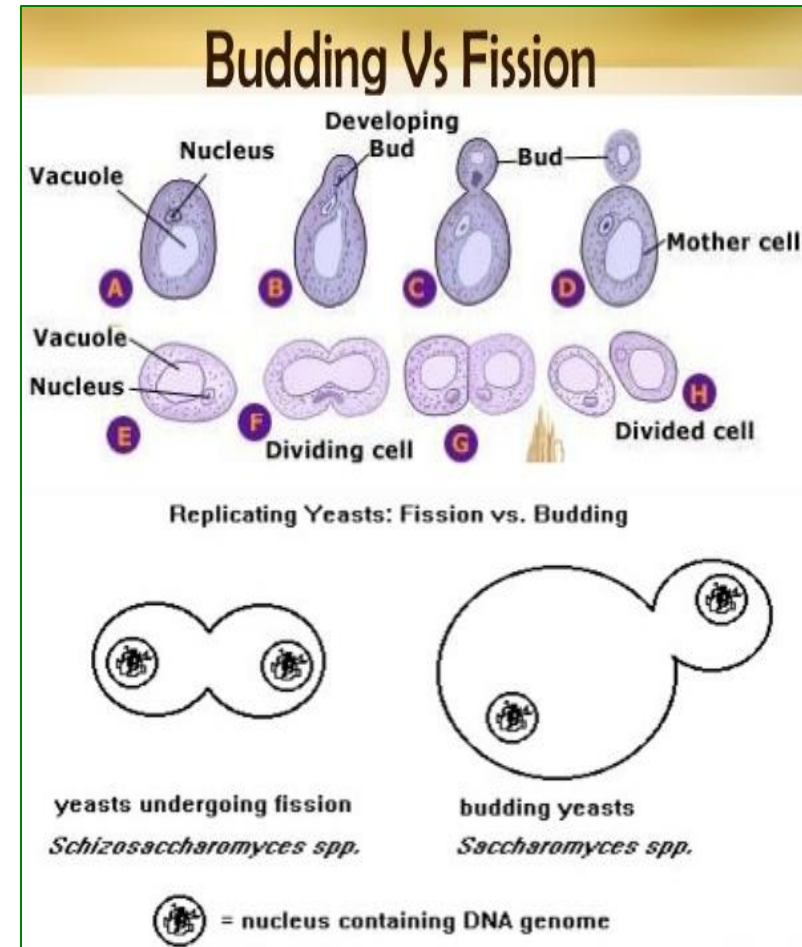
VEGETATIVE REPRODUCTION IN FUNGI

❖ Vegetative reproduction is any form of reproduction occurring in plants in which a new plant grows from a fragment of the parent plant or a specialized reproductive structure. Fission, budding and fragmentation are most common methods of vegetative reproduction in a number of fungi. In addition to above-mentioned common methods they also reproduced vegetatively by other means, such as sclerotia, rhizomorphs, etc.

❑ **Fission:** Some single-celled fungi, reproduce by simple cell division, or fission, in which one cell undergoes nuclear division and splits into two daughter cells; after some growth, these cells divide, and eventually a population of cells forms.

➤ **Process of Fission:** In binary fission a mature cell elongates and its nucleus divides into two nuclei.

- The daughter nuclei separates, cleaves cytoplasm centripetally in the middle till it divides parent protoplasm into two daughter protoplasm.
- A double cross wall is deposited in the middle to form two daughter cell.
- Ultimately the middle layer of double cross wall degenerates and daughter cells are separated.
- Examples: *Saccharomyces* , *Psygosaccharomyces*



❑ **Budding:** It is another method of vegetative reproduction, occurs in most yeasts and in some filamentous fungi. In this process, a bud develops on the surface of either the yeast cell or the hypha, with the cytoplasm of the bud being continuous with that of the parent cell.

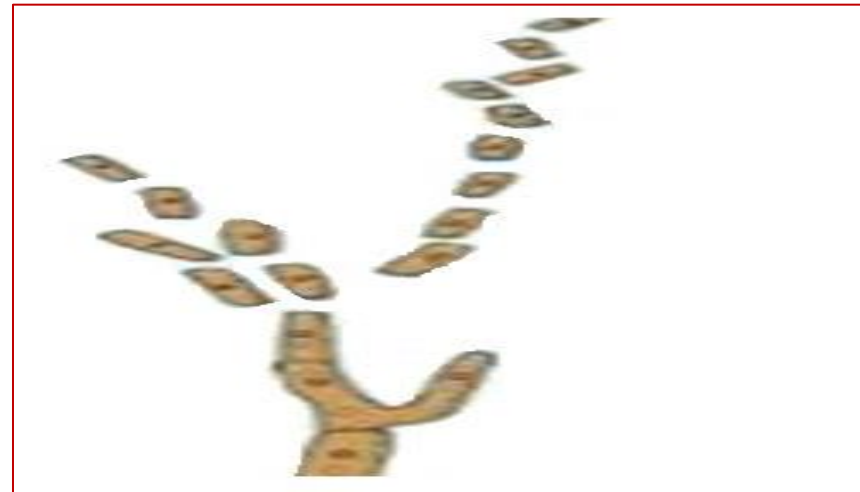
❖ The nucleus of the parent cell then divides; one of the daughter nuclei migrates into the bud, and the other remains in the parent cell. The parent cell is capable of producing many buds over its surface by continuous synthesis of cytoplasm and repeated nuclear divisions. After a bud develops to a certain point and even before it is severed from the parent cell, it is itself capable of budding by the same process. In this way, a chain of cells may be produced. Eventually, the individual buds pinch off the parent cell and become individual yeast cells.

➤ **Process of budding:**

- The cell wall bulge out and softens in the area probably by certain enzymes brought by vesicles.
- The protoplasm also bulge out in this region as small protuberance.
- The parent nucleus also divides into two, one of the daughter nucleus migrates into bud, the cytoplasm of bud and mother remain continuous for some time
- As the bud enlarges, a septum is laid down at the joining of bud with mother cell. Then bud separates and leads independent life.
- Some time, bud starts reproducing while still attached with mother cell. This gives branching appearance.
- Budding is the typical reproductive characteristics of Ascomycetes.
- Examples: Yeast

❑ Fragmentation:

- ❖ In filamentous fungi the mycelium may fragment into a number of segments, each of which is capable of growing into a new individual.
- ❖ In the laboratory, fungi are commonly propagated on a layer of solid nutrient agar inoculated either with spores or with fragments of mycelium.



Fragmentation

❑ Sclerotia:

- ❖ The sclerotia are resistant and perennating bodies. They survive for many years. Each sclerotium is cushion-like structure of compact mycelium. They give rise to new mycelia on the approach of favourable conditions.



Sclerotia

❑ Rhizomorphs:

- ❖ A modified mycelium, the rope-like rhizomorphs are also resistant to unfavourable conditions and give rise to new mycelia even after several years on the approach of favourable conditions.



Rhizomorphs

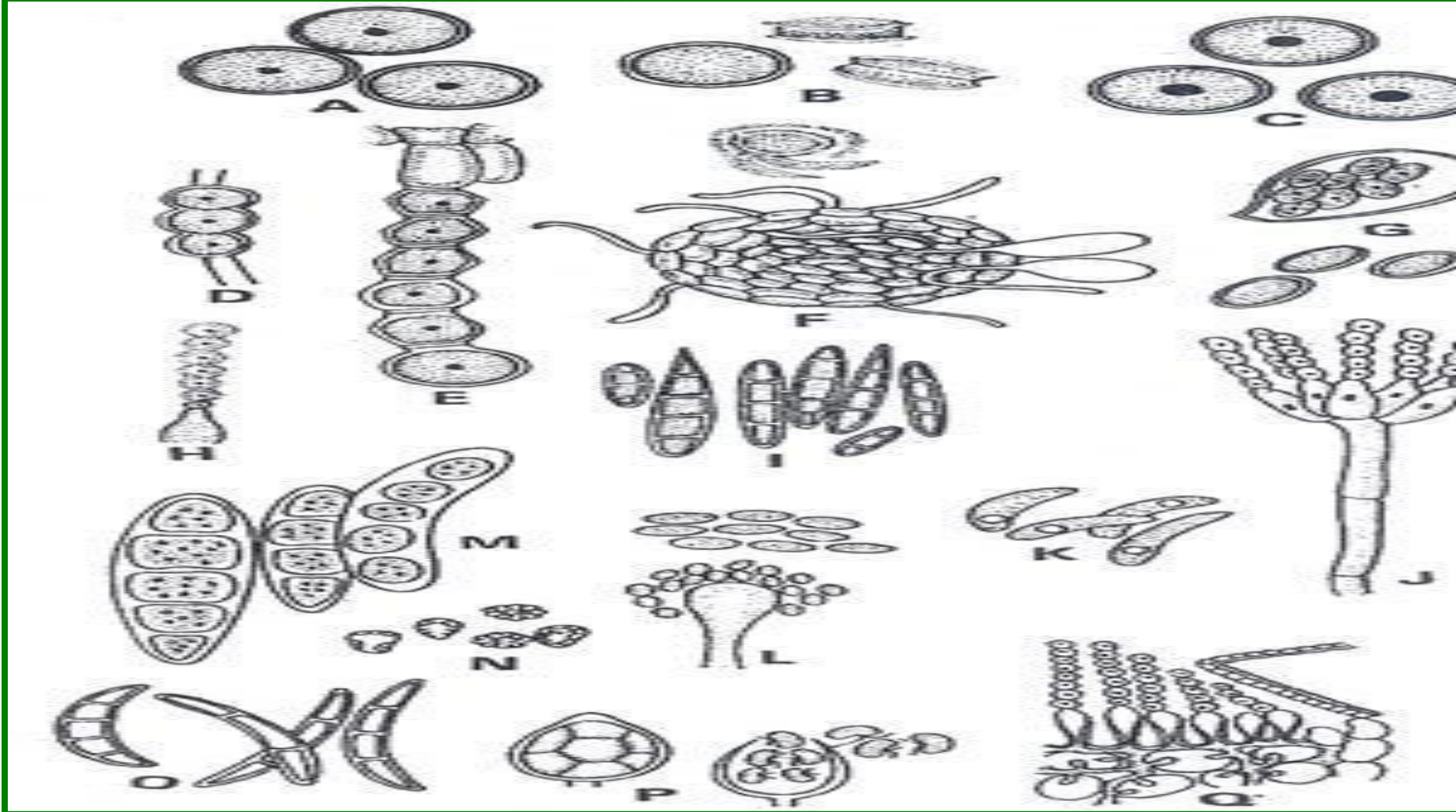
ASEXUAL REPRODUCTION IN FUNGI

- ❖ Typically in asexual reproduction, a single individual gives rise to a genetic duplicate of the progenitor without a genetic contribution from another individual. Perhaps the simplest method of reproduction of fungi.
- ❖ The majority reproduce asexually by the formation of spores. Spores that are produced asexually are often termed mitospores, and such spores are produced in a variety of ways.
- ❖ The spores are of diverse type and borne upon special structures called the sporophores. These spores are produced asexually and called the asexual spores.
- ❖ Usually the spores are uninucleate and nonmotile but multinucleate and motile spores are also found.
- ❖ The fungus producing more than one type of spores is called the pleomorphic or polymorphic.
- ❖ The spores produced inside the sporangia are termed the endogenous spores and the spores developing exogenously on the terminal ends of sporophores are called the exogenous spores.
- **Endogenous spores:** The endogenous spores are produced within the special spore producing cell the sporangium.
- ❖ The sporangia may be terminal or intercalary in their position. The sporophores which bear the sporangia on their apices are called the sporangiophores. They may be branched or unbranched.
- ❖ The spores produced inside the sporangia are called the endospores or endogenous spores produced inside the sporangia are called the endospores or endogenous spores.

- ❖ They may be motile or non-motile. The motile spores are called the zoospores and the non-motile aplanospores. The zoospores are produced inside the zoosporangia.
- ❖ The protoplasm of the sporangium divides into uninucleate or multinucleate protoplasmic bits and each bit metamorphoses into a spore.
- ❖ The endogenously produced zoospores are uni or biflagellate. Each spore is without any cell wall, uninucleate and vacuolate. They can move with the help of their flagella.
- ❖ They are usually kidney-shaped or reniform and the flagella are inserted posteriorly or laterally on them. Such zoospores have been recorded from *Albugo*, *Pythium*, *Phytophthora* and many other lower fungi.
- ❖ The aplanospores are non-motile, without flagella and formed inside the sporangia. They may be uni or multinucleate (e. g., *Mucor*, *Rhizopus*).
- ❖ These spores lack vacuoles and possess two layered cell walls.
- ❖ The outer thick layer is episore or exospore which may be ornamented in many cases. The inner thin layer is endospore.

➤ **Exogenous spores:**

- ❖ The spores producing externally or exogenously are either called the exogenous spores or conidia. They are produced externally on the branched or unbranched conidiophores.
- ❖ The conidiophores may be septate or aseptate. The conidia borne upon the terminal apices of the conidiophores or the ends of the branches of the conidiophores.



Various types of spores in fungi. A. chlamydospores of *Ustilago hordei*. B. ascospores of *Aspergillus*. C. chlamydospores of *Ustilago tritici*. D. chlamydospores of *Fusarium*, E. ascospores of *Erysiphe* F. cleistothecium of *Erysiphe*, G. Ascus and ascospores of *Erysiphe*, H. Conidia of *Aspergillus*, I. Conidia of *Cercospora*, J. conidiophore and conidia of *Penicillium*, K. conidia of *Colletotrichum*, L. aplanospores of *Mucor*, M. conidia of *Helminthosporium*, N. aplanospores of *Rhizopus*, O. conidia of *Fusarium* sp., P. sporangium and zoospores,

- ❖ The conidia may be produced singly on each sterigma or in chains.
- ❖ The conidial chains may be basipetal to acropetal in succession. The conidia are diverse in their shape and size.
- ❖ They may be unicellular or multicellular, uninucleate or multinucleate.
- ❖ Different genera may be recognized only by the presence of various shaped and various coloured conidia.
- ❖ The conidia of Fungi Imperfecti are multicellular and variously shaped, whereas the conidia of *Aspergillus* and *Penicillium* are smoky green coloured and the fungi are called 'the blue-green molds'.
- ❖ In other type of exospores, the sporophores develop in groups and form the specialized structure called the pustules, pycnia, aecidia, acervuli, and sporodochia.
- ❖ The pycnia are flask-shaped producing pycniospores in them.
- ❖ The acervuli are saucer- shaped widely open bodies having developed conidia in them on small conidiophores.
- ❖ In mushrooms the sporophores are compactly arranged and form an umbrella-like fructification.
- ❖ The terminal expanded portion bears gills.
- ❖ In each gill there are hundreds of sporophores called the basidia bearing basidiospores.
- ❖ The sporophores (basidia) are arranged in hymenia.

❑ Some Examples of Asexual Spores

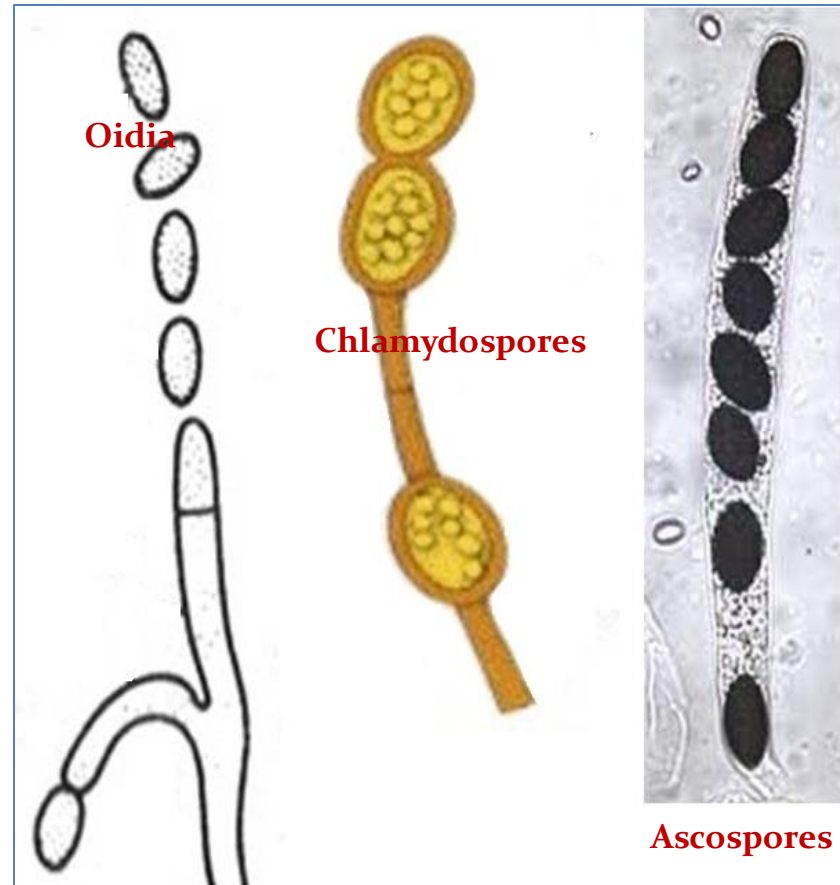
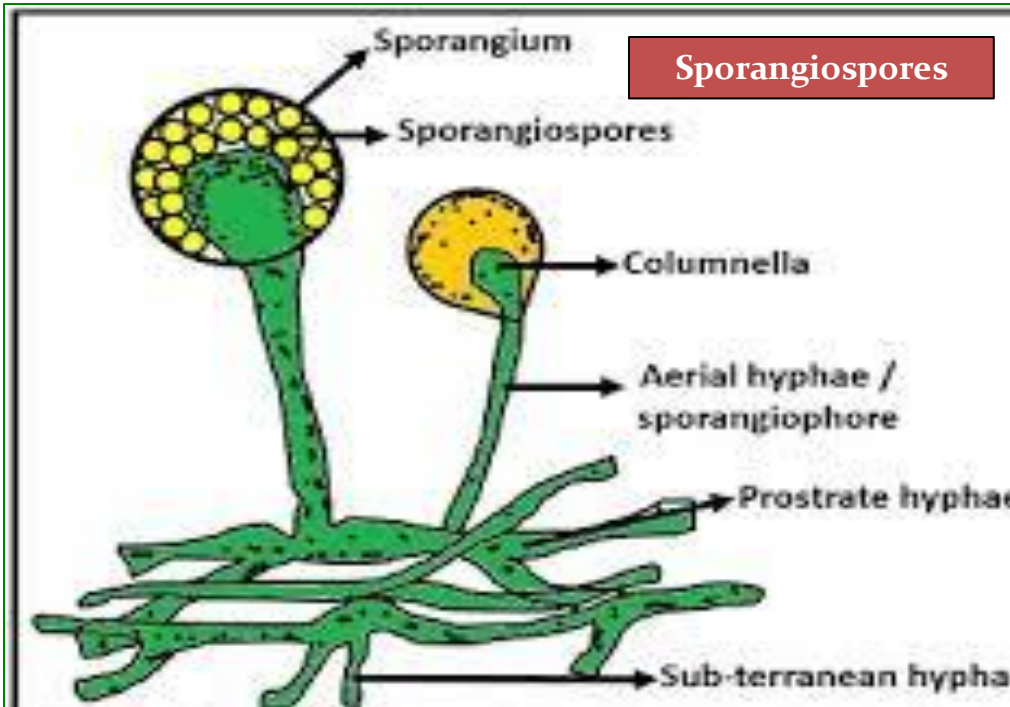
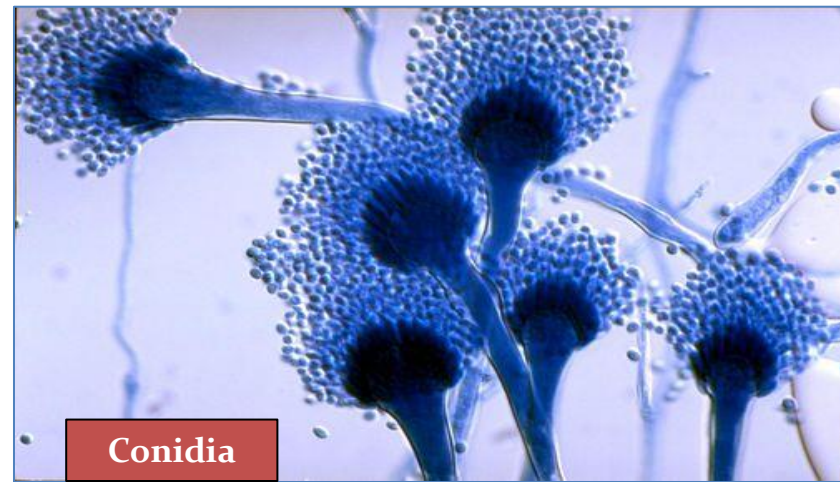
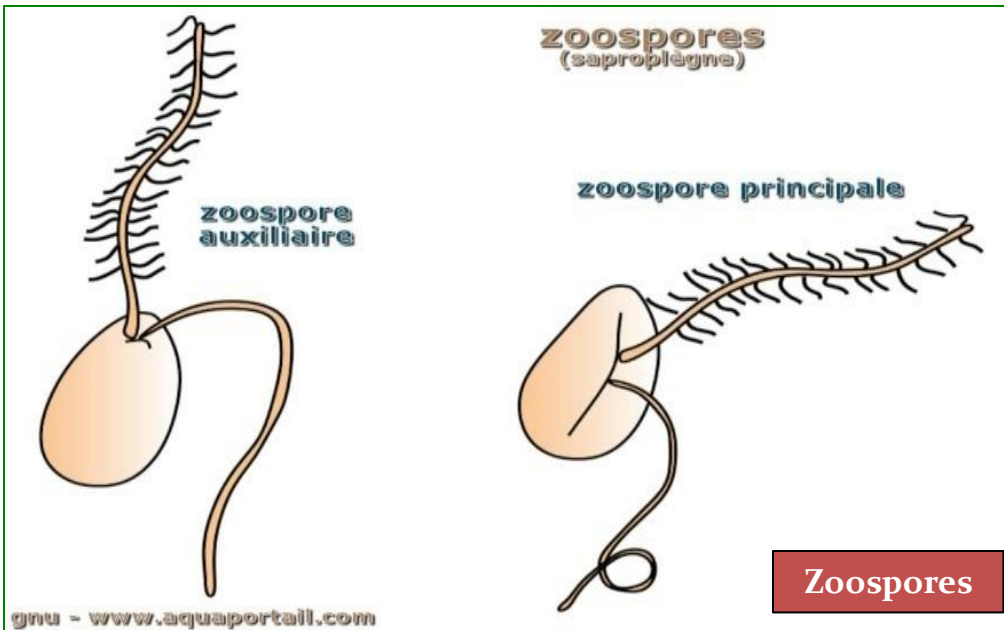
- ✓ **Sporangiospore:** These asexual spore are produced in a sac like structure called sporangia.
 - Sporangium are produced at the end of special aerial hyphae called sporangiophore.
 - Sporangium contains large numbers of haploid spores, which are released by rupture of sporangial wall. Examples: *Rhizopus*

- ✓ **Conidiospore:** Conidiospore or conidia are single celled, bicelled or multicelled structure born on the tip or side of aerial hyphal structure called conidiophore
 - Conidia are different from sporangiospore as these are not produced inside sporangium or any sac like structure.
 - Conidia are born singly or in chain. Examples: *Penicillium*, *Apergillus*

- ✓ **Arthrospore:** It is primitive type of spore formed by the breaking up of fungal mycelium.
 - A spore is formed by separation followed by fragmentation of hyphae. Examples: *Trichosporium*, *Geotrichum*, *Coccidioides immitis*

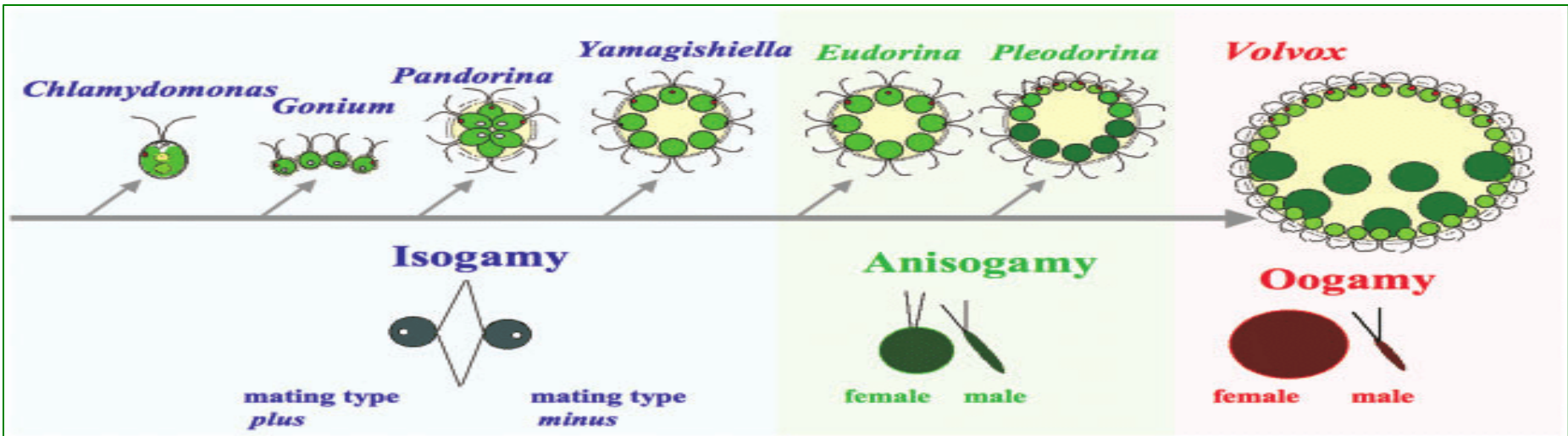
- ✓ **Chlamydospore:** These are usually formed during unfavorable condition and are thick walled single celled spore, which are highly resistant to adverse condition.
 - Hyphal cell or portion of hyphae contracts, loses water, round up and develops into thick walled chlamydospore.
 - When favorable condition returns, each chlamydospore give rise to a new individual fungi. Examples: ascomycetes, basidiomycetes, zygomycetes, *Histoplasma capsulatum*,

- ✓ **Blastospore:** It is a budding spores usually formed at the terminal end of hyphae.
 - These spore may remain attached to hyphae and bud further to give branching chain of blastospores. Examples: ascomycetes, basidiomycetes, zygomycetes



SEXUAL REPRODUCTION IN FUNGI

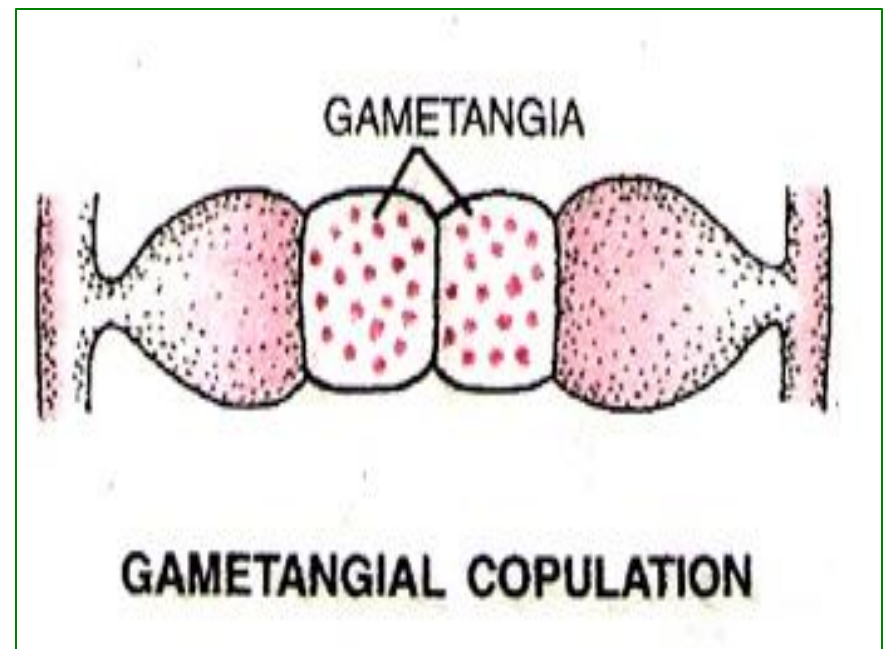
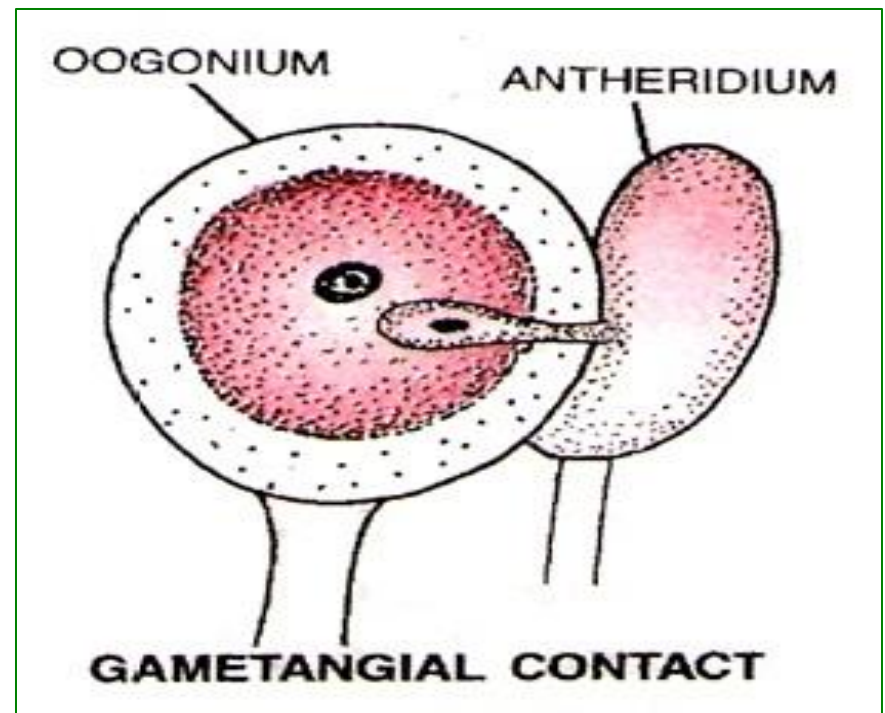
- **Sexual reproduction:** It involves the formation and fusion of gametes. Sexual reproduction is found in all groups of fungi except deuteromycetes or fungi imperfecti. Sexual reproduction has three distinct phases i.e. plasmogamy (protoplasmic fusion), karyogamy (fusion of nuclei) and meiosis (reduction division of zygote). The various methods of sexual reproduction in fungi are as follows:
- a. **Planogametic copulation:** This is the simplest type of sexual reproduction. In this process, fusion of two gametes of opposite sex or strains takes place where one or both of the fusing gametes are motile (flagellated). It results in the formation of a diploid zygote. This process is usually of these types:
- ✓ **Isogamy:** In this process, fusing gametes are morphologically similar and motile but physiologically dissimilar. These gametes are produced by different parents, e.g. *Synchytrium*.



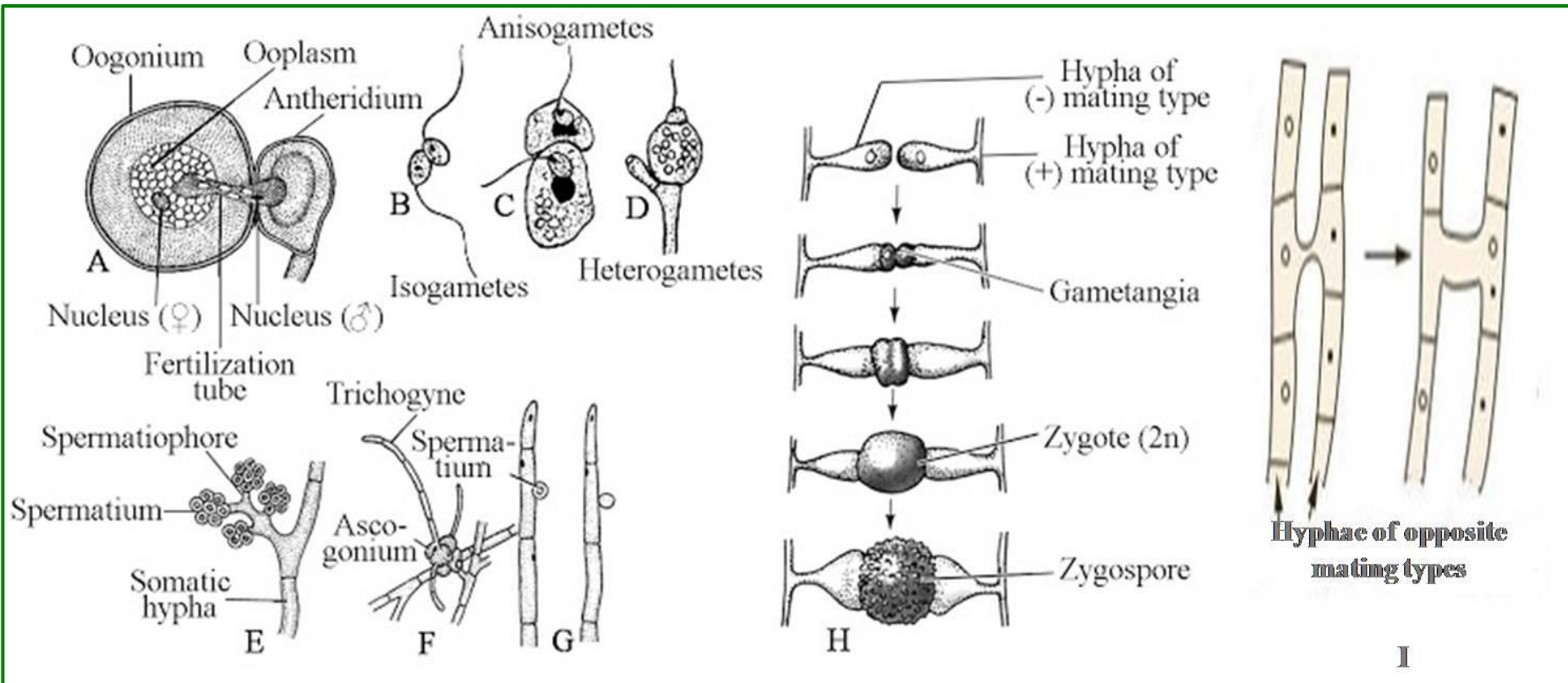
- ✓ **Heterogamy:** When the fusing gametes are morphologically as well as physiologically different, the process is known as heterogamy. Heterogamous reproduction is of two types: anisogamy and oogamy. Anisogamy consists of the fusion of two motile gametes where the male gamete is small and more active than the female gamete, e.g., *Allomyces*. In oogamy the motile male gamete (antherozoid) fuses with the large, non-motile female gamete (egg or ovum) e.g., *Synchytrium* etc.

- b. **Gametangial contact:** In this process two gametangia of opposite sex come in contact with one another. The male gametangium (antheridium) transfer male nucleus or gamete into the female gametangium (oogonium) either through a pore at the point of contact or through a fertilization tube, e.g., *Phytophthora*, *Albugo*, *Pythium* etc.

- c. **Gametangial copulation:** In involves the fusion of entire contents of two gametangia to form a common cell called zygote or zygospore, e.g., *Mucor*, *Rhizopus*.



- d. Spermatization:** Some fungi produce many minute, spore-like, single-celled structures called spermatia (nonmotile gametes). These structures are transferred through agencies like water, wind and insects to either special receptive hyphae or trichogyne of ascogonium. The contents migrate into receptive structure. Thus dikaryotic condition is established, e.g. *Puccinia*.
- e. Somatogamy:** This takes place in fungi where formation of gametes is absent. In such fungi, anastomoses takes place between hyphae and their somatic cells fuse to produce dikaryotic cells, e.g. *Agaricus*, *Peniophora* etc.



Sexual reproduction in fungi: (A) Gametangia contact, (B-C-D) Planogametic copulation, (E-F-G) Spermatization, (H) Gametangia copulation, (I) Somatogamy

❑ Some Examples of Sexual Spores

✓ Ascospore:

- It is usually single celled produced in a sac called ascus (plural;asci) and usually there are 4-8 ascospore in an ascus but the number may vary from species to species
- The ascospore are usually arranged in a linear order. In some case ascospores are long, narrow and are arranged in parallel order.

✓ Basidiospore:

- It is a reproductive spore produced by basidiomycetes.
- This single celled spores are born in a club shaped structure called basidium
- These basidiospore aerves as main air dispersal unit for the fungi.

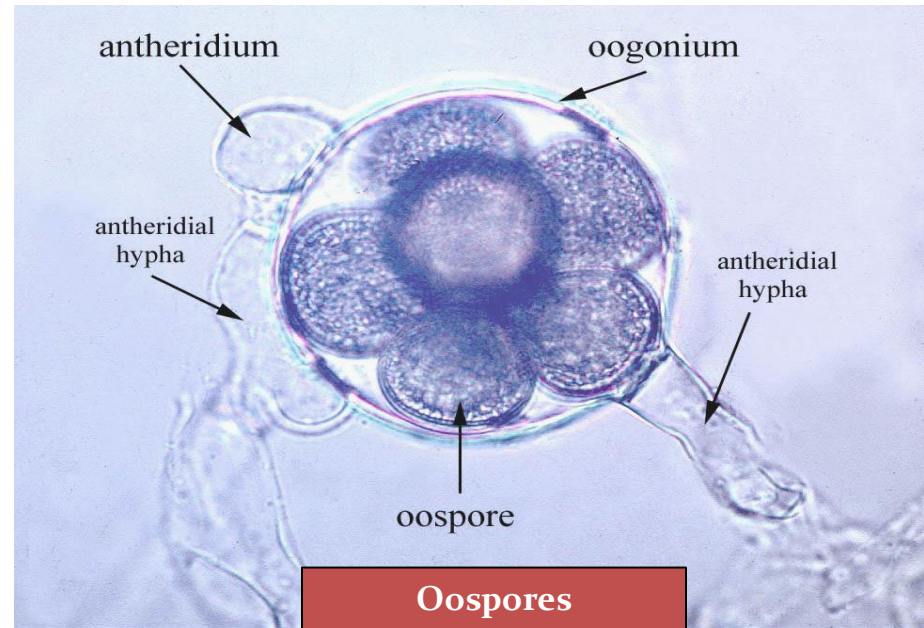
✓ Zygospor:

- Zygospor are thick walled spores formed when two sexually compatible hyphae or gametangia of certain fungi fuse together.
- In suitable condition, zygospor germinates to produce a single vertical hyphae which forms a aporangium and releases its spores

✓ Oospore:

- These are formed within a special female structure called Oogonium.
- Fertilization of egg by male gamete in female sex organ give rise to oospoes.
- There are one or more oospores in each oogonium.

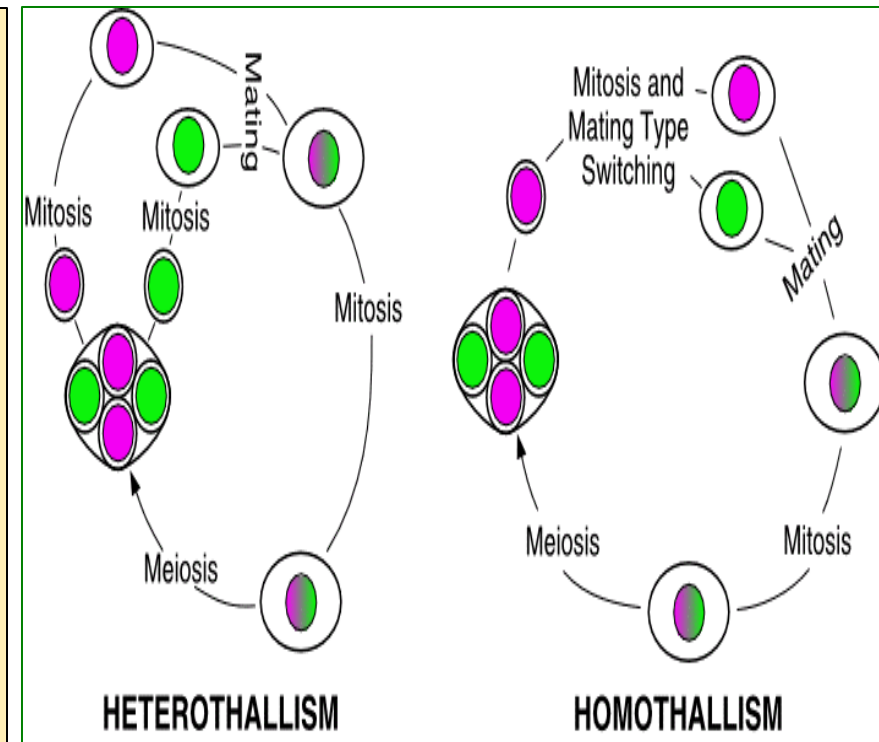
EXAMPLES OF SEXUAL SPORES IN FUNGI



❑ Sexual Incompatibility in Fungi

- ❖ Many of the simpler fungi produce differentiated male and female organs on the same thallus but do not undergo self-fertilization because their sex organs are incompatible.
- ❖ Such fungi require the presence of thalli of different mating types in order for sexual fusion to take place. The simplest form of this mechanism occurs in fungi in which there are two mating types, often designated + and – (or A and a).

- ❖ Gametes produced by one type of thallus are compatible only with gametes produced by the other type called heterothallic fungi.
- ❖ Many fungi, however, are homothallic; i.e., sex organs produced by a single thallus are self-compatible, and a second thallus is unnecessary for sexual reproduction.
- ❖ Some of the most complex fungi (e.g., mushrooms) do not develop differentiated sex organs; rather, the sexual function is carried out by their somatic hyphae, which unite and bring together compatible nuclei in preparation for fusion.

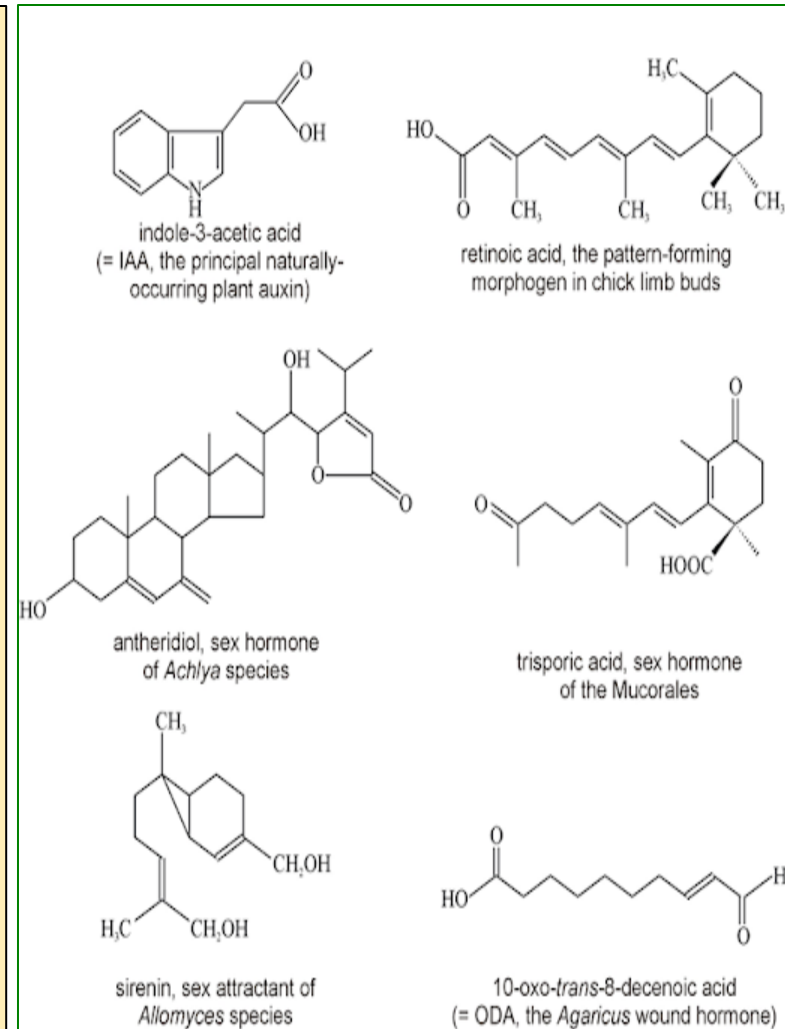


- ❖ Homothallism and heterothallism are encountered in fungi that have not developed differentiated sex organs, as well as in fungi in which sex organs are easily distinguishable.
- ❖ Compatibility therefore refers to a physiological differentiation, and sex refers to a morphological (structural) one; the two phenomena, although related, are not synonymous.

❑ Sexual Pheromones in Fungi

- ❖ The formation of sex organs in fungi is often induced by specific organic substances.
- ❖ Although called sex hormones when first discovered, these organic substances are actually sex pheromones, chemicals produced by one partner to elicit a sexual response in the other.

- ❖ In *Allomyces* (order Blastocladales) a pheromone named sirenin, secreted by the female gametes, attracts the male gametes, which swim toward the former and fuse with them.
- ❖ In some simple fungi, which may have gametangia that are not differentiated structurally, a complex biochemical interplay between mating types produces trisporic acid, a pheromone that induces the formation of specialized aerial hyphae.
- ❖ Volatile intermediates in the trisporic acid synthetic pathway are interchanged between the tips of opposite mating aerial hyphae, causing the hyphae to grow toward each other and fuse together.
- ❖ In yeasts belonging to the phyla Ascomycota and Basidiomycota, the pheromones are small peptides. Several pheromone genes have been identified and characterized in filamentous asco and basidiomycetes



KEY POINTS OF THE LECTURE

- ❖ Reproduction may be defined as a process in which individual species increase their number by producing the progeny.
- ❖ In fungi, reproduction is of three kinds; Vegetative reproduction, Asexual reproduction, Sexual reproduction.
- ❖ Many mycologists, however, included all methods of reproduction (vegetative and spore formation) which do not involve union of nuclei or sex cells or sex organs under asexual or somatic reproduction.
- ❖ Vegetative reproduction is any form of reproduction occurring in plants in which a new plant grows from a fragment of the parent plant or a specialized reproductive structure.
- ❖ Fission, budding and fragmentation are most common methods of vegetative reproduction in a number of fungi. In addition to above-mentioned common methods they also reproduced vegetatively by other means, such as sclerotia, rhizomorphs, etc.
- ❖ Typically in asexual reproduction, a single individual gives rise to a genetic duplicate of the progenitor without a genetic contribution from another individual. Perhaps the simplest method of reproduction of fungi.
- ❖ The majority reproduce asexually by the formation of spores. Spores that are produced asexually are often termed mitospores, and such spores are produced in a variety of ways.
- ❖ The fungus producing more than one type of spores is called the pleomorphic or polymorphic.
- ❖ The asexual spores of the fungi are two types; endogenous and exogenous.

KEY POINTS OF THE LECTURE

- ❖ The endogenous spores are produced within the special spore producing cell the sporangium.
- ❖ The spores producing externally or exogenously are either called the exogenous spores or conidia. They are produced externally on the branched or unbranched conidiophores.
- ❖ Sporangiospore, oidia, Conidiospore, Chlamydospore, Blastospore etc are the examples of asexual spores of the fungi.
- ❖ Sexual reproduction found in all groups of fungi except deuteromycetes or fungi imperfecti. Sexual reproduction has three distinct phases i.e. plasmogamy (protoplasmic fusion), karyogamy (fusion of nuclei) and meiosis (reduction division of zygote).
- ❖ The process of sexual reproduction involves three phases: Plasmogamy: fusion of protoplasm, Karyogamy: fusion of nucleus and Meiosis: reductional nuclear division.
- ❖ Various methods by which compatible nuclei are brought together in plasmogamy. Some are: Gametic copulation, Gamete-gametangial copulation, Gametangial copulation, Somatic copulation, Spermatization
- ❖ Ascospores, Basidiospores, zygosporangia and oospores are the examples of sexual spores.
- ❖ Many of the simpler fungi produce differentiated male and female organs on the same thallus but do not undergo self-fertilization because their sex organs are incompatible. Such fungi require the presence of thalli of different mating types in order for sexual fusion to take place.
- ❖ Sex pheromones, chemicals produced by one partner to elicit a sexual response in the other.

TERMINOLOGY

- ❑ **Ascocarp:** Fruitbody of an ascomycete fungus
- ❑ **Ascomycetes:** A - Class of fungi that produce their spores in sac-like cells called asci
- ❑ **Ascospores:** Sexual spores produced in the asci of ascomycetes fungi
- ❑ **Ascus:** (Pl., asci) the spore-producing cell of an ascomycetes fruitbody
- ❑ **Basidiocarp:** Fruitbody of a basidiomycete fungus
- ❑ **Basidiomycetes:** A - Class of fungi that produce their spores on basidia
- ❑ **Basidiocarp:** Fruitbody of a basidiomycete fungus
- ❑ **Basidiospores:** Sexual spores produced on the basidia of basidiomycetes fungi
- ❑ **Basidium:** (Pl., basidia) spore-producing cell of a basidiomycete fungus
- ❑ **Chlamydospores:** Asexual spores formed by the breaking up of fungal hyphae
- ❑ **Deuteromycetes:** Obsolete term for a group fungi not known to reproduce sexually
- ❑ **Endophyte :** fungus living within a plant without causing visible symptoms of harm
- ❑ **Hyphae:** (Pl., hyphae) filamentous thread of fungal mycelium
- ❑ **Mycelium:** Body of a fungus, most of which is underground or hidden within wood
- ❑ **Myxomycetes:** A large and commonly encountered group within the slime moulds
- ❑ **Rhizomorph:** A root-like mycelial strand comprising bunched parallel hyphae
- ❑ **Saprophyte:** An organism that obtains its nutrients from dead organic material
- ❑ **Septate:** (Describing hyphae) partitioned by cross walls known as septa
- ❑ **Septum:** (Pl., septa) a cross wall separating cells of a hyphal thread
- ❑ **Spore:** Reproductive structure of a fungus, usually a single cell
- ❑ **Sporophore:** Fungal fruitbody
- ❑ **Thallus:** (Pl., thalli) the body of a fungus or a lichen
- ❑ **Uredinales:** Rust fungi (an order within the Basidiomycota)
- ❑ **Zygomycota:** A - Class of simple fungi whose hyphae generally lack cross walls

SOME QUESTIONS RELATED TO THE LECTURE

- ☐ **Question 1:** What do you understand by vegetative reproduction in fungi?
- ☐ **Question 2:** Highlight the process of fission and budding.
- ☐ **Question 3:** Write a note on asexual reproduction in fungi?
- ☐ **Question 4:** Describe the difference between endogenous and exogenous spores.
- ☐ **Question 5:** Describe the various asexual spores of fungi in detail.
- ☐ **Question 6:** Discuss the method of sexual reproduction in fungi
- ☐ **Question 7:** Write the difference between Gametangial contact and Gametangial copulation
- ☐ **Question 8:** What are spermatization and somatogamy?
- ☐ **Question 9:** Discuss the sexual incompatibility in fungi.
- ☐ **Question 10:** Discuss the sexual spores in fungi.
- ☐ **Question 11:** Give the outline of sexual pheromones in fungi.

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