BASUDEV GODABARI DEGREE COLLEGE , KESAIBAHAL

BLENDED LEARNING STUDY MATERIAL

UNIT-II

DEPARTMENT OF BOTANY

1st SEMESTER BOTANY (GE)

PAPER 1ST - BIODIVERSITY

Department of Botany

SELF STUDY MODULE

Module Details:-

Class- 1st semester (2020-2021)
Subject Name: Botany (GE)
Paper Name : Biodiversity (microbes, Algae, Fungi and Archegoniates)

Paper-I

Unit-II

I. Algae: General characteristic, Ecology and distribution, Range of thallus organisation and reproduction, morphology and life cycles of the following chlamydomonasa, Oedogonium, Nostoc and Fueus, Vaucheria, Polysiphonia, Economic importance of algae.

II. Fungi: Introduction- General characteristic, ecology and significance range of thallus organization, cell wall composition, nutrition, reproduction and classification. True Fungi-General characteristic, ecology and significance, life cycle of Rhizopus (Zygomgcota) pencillium (Ascomycoto), Puccinia, Agaricus (Basidionycota), symbiotic Associations- Licheis.

Learning Objectives:-

After learning this unit with you should be able to
Range of thallus organization in algae,

1. Classification of Algae.
2. Various asexual methods of reproduction in algae.
3. Methodes of sexual reproduction in Algae.

4. Differents types of life cycles in algae.
5. General characters of algae.
6. Structure and reproduction in Chlamydomones.
7. Sexual reproduction and life cycle in Chlamydomones.
8. Methods of sexual reproduction in Oedogonium.
9. The reproduction of a nannandrous species of Oedogonium.
10. Morphology and life history of Vaucheteria.
11. Strucrure and reproduction in Nostoc.
12. Morphology and anatomy of thallus of Ficus.
13. 14.Organisation of sex organs in Fucus.
14. 15.Life history of Fucus.
15. Life cycle of polysiphonia.
16. 17.Zoospores and gametes in Algae.
17. Haplontic life cycle.
18. Thall us organisation in Fungi.
19. Various modification of Fungal mycelia.
20. Accocnt of fungal nutrition.
21. Different asexual methods of reproduction in Fungi.
22. Modern classification of Fungi.
23. Structure and reproduction in Rhizopous.
24. Structure and reproduction in Penicillium.
25. Morphology and structure of Agariues.
26. Dikaryotic phase in the life of puccinia.
27. Asexual reproduction in lichens.
28. Econonomic importance of lichens.
29. Classification of Lichens.

You can use the following video links:-

https://youtu.be/xbagR7LLfmuk - Thallus structure and organization of Algae.

https://youtu.be/p-JhnSVg09E- Life cycle of ehlamydomonas.

https://youtu.be/STKGRAcLGI4 - Life cycle of oedogonium.

https://youtu.be/dottHUTNg-3Y8- Life cycle of oedogonium.

https://youtu.be/7f7vgMG6FA - Life cycle of oedogonium.

https://youtu.be/rSwxn7g-Z7S- Life cycle of vaccuteria.

https://youtu.be/Dg7etEr4deo- Life cycle of polysiphonia.

https://youtu.be/-rTVGYVqWHA- Economic importance of Algae.

https://youtu.be/amTJIns AQro- General character of Fungi and thallus organization.

https://youtu.be/xwhqLwiE7c- Vrgetative structure and asexual reproduction of Rhizopous.

https://youtu.be/rpy2c3n5Nh8 - Rhizopous.

https://youtu.be/ixofLLUxa28 - Rhizopous.

https://youtu.be/FDc3qNpeXmc - Life cycle of Agaricus.

https://youtu.be/KqceWLqJsKg - Lichens introduction,Classification and Economic importance.

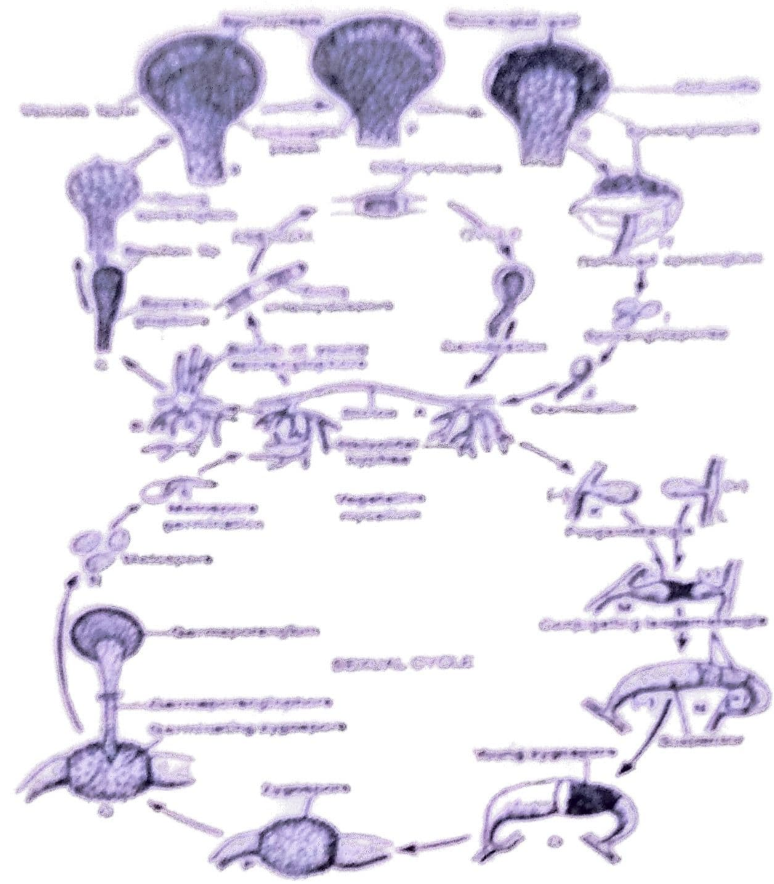
You can also used to following books.

1. Plant Biodiversity- By Baman Chandra Acharya
   Bijay kumar Mishra
   (Kalyani Publication)
2. Some notes.
3. Text book of Fungi.
4. Botany of Degree Studends.- B.P. Pandey
   S.Chanda.

Plan – Unit- II

No of period to be taken 09

Date	Time	Period	Topic Covered	Signature
01.03.21	12.30 to 1.30pm	01	Introduction of Algae, General characters, ecology and distribution, Range of thallus organisation and reproduction.	Al–
15.03.21	12.30 to 1.30pm	01	Morphology and life cycle of oedogonoium, chlamydomonous, Nostoc and Ficus.	Al–
22.03.21	12.30 to 1.30pm	01	Doubt clearing Class.	Al–
24.03.21	12.30 to 1.30pm	01	Life history of Vaucheria and polysiphonia. Economic importance of Algae.	Al–
31.03.21	12.30 to 1.30pm	01	Doubt clearing Class.	Al–
02.04.21	12.30 to 1.30pm	01	Introduction of Fungi, General character, Ecology and significance. Range of thallus organisation, cellwall composition, nutrition and classification.	Al–
10.04.21	8.15 to 9am	01	Life cycle of Rhizopous(Zygomycote) pancellium (Ascomycota) puccnia, Agaricus (Basidioimycota).	Al–
19.04.21	8.15 to 9.am	01	Symbotic association of Lichens.	Al–
29.04.21	8.15 to 9 am	01	Doubt clearing class.	Al– 29.04.21



COURSE: B.Sc Botany
SEMESTER: II
PAPER: Mycology and Phytopathology / BOT CC 203
TOPIC: Structure and life cycle of *Rhyzopus*
FACULTY: Dr. Urvashi Sinha
Email id: urvashi_vrm@yahoo.co.in

Taxonomic position of *Rhizopus*

Mycota
Eumycotina
Zygomycetes
Mucorales
Mucoraceae
Rhizopus
stolinifer

General characters:

1. Common fungi growing on stale bread, therefore, also called **Bread mould.**

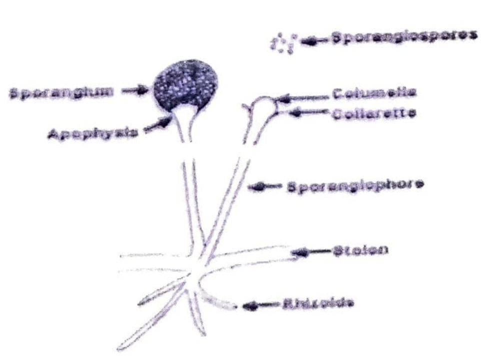
2. Lives as a saprophytes

3. Grows on damp decaying fruit, vegetables, pickles etc.

4. Under certain conditions it lives as facultative parasite on strawberry fruit causing leak and soft rot disease

5. This widespread genus includes at least eight species.

Structure of thallus:



1. The vegetative plant body is eucarpic and consists of white cottony, much branched mycelium.

2. The mycelial plant body is differentiated into nodes and internodes

3. The internodal region is the aerial and arching hyphae, known as stolon, which when touches the substratum forms the nodal region.

4. The nodal region bears much branched rhizoid grows downward, inside the substratum for anchorage and absorption of food.

5. The hyphal wall is microfibrillar and consists mainly of chitin-chitosan. In addition to chitin- chitosan, other substances like proteins, lipids, purines and salts like calcium and magnesium are also present in the hyphal wall.

6. Inner to the cell wall, cell membrane is present which covers the protoplast. The protoplast contains many nuclei, mitochondria, endoplasmic reticulum, ribosome, oil droplets, vacuoles and other substances. The size of the vacuole enlarges with age by coalescence of smaller vacuoles.

Reproduction in *Rhizopus:*

Rhizopus Stolonifer reproduces by vegetative, asexual and sexual mode.

1. Vegetative reproduction: It takes by fragmentation. Due to accidental brekage the stolon may break into two or more small units. Each unit is capable of growing as mother mycelium

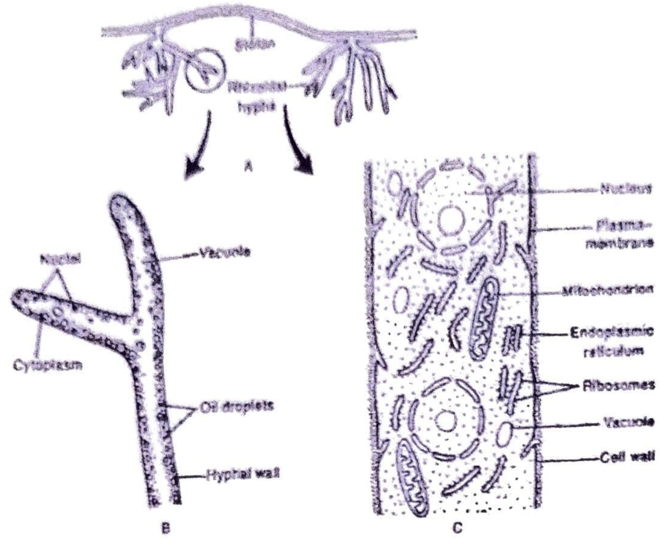


Fig. 4.25 : *Rhizopus stolonifer* : A. Vegetative mycelium, B. Portion of hypha under light microscope, C. Portion of hypha under electron microscope

2. Asexual reproduction: By means of

(a) sporangiospore and (b) chlamydospores

(a) sporangiospores formation:

During favourable condition, the non-motile spores such as sporangiospores or aplanspores are formed inside the sporangium.

The sporangium develops singly at the apex of sporangiophore.

The sporangiophore develops in tuft from the upper side of node opposite to the rhizoidal hyphae

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

With maturity, the protoplast inside the sporangium is differentiated into a thick dense layer of multinucleate cytoplasm towards the peripheral region just inside the sporangia wall, called the sporoplasm and a vacuolated portion with a few nuclei towards the centre, called columellaplasm.

A series of small vacuoles then appears between the sporoplasm and columellaplasm

These vacuoles become flattened and coalesce to form a continuous cleavage cavity. This is followed by the formation of a septum towards innerside of the cavity. With further development, the septum becomes dome-shaped and pushes its way into the sporangium.

Protoplast of the sporoplasm then undergoes cleavage to produce many small multinucleate (2-10 nuclei) segments. These segments are transformed into globose non-motile sporangiospores.

After the maturation of spores, the wall of sporangium dries and columella collapses like an inverted cup with irregular surface.

The sporangial wall breaks in different fragments leaving a portion as collar on the sporangiophore. The powdery mass of spores are exposed to the atmosphere

In ideal moisture and temperature, if the spores fall on suitable substratum, they germinate by germ tube to form new mycelia

(b) Chlamydospore:.

During unfavourable condition, thick-walled, nutrition-rich, intercalary mycelium segments arise by septation of mycelium, termed as chlamydospores.

They get separated from each other when the connecting mycelium dries up.

With the onset of favourable condition, the chlamydospore germinates and gives rise to a new mycelium

2. Sexual reproduction:

Sexual reproduction takes place during unfavourable condition by means of gametangial copulation.

The gametangia look alike, but equal or unequal in size and, by conjugation, they give rise to zygospore.

Most of the species of Rhizopus are heterothallic (Rhizopus. stolonifer), but few species (R. sexualis) are homothallic.

In heterothallic species, zygospores are produced by the union of two gametangia developed from mycelia of compatible strains

in homothallic species, the uniting gametangia develop from mycelia that derived from a single spore.

The heterothallic species are cultured, two mycelia of compatible strain come near to each other, the mycelia produce small outgrowth, called progametangia.

The apical region of the two progametangia come in close contact . Nuclei and cytoplasm of each progametangium push more and more towards the apical region which swell up with dense protoplasm.

The rear region becomes vacuolated. A septum is laid down separating the apical region, which is called gametangium; and the basal region, is called suspensor.

The undifferentiated multi-nucleate protoplast of the gametangium is called aplanogamete or coenogamete .

After maturation of gametangia, the common wall at the point of their contact dissolves and the protoplast of both the gametangia unite to form zygospore

The nuclei of opposite gametangia fuse together to form diploid (2n) nuclei and unpaired nuclei gradually degenerate.

The young zygospore enlarges and secretes five layered (two in exospore and three in endospore) thick wall, which undergoes a period of rest .

After resting period, the zygospore germinates. On germination, the innermost layer comes out after cracking the outer walls and produces a promycelium.

The promycelium is differentiated into a lower stalk like germsporangiophore and an upper spherical germsporangium

Meiosis occurs during zygospore germination and the haploid nuclei form haploid spores like sporangiospores inside the germsporangium. These spores are also known as meiospores .

Each meiospore after liberation germinates like sporangiospore, and forms new mycelium like mother thallus .

Sometimes failure of gametangial copulation results in parthenogenic development of zygo-spore, by any one gametangium, called azygospore or parthenospores

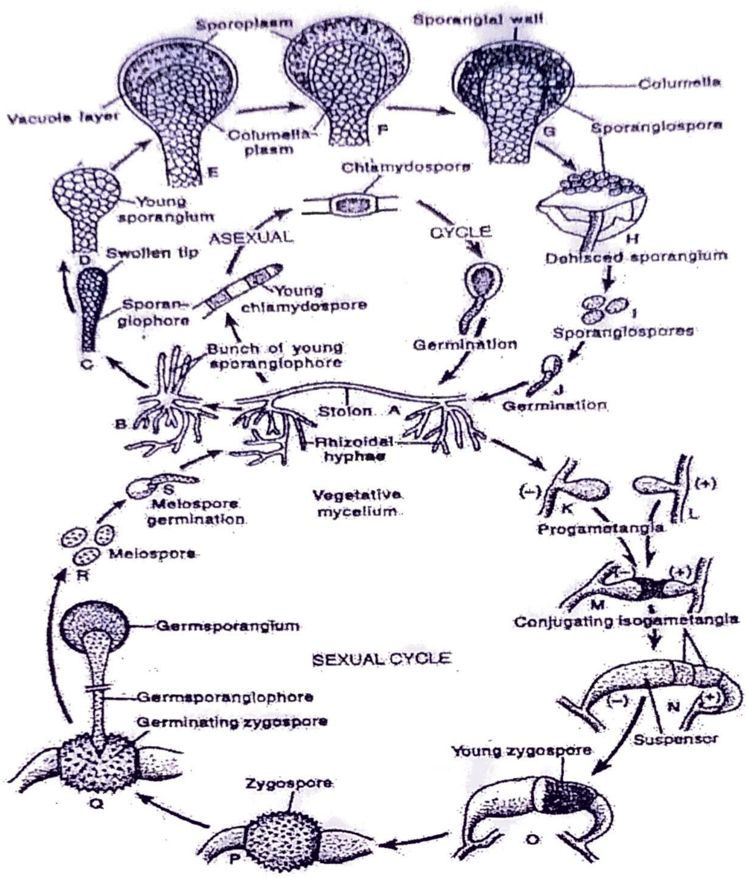


Fig. 4.26 : Life cycle of *Rhizopus stolonifer*

REPRODUCTION OF FUNGI

INTRODUCTION

A fungus is a member of a large group of eukaryotic organisms that includes microorganisms such as yeasts and molds (British English: moulds), as well as the more familiar mushrooms. These organisms are classified as a kingdom, Fungi, which is separate from plants, animals, and bacteria. One major difference is that fungal cells have cell walls that contain chitin, unlike the cell walls of plants, which contain cellulose. These and other differences show that the fungi form a single group of related organisms, named the *Eumycota* (*true fungi* or *Eumycetes*), that share a common ancestor (a *monophyletic group*).

Fungal reproduction is complex, reflecting the differences in lifestyles and genetic makeup within this diverse kingdom of organisms. It is estimated that a third of all fungi reproduce using more than one method of propagation; for example, reproduction may occur in two well-differentiated stages within the life cycle of a species, the teleomorph and the anamorph. Environmental conditions trigger genetically determined developmental states that lead to the creation of specialized structures for sexual or asexual reproduction. These structures aid reproduction by efficiently dispersing spores or spore-containing propagules.

Reproduction

Reproduction is the biological process by which new "offspring" individual organisms are produced from their "parents". Reproduction is a fundamental feature of all known life; each individual organism exists as the result of reproduction. The known methods of reproduction are broadly grouped into two main types: sexual and asexual.

TYPES OF FUNGAL REPRODUCTION

Fungi also have 3 types of reproductions:

- **A. Vegetative**
- **B. Asexual**
- **C. Sexual**

VEGETATIVE REPRODUCTION

It is the type of reproduction which involves the somatic portion of the fungal thallus where new individuals are formed without the production of seeds or spores by meiosis or syngamy.

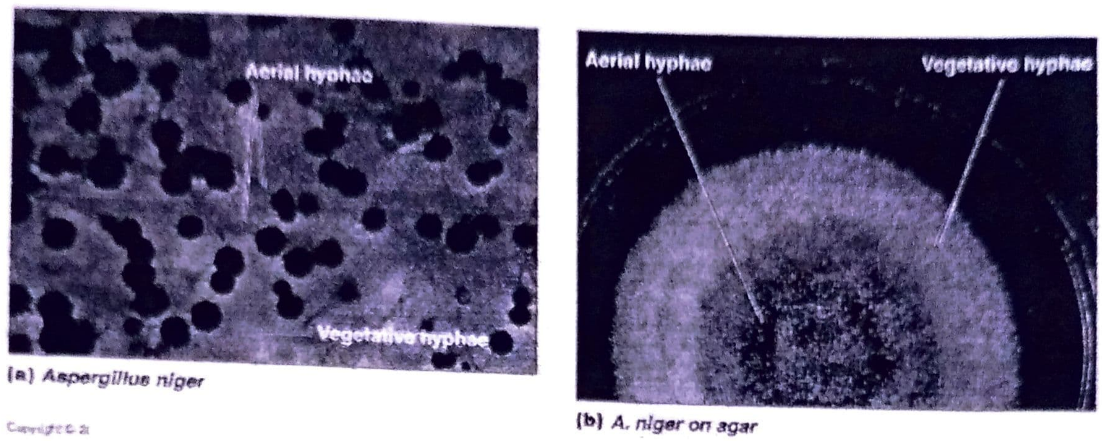


FIGURE: THE VEGETATIVE HYPHAE

Vegetative reproduction takes place by the following methods:

1. **Fragmentation**
2. **Fission**
3. **Budding**
4. **Oidia**
5. **Chlamydospores**
6. **Rhizomorphs and**
7. **Sclerotia.**

Fragmentation

In fragmentation, which may result from accidental severing of the mycelium into bits or fragments or by mechanical injuries or otherwise, the mycelium breaks into segments of hyphae. Each segment by further division of cells and apical growth develops into a new mycelium under favorable conditions.

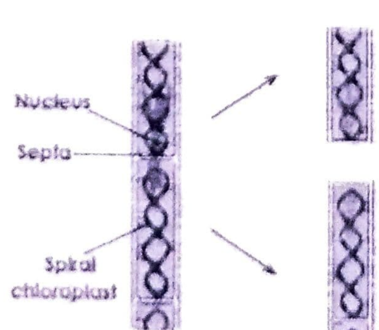


FIGURE: FRGMENTATION

Fission

In unicellular fungi like the fission yeast, the single cell multiplies by fission. Here, the parent cell elongates and divides transversely into two daughter cells. First, the nucleus divides, followed by the division of the cytoplasm and wall formation, thus dividing the parent cell into two. The two daughter cells separate and lead independent lives.

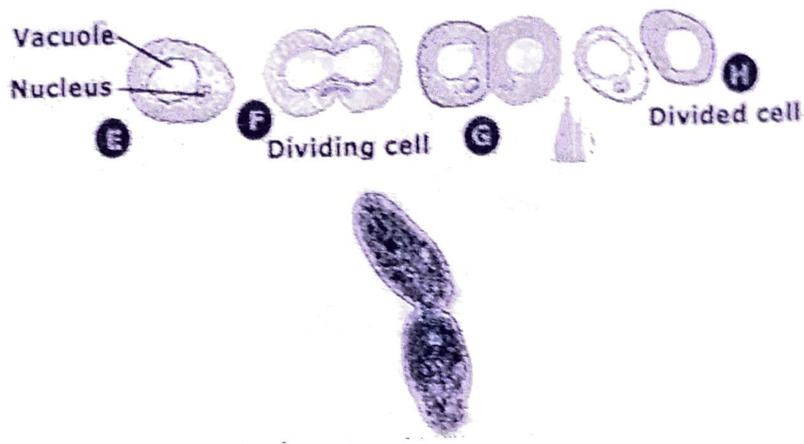
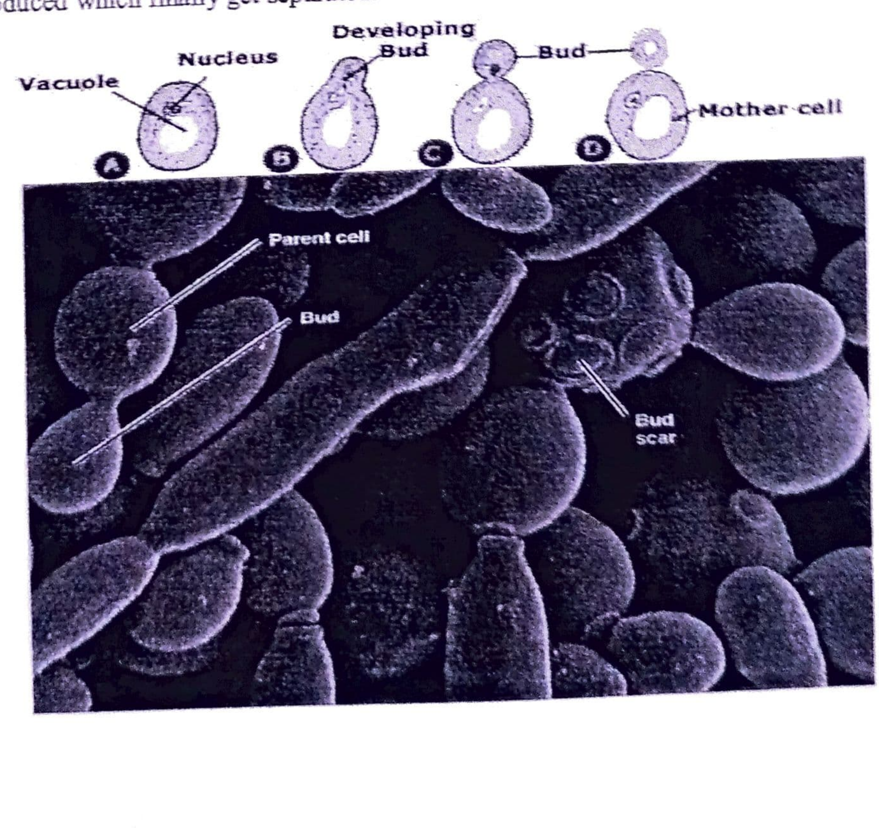


FIGURE: FISSION

Budding

In budding yeast, the cells reproduce by a process called budding. Here, the parent cell puts out a small outgrowth which is called a bud. The bud gradually enlarges and finally gets separated from the parent cell by a cross wall. This end develops into new individual yeast. Sometimes the bud before separation from the parent cell may produce a new bud and in this way a chain of buds may be produced which finally get separated.



Oidia

In some filamentous fungi, the hyphae break up into individual cells which are called oidia or arthrospores. The cells become rounded or oval in shape and appear like the beads of a rosary. Each oidium or arthrospore develops into a new mycelium.

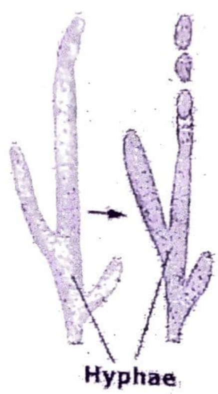


FIGURE: OIDIA

Chlamydospores

The chlamydospores are one-celled fragments, which function as perennating bodies. They are formed either singly or in chains in the vegetative hyphae. The chlamydospores develop thick, resistant walls and accumulate food materials and thus help the fungus to tide over unfavorable conditions. With the return of favorable conditions each chlamydospores develops into a new mycelium. e.g. ***Mucor, Fusarium.***

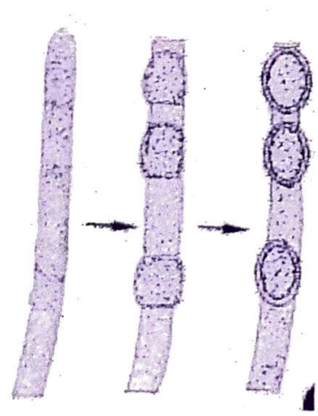


FIGURE: CHLAMYDOSPORES

Rhizornorphs

In some higher fungi, several hyphae may become interwoven to form rope-like structures called rhizomorphs. Under favourable conditions, they resume growth to give rise to new mycelia. These fine, root-like strands, usually dark brown in colour called rhizomorphs, serve as a means of perennation. Under unfavourable conditions rhizomorphs remain dormant but with the onset of favourable conditions the rhizomorphs resume growth and may also give rise to fruiting bodies.

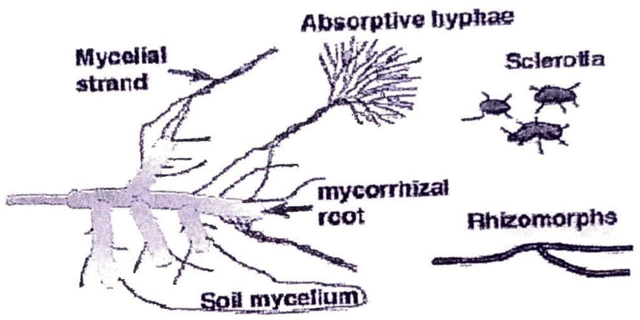


FIGURE: RHIZORNORPHS

Sclerotia

In some cases, as in Claviceps, the hyphae become interwoven to form a compact mass and get surrounded by a hard covering or rind. Such structures are called SCLEROTIA. They remain dormant under unfavourable conditions and germinate into new mycelia on the return of favourable conditions. They serve as a means of perennation and vegetative propagation. They may be rounded, cylindrical. Cushion-shaped or irregularly shaped with a dense mass of thick walled hyphae. The hyphae form a compact, pseudoparenchymatous tissue. With the return of favourable conditions a sclerotium germinates to form a new mycelium.

e.g. ***Claviceps*** (ergot).

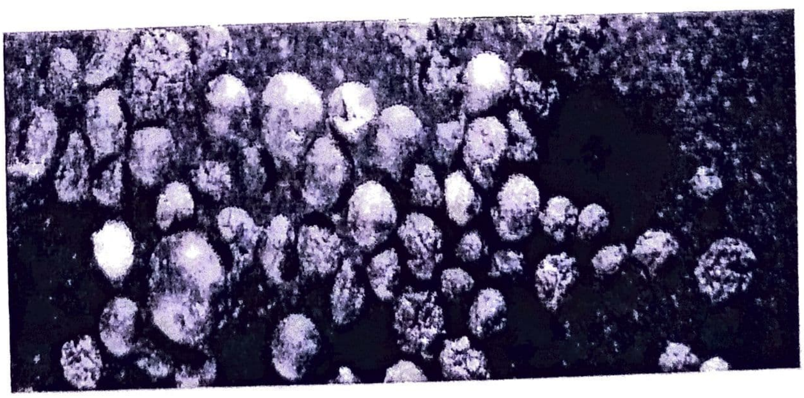


FIGURE: SCLEROTIA

ASEXUAL REPRODUCTION

In fungi asexual reproduction is a more common method than sexual reproduction. It is usually repeated several times in a season. It takes place by the formation of special reproductive cells called spores. The formation of spores in fungi is called sporulation. Each spore develops into a new mycelium. These spores are produced as a result of mitosis in the parent cell and hence they are also called mitospores. The spores vary in colour, shape and size, number, arrangement on hyphae and in the way in which they are borne. They may be hayline, green, yellow, orange, red, brown to black in colour and are minute to large in size. In shape they vary from globose to oval, oblong, needle-shaped to helical. Thus an infinite variety of spores can be observed in fungi and you will find them very fascinating under the microscope.

Usually the spores are unicellular. They may be uninucleate or multinucleate. In some fungi like *Alternaria* and *Curvularia* they are multicellular.

The mitospores produced in fungi are of three types-

1. Sporangiospores
2. Zoospores
3. Conidiophores

Sporangiospores

The sporangiospores are produced inside a sac-like structure called sporangium. The hypha bearing a sporangium is called sporangiophore. They are characteristically branched. The sporangiospores may be motile or non-motile. The non-motile sporangiospores are called aplanospores. These are characteristic of terrestrial species like *Mucor* and *Rhizopus*.

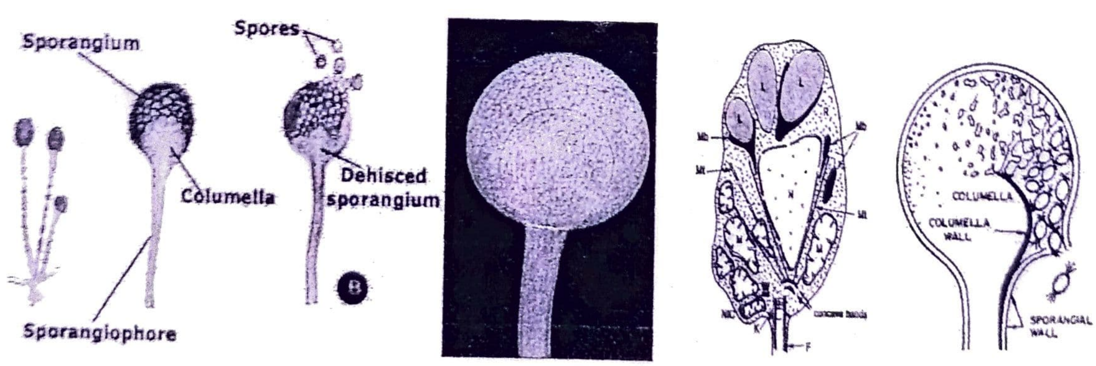
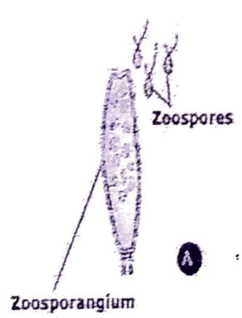
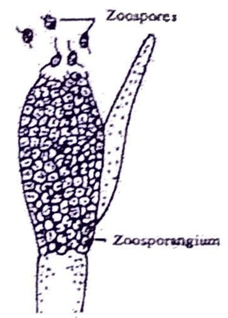


FIGURE: ALL ARE SPORANGIOSPORES

Zoospores

In aquatic fungi like ***Pythium*** of the Division Oomycota motile biflagellate sporangiospores are produced. These are called **zoospores** and the sporangium bearing them is called **zoosporangium.** A zoospore is a motile spore lacking a cell wall. After a swarming period it secretes a wall and germinates to form a germ tube. In contrast to zoospores, the aplanospores have a definite spore wall and are dispersed by wind and insects.





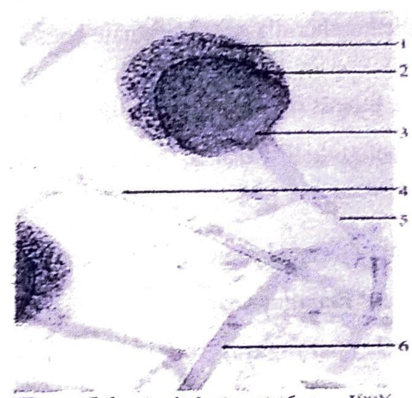
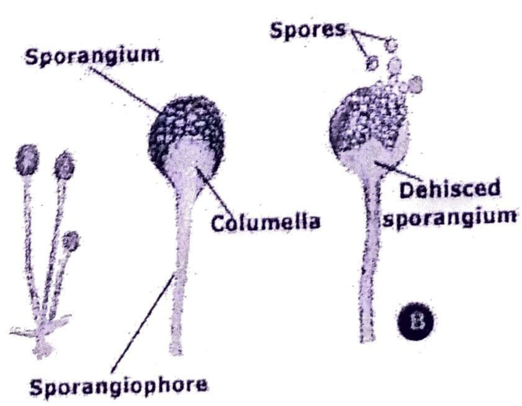


Figure 5.4 A whole mount of the bread mold *Rhizopus* 100X
1. Sporangium
2. Spores
3. Columella
4. Rhizoid
5. Sporangiophore
6. Stolon (hyphae)

FIGURE: ZOOSPORES

Conidiophores

The conidia are non-motile, deciduous mitospores formed externally as single separate cells. They develop either directly on the mycelium or on morphologically differentiated hyphae called **conidiophores.** The conidiophores may be simple or branched, septate or aseptate. The conidia are produced singly e.g., ***Phytophthora*** or in chains at the tips of the conidiophores e.g. ***Aspergillus*** or at the tips of their branches e.g., ***Penicillium.*** Often the conidiophores arise singly and are scattered in the mycelium. Sometimes they arise in specialised structures called fruiting bodies. According to their appearance they are termed as **synnema, sporodochia, acervuli** (saucer-shaped), **pycnidia** (flask-shaped, globular) or **pustules.**



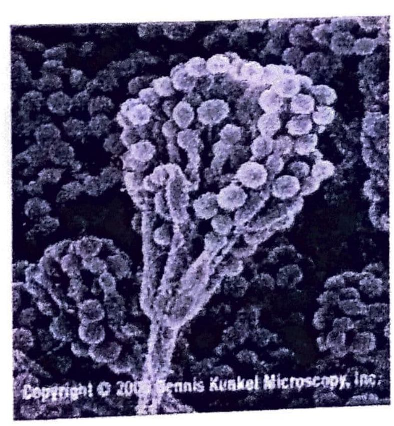


FIGURE: CONIDIOPHORES

SEXUAL REPRODUCTION

The sexual stage in fungi is called the perfect state in contrast to the imperfect state which is the asexual stage. Sexual reproduction involves the fusion of two compatible sex cells or gametes of opposite strains. Fungal sex organs are called gametangia. They may be equal in size. In many higher ascomycetes morphologically different gametangia are formed. The male gametangia are called antheridia and the female ones ascogonia.

The fungus may be homothallic, that is, the hsing gametes come from the same Mycelium or may be heterothallic, that is, the fusing gametes come from different strains of mycelia.

In fungi, sexual reproduction involves the following three phases:

1. **Plasmogamy**
2. **Karyogamy and**
3. **Meiosis**

These three processes occur in a regular -sequence and at a specific time, duriug the sexual stage of each species.

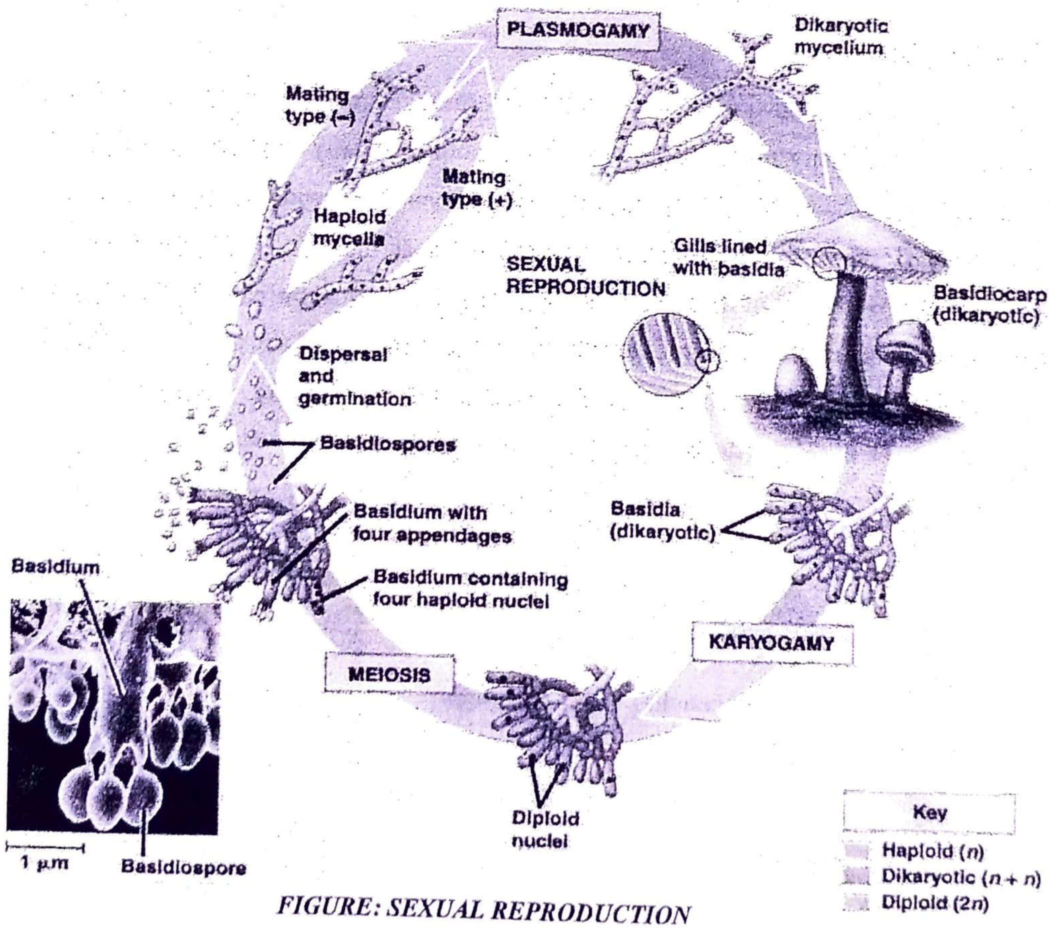


FIGURE: SEXUAL REPRODUCTION

Plasmogamy

It is the union of protoplasts of reproductive hyphae or cells, one from the male and the other from the female to bring about the nuclei of the two parents close together as a pair. However, the two nuclei do not fuse with each other. Such a cell is called a dikaryon. The dikaryotic condition is unique to fungi and may continue for several generations as the two nuclei (dikaryon) divide simultaneously during cell division. These are passed on to the daughter hypha.

Karyogamy

The fusion of the two nuclei which takes place in the next phase is called karyogamy. It may immediately follow plasmogamy as in lower fungi, or it may be delayed for a long time as in higher fungi.

Meiosis

Karyogamy which eventually occurs in all sexually reproducing fungi is sooner or later followed by meiosis producing four genetically different spores.

Different Methods of Plasmogamy

Planogametic Copulation

It involves fusion of two gametes. Like in algae sexual union in fungi may be isogamous, anisogamous or oogamous. Anisogamy and oogamy are together called heterogamous sexual reproduction. Isogamy is the simplest type of sexual reproduction, where the fusing gametes are morphologically similar e.g. *Olpidium* and *Catenaria*. Anisogamy, where the fusing gametes are dissimilar is found in one genus, *Allomyces*, a chitrid. In oogamy as you may recall the motile antherozoid enters oogonium and unites with egg or oosphere forming a zygote. Oogamy is seen in fungi like *Pythium* and *Albugo*.

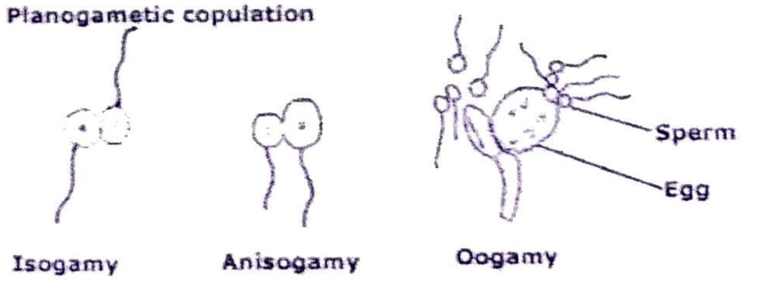


FIGURE: PLANOGAMETIC COPULATION

Gametangial Contact

The male gamete is not a separate entity but the nucleus in the antheridium represents the gamete. As you can see in the Fig. 9.6 the oogonium and antheridium form a contact through a tube and one or more nuclei, inside the antheridium migrate into the oogonium. You may note that in this case the two gametangia do not fuse. It is observed in *Penicllium.*

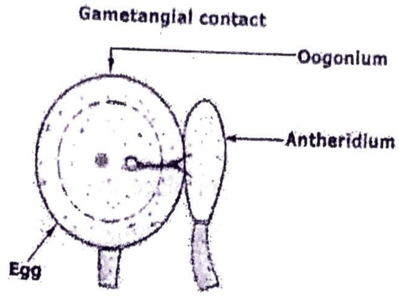


FIGURE: GAMETANGIAL CONTACT

Gametangial Copulation

The Go gametangia make contact and the entire contents of the two fuse together and become one e.g., *Mucor* and *Rhizopus.* In some fungi the entire protoplast of one gametangia flows into the other through a pore. Among the two, the recipient is the female and the donor is the male.

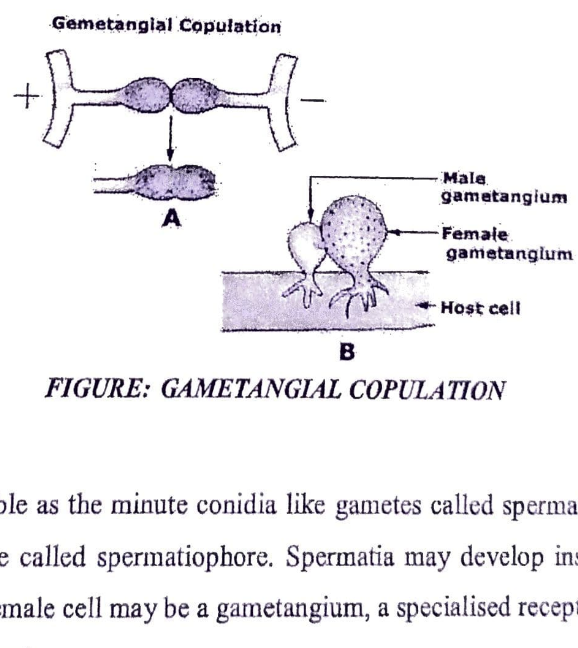


FIGURE: GAMETANGIAL COPULATION

Spermatization

This mode is quite remarkable as the minute conidia like gametes called spermatia are produced externally on special hyphae called spermatiophore. Spermatia may develop inside the cavities called spermatogonia. The female cell may be a gametangium, a specialised receptive hypha or even a vegetative hypha.

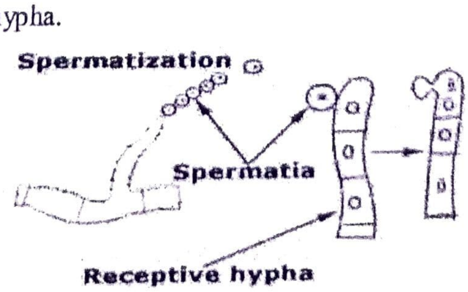


FIGURE: SPERMATIZATION

Somatogamy

In higher fungi like Ascomycetes and Basidiomycetes there is a progressive degeneration of sexuality. The entire process is very much simplified by the fusion of two mycelia which belong to opposite strains. The post-fertlization changes result in the production of a fruiting body which is called ascocarp in Ascomycetes and basidiocarp in Basidiomycetes.

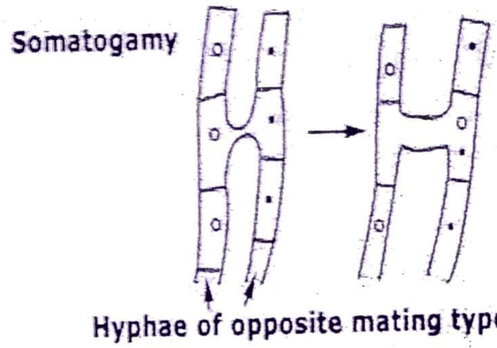


FIGURE: SOMATOGAMY

CONCLUSION

In most fungi, cells are haploid. The body of a fungus is called the mycelium and it grows underground. The mycelium is made up of many individual filamentous hyphae, threadlike strings of cells, in a tangled mass. This structure makes it possible for every cell to be relatively unspecialized and in close contact with the environment. Hyphae are often surrounded by a cell wall made of tough chitin. Hyphae are often divided by walls (septa) which contain holes, allowing materials to pass through the body of the fungus. It is thought that some fungi mycelia may be the biggest living organisms on the planet, covering a span of several states in the soil.

Study of Economic Importance of Algae

1. Food:

- Algae have been in use as human food for centuries in various parts of the world.
- Algae are taken in several ways according to the choice and taste of the people.
- They may be taken as a salad, cooked with meat or eaten as vegetable etc.
- Some are added for flavour to various dishes, while extract from others is taken as a beverage
- Their nutritional value is quite high, as they contain a good amount of proteins, carbohydrates, fats and vitamins, especially A, B, C and E.
- Not only is algae considered worldwide to be a low cost source of protein, but it also contains a number of important minerals such as iron, potassium, magnesium, calcium, manganese, and zinc

Commonly used species are -Chlorophyta – *Chlorella, Ulva lactuca* (Sea lettuce), *Enteromorpha compressa, Caulerpa racimosa.*

Phaeophyta - *Laminaria saccharina, Alaria esculenta, Sargassum sp., Durvillea* sp

Rhodophyta - *Porphyra tenera, Rhodymenia palmata* (Dulse), *Chondrus crispus* (Irish moss), *Gigartina stellata, Gracilaria* sp.

and Cyanophyta - *Nostoc sp.*

In Japan, about 20 different kinds of algae are being harvested and eaten. **'Aonori'** is a preparation of *Monostroma*, **'Kombu'** of *Laminaria* and **'Asakusa-Nori'** of *Porphyra spp.*

2. Fodder:

The sea weeds as fodder have been widely used. In Norway, *Rhodymenia palmata* has come to be known as **'Sheep's weed'** since sheep are very fond of this particular alga. *Laminaria, Ascophyllum sp., Sargassum sp.* and *Fucus sp.,* are also fed to cattles.

3. Pisciculture:

Algae, both floating and attached forms, marine as well as fresh water, provide the primary food for fish and other aquatic animals. The great fishing grounds of the seas are found where these are present in large numbers. In many countries pond culture for fishes has been taken up and they are fed with various forms of algae.

4. Fertilizers:

The large Brown and Red algae are used as organic fertilizers, especially on land close to the sea. Coralline algae *Lithothamnion calcareum* and *Lithophyllum sp.*, and green algae *Chara* are used profusely for liming the soil.

Cyanophyta like *Aulosira fertilissima* has capacity to fix atmospheric nitrogen and thus enrich the soil. In the paddy fields they have been seen to produce an effect almost similar to that of manuring with ammonia. In India, the nitrogen-fixing blue-green algae play crucial part in maintaining the fertility of the rice fields.

5. Reclamation of Alkaline, 'Usar' Land:

In India, vast tracts of land cannot be cultivated for crops because of high alkalinity of the soil, commonly known as **'usar'** soil. The **'usar'** lands would be cultivable, if their pH could be lowered, and organic contents and the water holding capacity of the soil is increased.Blue green algae like- *Nostoc, Scytonema, Anabaena* and *Aulosira,* can be of use in the reclamation of the 'usar' lands.

6. Commercial Products:

Many forms of marine algae, Phaeophyta and Rhodophyta, are highly valuable for certain commercial products, chiefly agar-agar, algin or alginic acid and carrageenin.

- **Agar-Agar (Agar):**

Agar-agar is obtained from various species of red algae for e.g., *Gelidium corneum, Gracilaria lichenoides, Chondrus, Gigartina, Phyllophora, Pterocladia* etc. It is a non-nitrogenous extract and the chief constituent of agar is a carbohydrate galactan.

The important use of agar is in microbiology and tissue culture (in the preparation of culture media for growing algae, fungi and bacteria in the laboratories). Other uses are in the cosmetics, paper and silk industries, in dentistry for making impressions, in canning fish, to prevent the soft fish from being shaken to pieces during transit, in sizing material, in clarifying liquors etc. It is also used as food and in the preparations of ice-cream, jellies, sweets and baking.

- **Carrageenin:**

This is a metabolic product similar to agar, obtained from *Chondrus crispus, Gigartina stellata* etc. The mucilage has several important industrial applications for e.g., in textile industry, in paper making to give body to the paper, in the manufacture of straw and felt hats as a stiffening agent; as an ingredient in cosmetics, shoe-polishes, hand lotions, tooth paste etc., as an emulsifying and suspending agent, in the baking, dairy industries and in clarifying liquors.

- **Algin and Alginates:**

Species of *Laminaria, Ascophyllum, Macrocystis, Nereocystis, Ecklonia, Durvillea* and *Sargassum* are the chief sources of commercial algin.

Algin is a calcium magnesium salt of alginic acid present in the intercellular substance of the Phaeophyta. They have colloidal properties. Its salts are used in the manufacture of variety of goods ranging from ice-cream, salad cream, custard and jams to cosmetics, films, fabrics, ceramics and textiles. They are also used as a suspending agent in compounding drugs, lotions and emulsions; in the rubber industry in latex production; as an insulating material and as dental impression powder, as a gel in the freezing of fish and in the medicinal antibiotic capsules.

- **Funori:**

A product similar to agar obtained from *Gliopeltis furcata* and *Chondrus, spp*. It is chiefly used as glue and as a sizing agent.

7. **Binding of Soil Particles:**

Algae act as an important binding agent on the surface of the soil. Disturbed or burnt soils are soon covered with a growth of green and blue-green algae thus reducing the danger of erosion. The role of Cyanophyta members as a pioneer in colony formation and thus in soil formation is well known.

8. **Medicinal use:**

Digenia simplex, a red alga, provides an antihelmnitic drug. Agar-agar, for its absorptive and lubricating action, is used medicinally in the prevention of constipation.

Antibiotics: The antibacterial product chlorellin, obtained from *Chlorella* is well known and is used against coliforms and other related intestinal bacteria.

Extracts from *Rhodomela larix* and *Ascophyllum nodosum* are effective against both gram positive and gram negative bacteria. Several algae like *Pelvetia, Laminaria, Polysiphonia, Nitzschia* and *Hapalosiphon*, have been reported to possess antibiotic or antibacterial properties.

9. **Sewage Disposal:**

The most common algal species present in the sewage oxidation ponds are *Chlamydomonas, Scenedesmus, Chlorella, Euglena, Eudorina* and *Pandorina*.

10. Diatomite (Kieselguhr):

Large deposits of fossil marine diatoms are called **'Diatomaceous earth'** or **'kieselguhr'**. Silica, is deposited on the cell walls of the diatoms and as the silica walls are hard and chemically inert, the sediments accumulate in marine and fresh water basins.

Kieselguhr was used as an absorbent of nitro-glycerine in the manufacture of dynamite. Because of its hard and chemically inert nature, kieselguhr is mainly used in insulation, as a filtering agent and as an abrasive, in the industrial filtration processes of sugar refining, brewing and wine making, in the recovery of chemicals and for removing waste mycelium in the production of antibiotics. It is used as an industrial catalyst, as filler in paints and varnishes, in paper industry; and in insulation materials for use at extremes of temperatures. It is also used widely to absorb coloured substances from oils and other liquids; as a cleaning powder in soaps and in metal polishes.

LIFE HISTORY OF OEDOGONIUM

Classification

Class – Chlorophyceae
Order – Oedogoniales
Family –Oedogoniaceae
Genus – *Oedogonium*

Distribution

There are more than 285 species found everywhere, but only in fresh water. In India, more than 114 species are found. The more common Indian species are *O. elegans*, *O. undulatum*, *O. areolatum* etc.

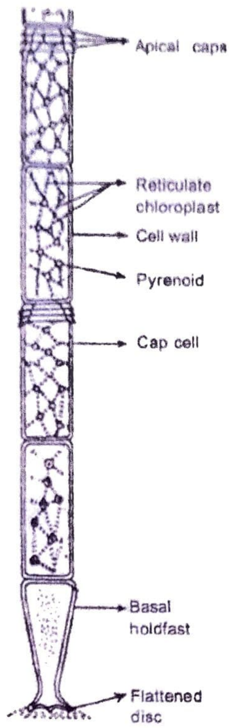
Habit and habitat

It is a freshwater alga found in fresh water bodies like ponds, tanks, ditches, quiet areas of rivers. Some species are epiphytic on aquatic plants. while, one species, *O. terrestris* is found on moist soil.

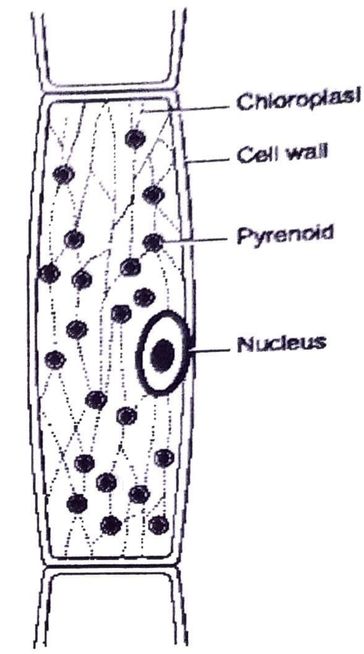
The plant body is thalloid, green, filamentous, unbranched with basal cell as holdfast which attaches the plant with substratum.

Thallus structure

The thallus is filamentous, multicellular and unbranched. All the cells of the filament are cylindrical except the basal and apical cell. The basal cell is colourless and forms holdfast. The proximal end of the hold fast extends to produce finger like projections which help the filament to attach on the substratum. The apical cell is rounded or elongated in



a) A part of filament



b) A cell enlarged

Shape. The vegetative cell is cylindrical and possesses a thick cell wall. The inner layer is cellulosic and the outer layer is made up of pectin. A thin layer of chitin is present above the pectin layer. The protoplasm contains reticulate, parietal chloroplast and it extends from one end of the cell to the other. It is made up of microtubules. A single nucleus and many pyrenoids are present. There is one large central vacuole. The pigmentation is typical chlorophycean type having chlorophyll a, b, β-carotene and xanthophyll.

The terminal cell is rounded. Some cells below the terminal cell possess apical caps which are ring like markings on their upper part called apical caps. Such cells are known as cap cells. The presence of cap cell is characteristic feature of *Oedogonium*.

Reproduction

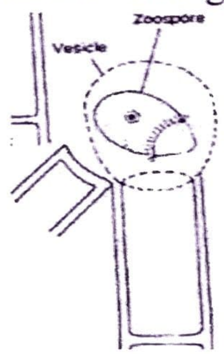
Oedogonium reproduces by vegetative, asexual and sexual methods.

Vegetative reproduction

It takes place by fragmentation and akinete formation.

Asexual reproduction

During favourable conditions, some of the vegetative cells function as zoosporangia and a single zoospore is produced per zoosporangium. A ring of short flagella is found at the base of colourless, beak like anterior end of the zoospore.The zoospore is released from the zoosporangium and swims in water. If it reaches a suitable substratum, it divides into two cells. The lower cell forms holdfast. The green upper cell divides and produces the filament.



Liberation of zoospore

A single zoospore

Sexual reproduction

The sexual reproduction in *Oedogonium* is of advanced oogamous type. Sexual reproduction is more frequent in still waters than in running water. The male gametes are produced in antheridia and the female gametes are produced in oogonia. Depending upon the nature of antheridia producing plants, *Oedogonium* species are of two types:

(i) Macrandrous:

Here, antheridia are produced on normal size plant. Macrandrous species may be monoecious or dioecious. Monoecious macrandrous species are *O. fragile, O. hirnii, O. kurzii and O. nodulosum*. In dioecious macrandrous species antheridia and oogonia are produced on separate male and female plants of normal size.

(ii) Nannandrous:

The oogonia are normal. The antheridia are produced on special type of dwarf plants, known as Dwarf male. Dwarf males are formed by androspores which are produced in androsporangia. If androsporangia and oogonia are formed on same plant, they are called gynandrosporous e.g., *O. concatinatum*. If androsporangia and oogonia are formed on different plants, then called idioandrosporous e.g., *O. confertum*.

Antheridia:

(i) In macrandrous forms:

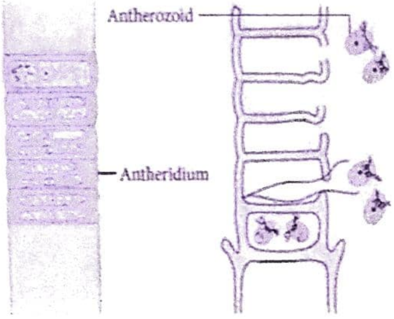
Normally a cap cell forms one antheridial mother cell which divides to forms a row of 2-40 antheridia. The antheridia are broad, flat, short and cylindrical. The contents of an antheridial cells divide longitudinally into two antherozoids. The antherozoids are liberated in the same fashion as zoospores.

The liberated antherozoids are pale green or yellow green, oval or pear shaped. The antherozoids are motile about 30 sub-apical flagella present at the base of beak or hyaline spot. The antherozoids swim freely in water before they reach oogonia. The antherozoids are similar to zoospores in structure but these are smaller than zoospores.

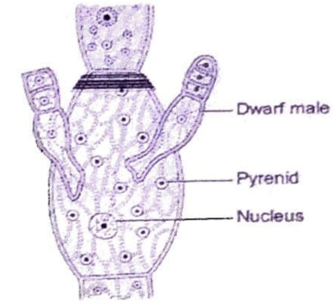
(ii) In nannandrous forms:

The antheridia are formed on dwarf males or nannandria. The dwarf male filament is produced by the germination of a special type of spore known as androspore. The androspore is produced singly within an androsporangium.

The androsporangia are flat, discoid cells slightly larger than antheridia. Each androsporangium produces a single androspore just as in the case of zoospore. Liberation of androspore is similar to that of



Antherozoid formation and liberation



Dwarf male on oogonial wall

zoospore. The androspores look similar to zoospore except for the smaller size.

After swimming about for some time, the androspore settles on oogonial wall e.g., *O. ciliatum* or on the supporting cell e.g., O. *concatenatum*. The androspore germinates into a dwarf male. The nannandria are 2-4 celled long. It has a basal attaching cell, the stipe and all others cells are antheridial cells.

Here, antheridia and their further developments are same as in macrandrous form. The antherozoids are released by disorganization of antheridial cell or through the opening.

Oogonia:

In Oedogonium the oogonia are highly differentiated. The structure and development of oogonium is identical in macrandrous and nannandrous species. Like antheridia, any freely divided or actively growing cap cell functions as the oogonial mother cell. The oogonial mother cell divides by transverse division into two unequal cells. The upper larger cell contains more cytoplasm, food and enlarges into spherical or flask shaped oogonium and the lower smaller cell function as supporting cell or suffultory cell. When supporting cells divide again, many oogonia are formed in chain.

The protoplast in oogonium transforms into a single egg or oosphere. The oosphere is non-motile, green due to chlorophyll and has a central nucleus. As the ovum matures, the nucleus moves to periphery, the oosphere retracts slightly from the oogonial wall and develops a hyaline or receptive spot just outside the nucleus. The receptive spot receives antherozoids for fertilization.

Fertilization:

The antherozoids swim through the opening of oogonial wall and enter the egg through hyaline receptive spot. Only one male antherozoid is able to fuse with ovum. After fusion the diploid zygote secretes a thick wall around itself and forms oospore. The colour of the oospore changes from green to reddish brown. The oospore is liberated by the disintegration of oogonial wall.

Oospore and its germination

The oospore is spherical and reddish brown in colour. It is three layered and contains a diploid nucleus and dense cytoplasm. Oospore is a resting spore and it may become dormant for a year or more. The diploid oospore divides meiotically to form four haploid daughter protoplasts. Each daughter protoplast metamorphosises into a zoospore, known as meiozoospore. The meiozoospores are liberated in a vesicle. Soon the vesicle breaks and meiozoospores come in water. Each spore germinates and forms a new plant.

CHARACTERISTICS OF FUNGI

1. THALLUS ORGANIZATION

- Except some unicellular forms (e.g. yeasts, Synchytrium).
- The fungal body is a thallus called mycelium.
- The mycelium is an interwoven mass of thread-like hyphae (Sing., hypha).
- Hyphae may be septate (with cross wall) and aseptate (without cross wall).
- Some fungi are dimorphic that found as both unicellular and mycelial forms e.g. *Candida albicans.*

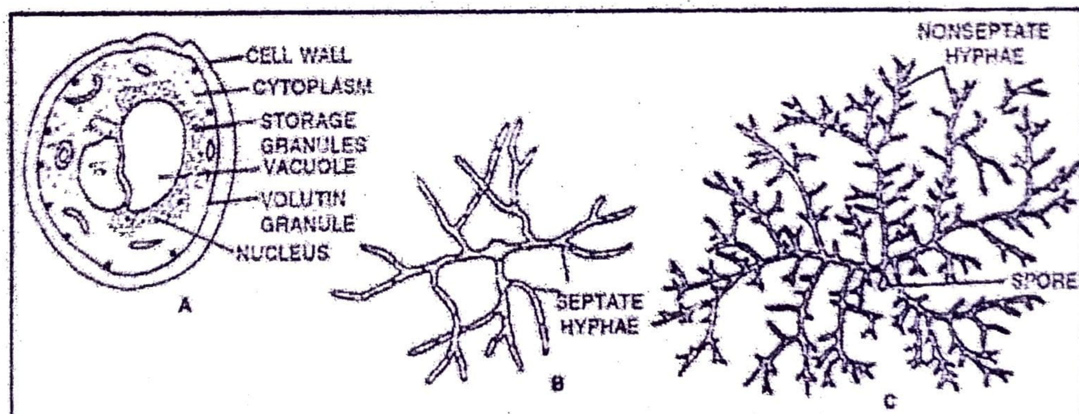


Figure 6.1 Fungi A. Yeast-unicellular thallus B. mycelium with septate hyphae C. mycelium with aseptate or coenocytic hyphae

2. DIFFERENT FORMS OF MYCELIUM

(a) Plectenchyma (fungal tissue):

In a fungal mycelium, hyphae organized loosely or compactly woven to form a tissue called plectenchyma.

It is two types:

i. Prosenchyma or Prosoplectenchyma:
In these fungal tissue hyphae are loosely interwoven lying more or less parallel to each other.

ii. Pseudoparenchyma or paraplectenchyma:

In these fungal tissue hyphae are compactly interwoven looking like a parenchyma in cross-section.

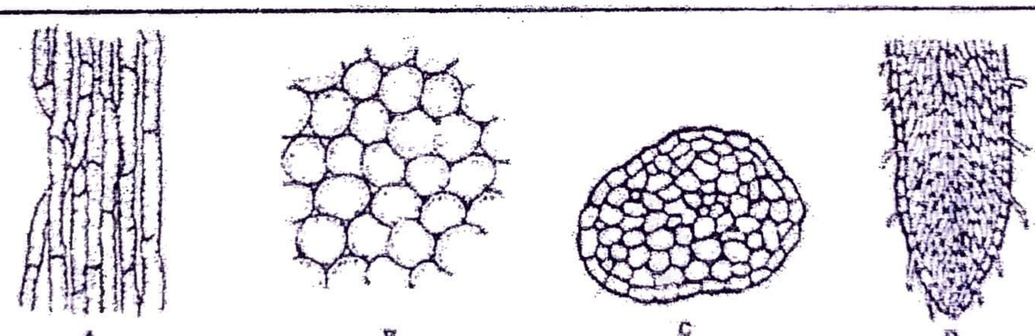


Figure 6.2 Different forms of fungal mycelium

(b) Sclerotia (Gr. Skleros=haid):

These are hard dormant bodies consist of compact hyphae protected by external thickened hyphae. Each Sclerotium germinates into a mycelium, on return of favourable condition, e.g., *Penicillium*.

(c) Rhizomorphs:

They are root-like compactly interwoven hyphae with distinct growing tip. They help in absorption and perennation (to tide over the unfavourable periods), e.g., *Armillaria mellea*.

3. NUTRITION

The fungi lack chlorophyll. Therefore, they cannot synthesize their own food.

Depending on from where and how they get nutrition, fungi are of following types:

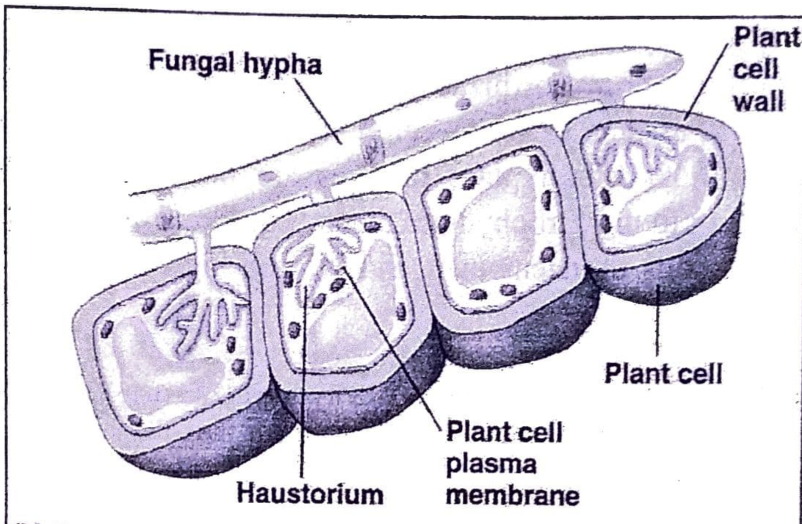
(a) Saprotrophs (= saprobes):

They obtain food from dead and decaying organic matter. They secrete digesting enzymes to outside which digest the substratum and then absorb nutrients, e.g., *Mucor*, *Rhizopus* (bread mould) etc.

(b) Parasitic:

- They obtain food from living.
- They may be facultative or obligate.
- **Facultative** parasites grow on a variety of tissues and often cause 'soft rot' of the tissue, e.g., *Ustilago*. (In **facultative mutualism**, each organism can survive independently, but it benefits both to remain together.)

- The **obligate-** parasites absorb through specialized haustoria. (In **obligate mutualism**, one organism cannot survive without the other. This term is easy to remember because both organisms are obligated, or forced to, rely on one another).



(b) Haustoria

- The parasitic fungi that grow on surface of host cells and absorb food through haustoria are called **ectoparasites or ectophytic parasites** (e.g., *Mucor, Erisphae*).

- When parasitic fungi grow inside the host tissue arc called **endoparasites or endophytic parasites** (e.g., *Pythium, Puccinia*).

(b) Predacious:

Some soil fungi develop ring-like noses to trap annelids, nematodes etc. e.g., *Arthrobotrys, Zoophagus, Dactylella* etc.

(d) Symbiotic:

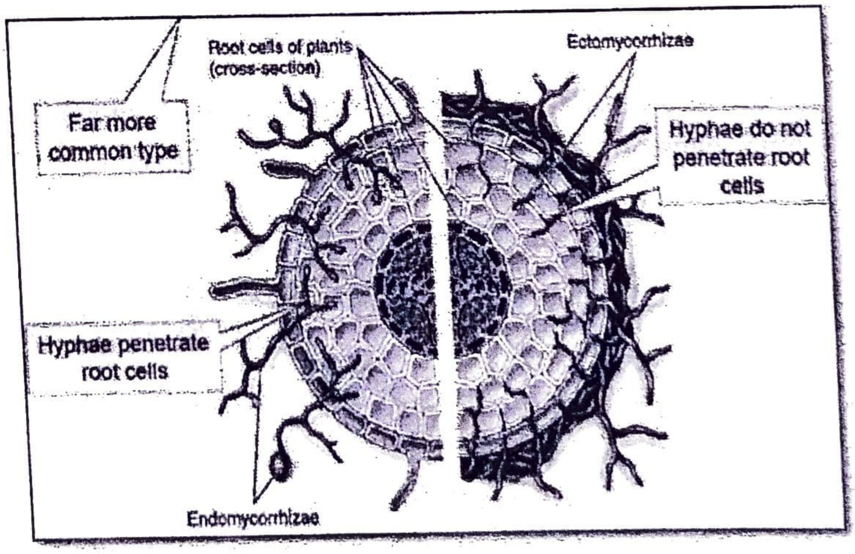
- They live in mutualistic relationship with another organism by which both are benefited.

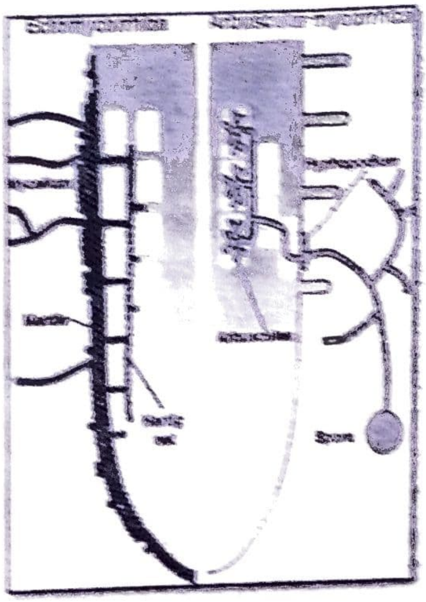
- The two common examples are lichens and mycorrhiza.

- Lichens are symbiotic associations between fungi and algae. The fungal partner is a member of ascomycetes or basidiomycetes that provides water and nutrients, while the algal partner is a green alga or cyanobacteria that prepares food by photosynthesis.

- Mycorrhizas or mycorrhizae (fungus roots in Greek) are the mutualistic symbiotic associations between soil fungi and the roots of most plant species (95% of all plant families are predominantly mycorrhizal). According to the carbohydrate theory (Bjorkman, 1949), the plants that grow in soils deficient in P and N, and high intensity light develop mycorrhizas.

- The two most common types of mycorrhizas are the ectomycorrhizas (ECM) and the endomycorrhizas (also known as arbuscular mycorrhiza, AM or VAM).





- The two groups are differentiated by the fact that the hyphae of ectomycorrhizal fungi do not penetrate the cell wall of the plant's root cells.
- While the hyphae of arbuscular mycorrhizal fungi penetrate the cell wall.

4. HETEROTHALLISM AND HOMOTHALLISM

- F. Blakeslee (1904) discovered mating types or genetically distinct strains in Mucor.
- He called fungi with different mating types are called heterothallic and
- Fungi without mating types are called homothallic.
- Nowadays we call some fungi and algae homothallic if both male and female gametes produce in the same individual can fertilize each other and
- Heterothallic if the gametes can only be fertilized by gametes from another individual of the same species.

➤ Heterothallism introduces variations in the species.

5. REPRODUCTION:

Like most other thallophytes, fungi also reproduce by vegetative, asexual and sexual means. However, asexual reproduction is generally predominant depending upon the involvement of the entire thallus or a part of it, the fungi may be holocarpic or eucarpic.

(i) Holocarpic:

In this category of fungi the entire thallus gets converted into one or more reproductive bodies. Hence, the vegetative and reproductive phase can never occur at the same time.

(ii) Eucarpic:

Most of the fungi are eucarpic. Here only a part of the thallus is involved in the development of reproductive organs and remaining thallus remains vegetative. In eucarpic fungi, vegetative and reproductive phases exist at the same time.

The various methods of sexual reproduction in fungi are as follows:

(i) Planogametic copulation:

This is 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 three types:

(a) Isogamy:

In this process fusing gametes are morphologically similar and motile but physiologically dissimilar. These gametes are produced by different parents e.g. *Synchytrium*.

(b) 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 (antherozooid) fuses with the large, non-motile female gamete (egg or ovum), *Monoblepharis*, *Synchytrium* etc.

(ii) 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, Sphaerothera, Albugo, Pythium* etc.

(iii) Gametangial copulation:

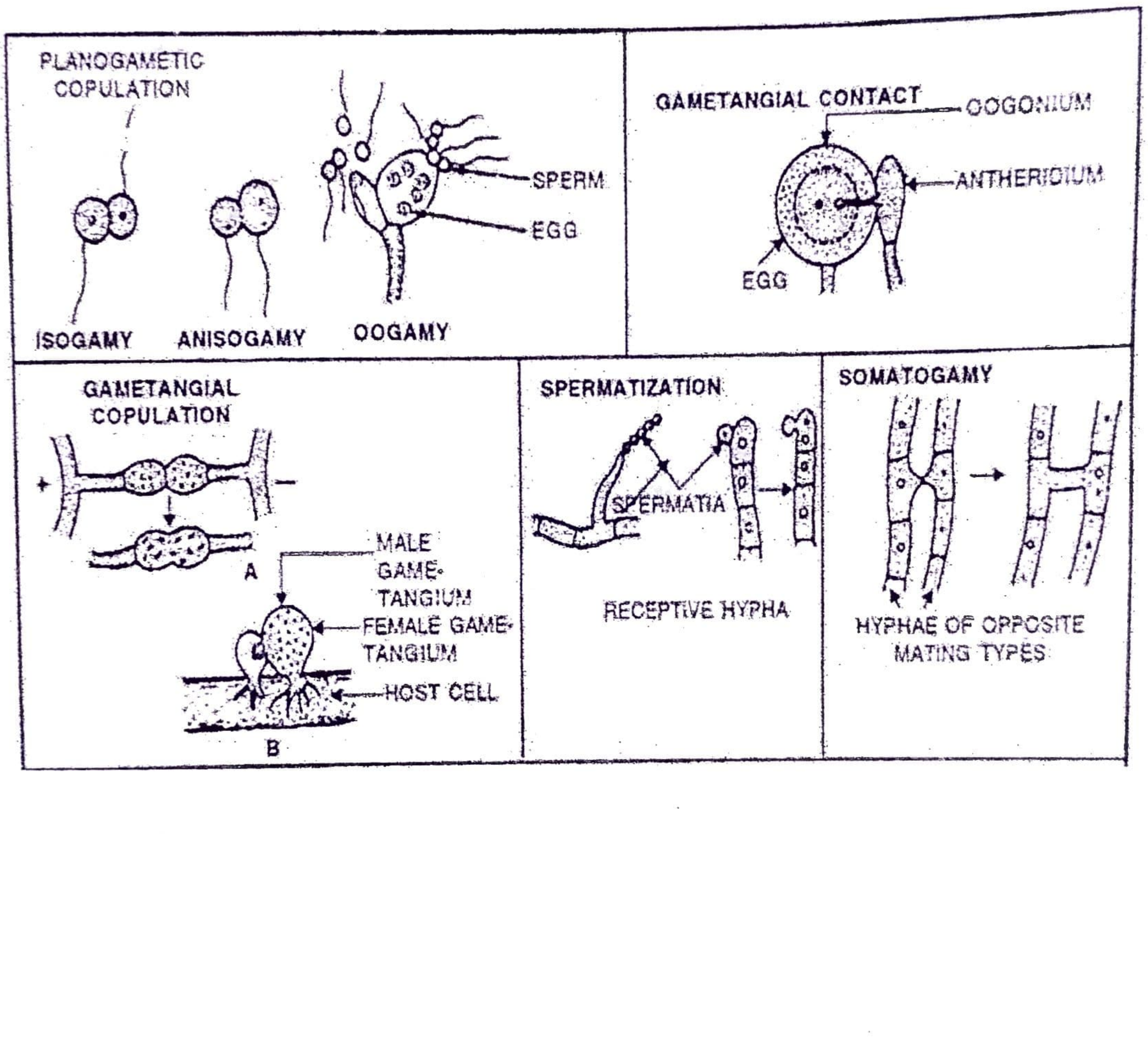
It involves the fusion of entire contents of two gametangia to form a common cell called zygote or zygospore, e.g., *Mucor, Rhizopus*.

(iv) 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*.

(v) 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.



BiolB239

Saul Purton

Lecture 4: *Chlamydomonas* - a model for plant cells

What is *Chlamydomonas reinhardtii*?

- Unicellular eukaryote
- Green alga (Chlorophyte) [note: plants have evolved from within the chlorophyte lineage, so green algae can be considered as simple plants].
- *Chlamydomonas* species found in freshwater and damp soils around world (over 400 reported species).
- *C. reinhardtii* appears to be restricted to Eastern side of North America.
- Major *C. reinhardtii* strain used in lab (137c) dates from 1945 - isolated from field in Massachusetts by G.M. Smith.

Cell architecture:

- ovule cell 10-20 um in length
- Single cup-shaped chloroplast (204 kb genome - completely sequenced) partially surrounding the nucleus (~100 Mb haploid genome – completely sequenced)
- Two anterior flagella
- Eyespot (stigma)
- several small mitochondria (15.8 kb genome - completely sequenced)
- cell wall made of glycoproteins

Chlamy life cycle

Vegetative

- Vegetative cells are haploid
- Will grow by binary fission to form colonies, or in liquid culture to ~2 x 10^7 cells/ml.
- Can be synchronised by 12h light : 12 hour dark cycle.

Sexual cycle (response to adverse conditions)

- Two stable mating types mt+ and mt–.
- Vegetative cells will undergo transformation to form sexually-competent gametes if deprived of nitrogen source.
- Flagellar pairing initiates a cascade of events. Ultimately leading fusion of the two cells and formation of a diploid zygote.
- Thick cell wall forms around zygote (allows long-term survival in dormant state).
- Restoration of nutrients and light -> germination of zygote.
- Meiosis results in the formation of 4 haploid daughter cells (=Tetrad).

Inheritance patterns/genetic mapping

- Nuclear markers inherited according to Mendelian rules (ie 2 : 2 in tetrad).

- Chloroplast and mitochondrial mutations inherited uniparently (4:0) from mt+ and mt– parents, respectively.

Hence, it is easy to discriminate between the three possible sites of mutation.

- For nuclear mutations, can do simple genetic analysis to look for linkage of two markers.
- Can also do complementation studies and analyse dominant vrs recessive mutations by creating vegetative diploid lines.

Nuclear genetic map comprises17 linkage groups (probably equates to 17 chromosomes in haploid cell). Several hundred genetic markers now placed on maps.

Mutagenesis

- Chlamy will grow in liquid culture or as clonal colonies on solid medium. Can therefore add mutagen (eg EMS) to culture or zap with UV, X-rays, etc., and then plate millions of cells.
- Because, nuclear genome haploid then mutants will have a phenotype (lethal mutations will obviously not be recovered, but can use stable diploid strains to isolate these).
- Classes of mutant
  - Photosynthetic (require acetate for survival)
  - Respiratory (require light)
  - Flagella
  - Pigment and starch metabolism
  - Phototaxis, chemotaxis
  - Various metabolic mutations (*e.g.* arginine biosynthesis)

Molecular-genetics

An important reason for using *Chlamy* as a model system is that all three genomes can be transformed.

Nuclear transformation:

Methods for DNA delivery:

- Gun
- Glass beads (preferred)
- Electroporation

Selectable markers:

- Auxotrophic markers eg *ARG7* (rescues arg7 mutant to growth without exogenous arginine)
- Dominant markers (eg *BLE* – resistance to the drug bleomycin)

Integration pattern:

- Random (illegitimate recombination)
- Copy no. high with gun, low with beads/electroporation (can set conditions to give ~1 integration event per transformant cell)

Applications:

- Relating gene to mutation by showing can complement mutation by transformation with wild-type gene (eg *arg7* with *ARG7*), and fine mapping the ends of gene.
- Isolation of genes by genomic complementation (pools of cosmid clones)
- Positional cloning (testing for complementation by transformation using BACs, cosmids, *etc*).
- Using GFP constructs as reporters of promoter activity/promoter traps.
- Expression of foreign genes.
- Insertional mutagenesis (to create tagged genes).
- Specific gene knockouts (saturation approach).
- Gene knockdowns using RNAi constructs.

Organellar Transformation

Transformation of both the chloroplast and mitochondrial genomes has been reported. So far only chloroplast transformation has been exploited, but recent work indicates that genetic manipulation of mitochondrial genes is now feasible.

- Method for DNA delivery - biolistics
- Mode of integration - homologous recombination
- Markers - bacterial antibiotic resistance genes (fused to chloroplast promoter)
  - aadA (-> Spec resistance)
- Can use marker to:
  - Disrupt/delete specific chloroplast genes
  - Introduce site-directed changes to specific chloroplast genes
  - Introduce other foreign genes

<u>*Chlamy* - a powerful model for studying photosynthesis</u>

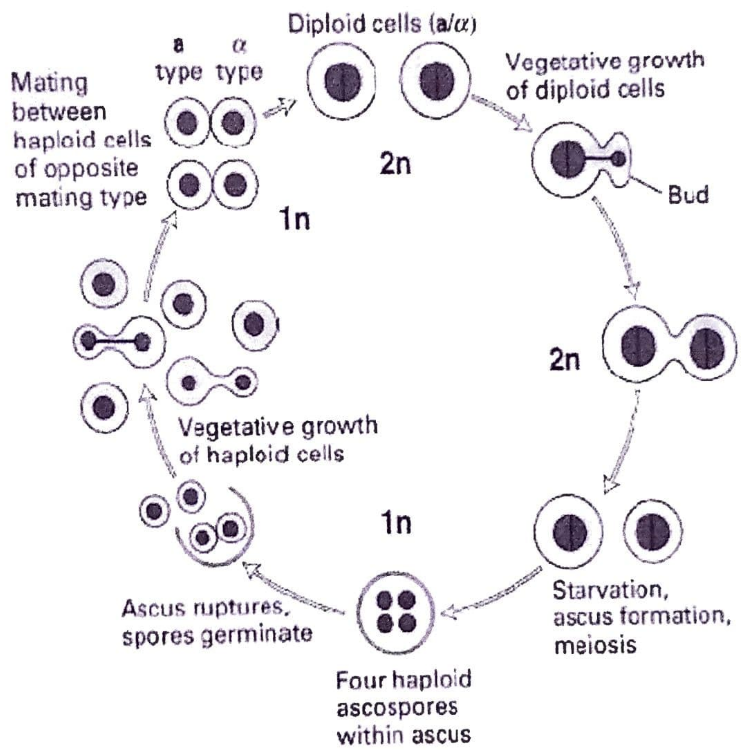
- Photosynthetic apparatus very similar to that of plants
- Quick and easy to grow
- Single cell type
- Easy classical genetics
- Can dispense with photosynthesis (when supplied with acetate as C source)
- Makes chlorophyll (and hence complexes) in dark (unlike flowering plants)
- Can genetically engineer key photosynthetic genes in chloroplast
- Can down regulate nuclear photosynthetic genes by RNAi (or obtain null mutants using insertional mutagenesis screens)
- Nuclear genome has been sequence (extensive EST collection already), chloroplast genome also done.

SEM2, CC4, Unit 3

Ascomycota: Life cycle of *Saccharomyces*, *Talaromyces* (*Penicillium*), *Neurospora* and *Ascobolus*

Dr. Subhadip Chakraborty

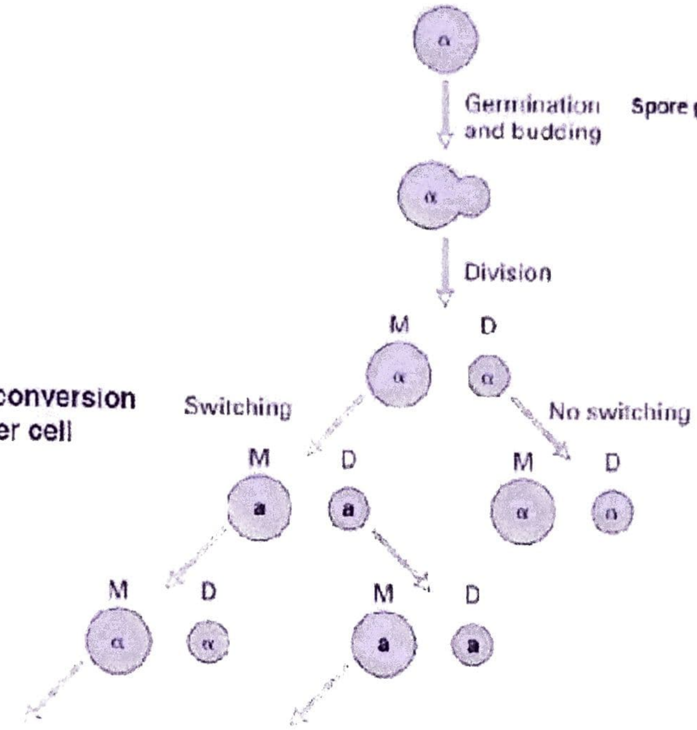
Life cycle of the budding yeast, *S. cerevisiae*



Haploid yeast cells can be "*a*" or "α" mating type

Spore germination

Mating-type conversion in mother cell



Apothecium or Ascocarp or Fruiting Body:
After plasmogamy the ascogenous hyphae are produced from the fertilized ascogonium. The paired nuclei migrate into these hyphae and transverse walls are then laid down dividing them into several cells. The dikaryotic cell at the tip of ascogenous hyphae divides to form four nuclei.

Walls are formed in such a manner that a terminal or ultimate uninucleate hook cell, a bi-nucleate arch cell (penultimate cell) and a uninucleate stalk or anti-penultimate cell is formed (crozier formation). The two nuclei of the penultimate cell fuse and thus young ascus is formed. The diploid nucleus in the young ascus divides by meiosis and then mitosis to form eight haploid nuclei which get organised into ascospores (Fig. 4).

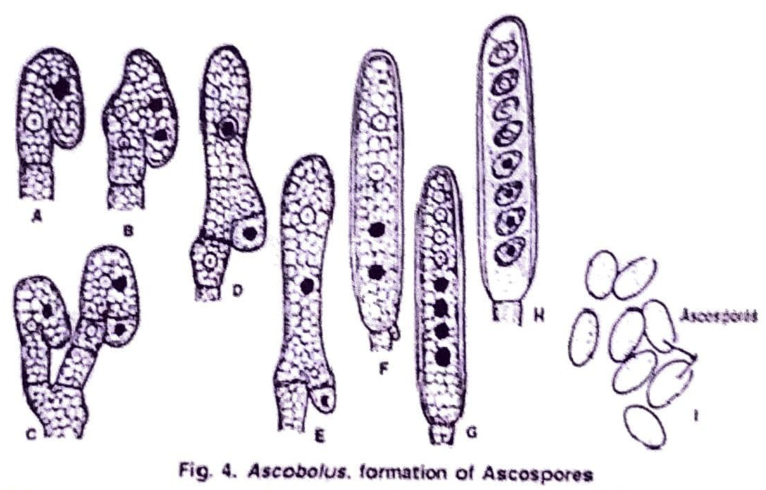


Fig. 4. *Ascobolus.* formation of Ascospores

Mature asci are long, calavate with eight ascopores. The ascopores are one-celled, double-walled, ellipsoidal or spherical, purple or dark brown. Some vegetative hyphae grow up among the ascogenous hyphae and give rise to slender paraphysis. Sheath of sterile hyphae surround the asci and paraphysis and ultimately a cup shaped yellow structure develops. It is called apothecium.

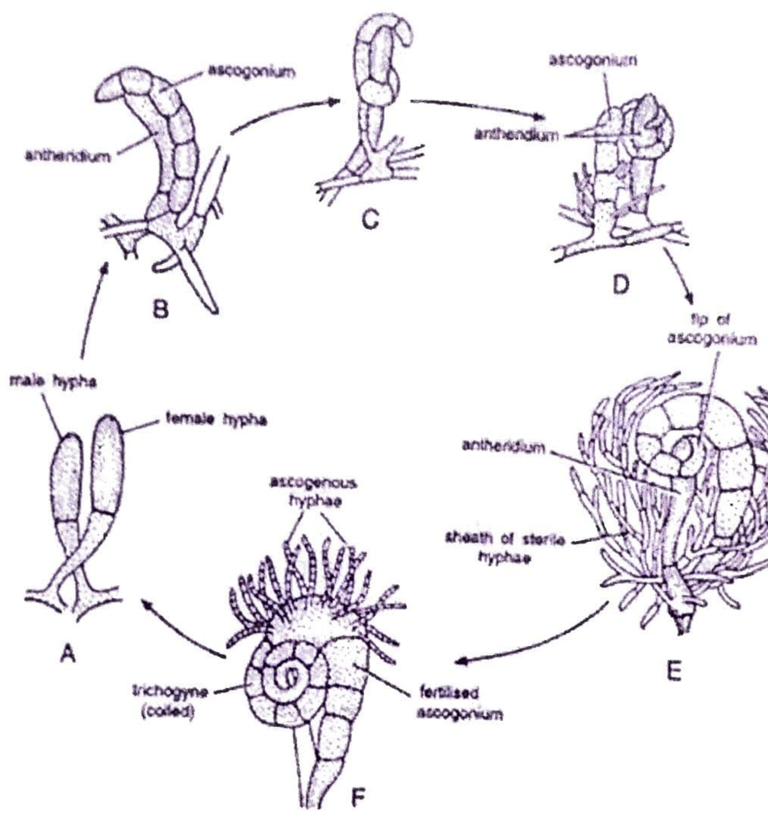


Fig. 3. *Ascobolus*. Sexual reproduction

Antheridium:

The antheridium on maturity is club shaped and multinucleate. Antheridial branches which bear antheridia are cylindrical and remain erect.

Ascogonium:

The mature ascogonium is globose and multinucleate (100 or more nuclei). It cuts off terminally a long trichogyne which by separations becomes 5-8 celled structure.

Fertilization:

The trichogyne coils around the body of the antheridium and reaches at the antheridial tip. The walls of contact between two (tip of antheridium and trichogyne) dissolve (plasmogamy) and the male nuclei pass into the apical cell of trichogyne from which they finally reach the ascogonium. The male and female nuclei arrange themselves in pairs towards the periphery of the ascogonium.

(ii) Sexual reproduction.

(i) Asexual Reproduction:

Formation of Chains of oidia or arthrospores has been seen but these are not of frequent occurrence.The oidia can germinate to from a new mycelium (fig.2.). oidia serve both as sexual spore and male cells.

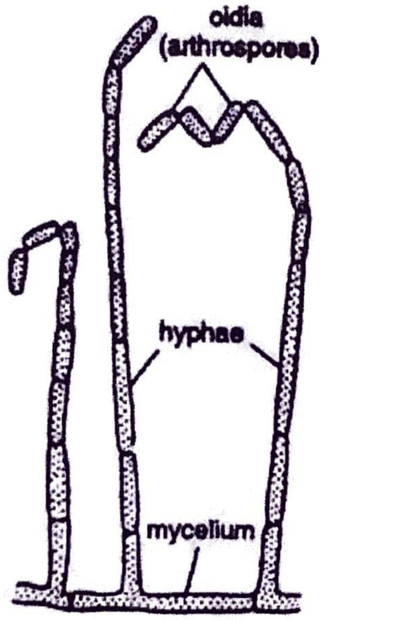


Fig. 2. *Ascobolus* : Arthrospores formation

(ii) Sexual Reproduction:

Sexual reproduction is oogamous (fig. 3). The species of Ascobolus may be heterothellic (A. stercovarius A. immersus) or homothallic (A. crenulatus). Male and female sex organs are called antheridia and ascogonia respectively.

1. Habit and Habitat of Ascobolus
2. Vegetative Structure of Ascobolus
3. Reproduction of Ascobolus

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1. Habit and Habitat of Ascobolus:

Ascobolus is represented by 48 species. It is coprophilous fungus growing on dung of herbivorous animals. A furfuraceus grows on old dung of cow while A. carbon Arius grows on old bonfire sites. In India, Ascobolus is represented by 12 species. Some common Indian species are A. magnificus, A. virdis etc.

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2. Vegetative Structure of Ascobolus:

Thallus is represented by mycelium. It is well developed, perennial and consists of profusely branched hyphae. Hyphae are septate and the cells are multinucleate. The hyphae ramify within the substratum and form a complex system which helps in the absorption of the food material for the aerial fruiting bodies called apothecia (Fig. 1). The apothecia are yellowish or greenish when young and purplish brown at maturity.

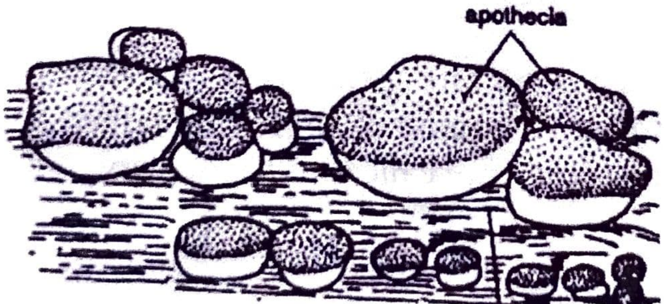

Fig. 1. ***Ascobolus*** **: Aerial apothecia.**

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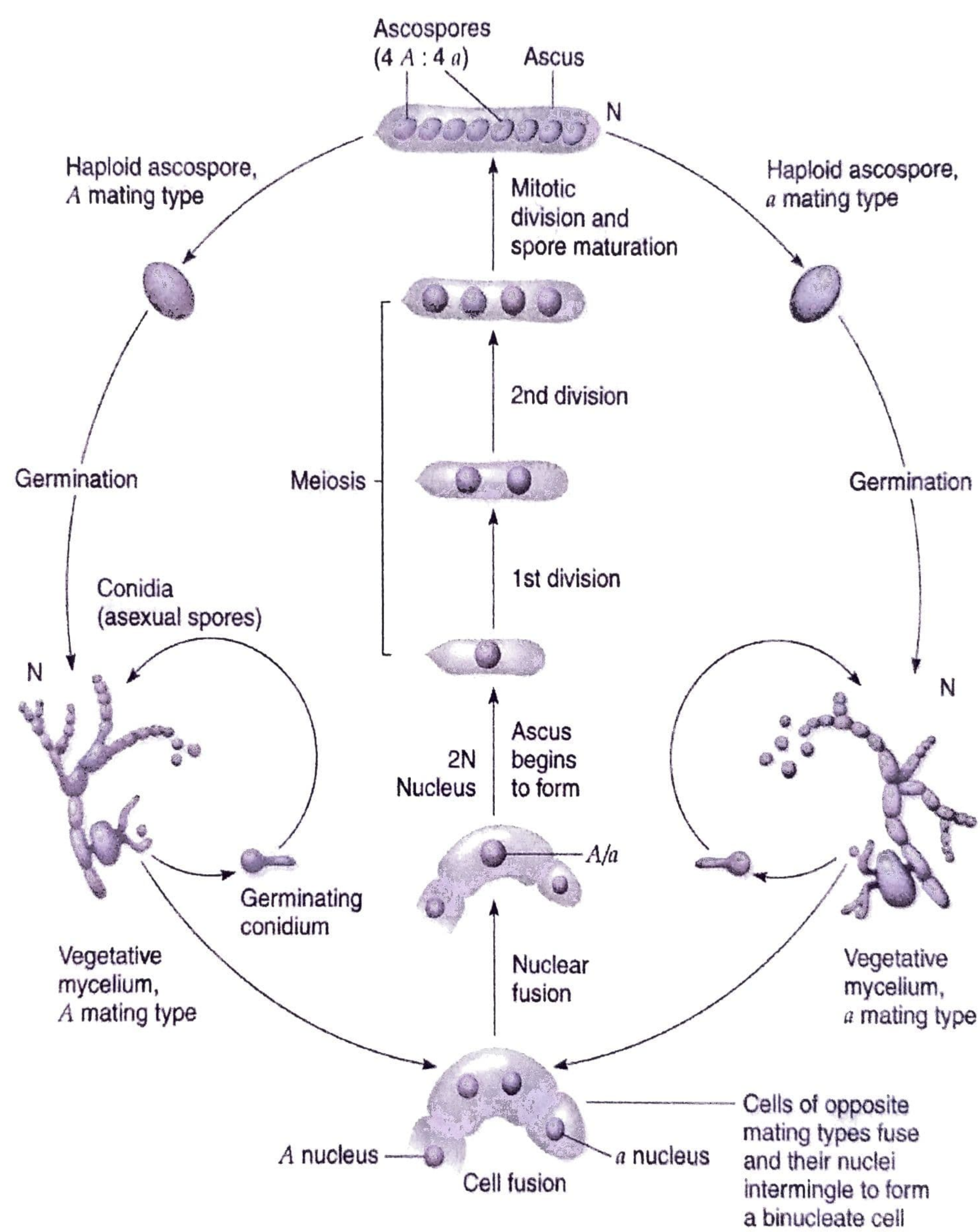
3. Reproduction in Ascobolus:

Ascobolus reproduces by two methods:

(i) Asexual reproduction



n this article we will discuss about Ascobolus. After reading this article you will learn about: 1. Habit and Habitat of Ascobolus 2. Vegetative Structure of Ascobolus 3. Reproduction.

Contents:

Lifecycle of *Neurospora*, a haploid bread mold

Given two *haploid* vegetative **mycelia** of opposite **mating types** (***A*** and ***a***), physical contact allows haploid nuclei to fuse to form a *diploid* ***Aa*** nucleus. The nucleus undergoes two typical **meiotic** divisions to form four haploid gametes: ***A*** and ***a*** products of the second division remain in linear order in the ascus. A further mitotic division produces eight **ascospores**. Release of the ascospores and germination completes the life cycle.

For purposes of genetic experimentation, the significant features are (1) the vegetative mold is *haploid*, such that all metabolic pathways are controlled by a single allele, and (2) the separation of the products of second meiosis at either end of the ascus means that each quartet expresses different alleles at each locus: the ascus can be dissected and the four identical spores at either end used in crosses.

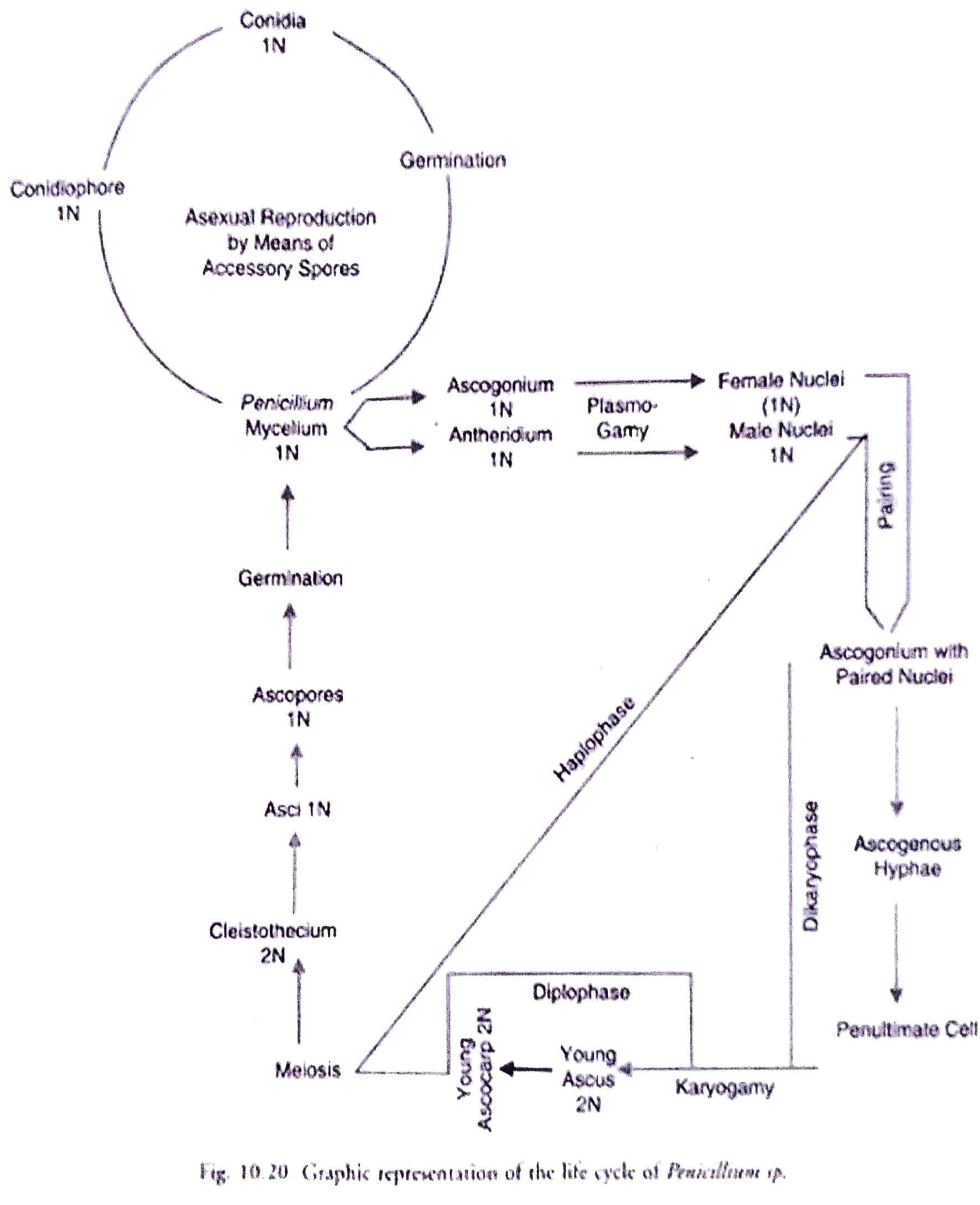


Fig. 10.20 Graphic representation of the life cycle of *Penicillium sp.*

Life cycle of *Talaromyces*: Pathogenic fungi have evolved traits that allow them to infect and grow on or in a host. One such trait is the ability to alternate growth forms, where each is suited to a particular environment. This ability is called dimorphism, and it is exhibited by a diverse group of pathogenic fungi (Fig. 1). P. marneffei is an emerging human-pathogenic fungus endemic to Southeast Asia, where it is considered to be AIDS defining. P. marneffei infections occur primarily in individuals with defined immunocompromising conditions; however, a small number of cases of infection in patients without a diagnosed immunodeficiency have also been reported (1, 2). In none of the latter cases has immunocompetency been demonstrated. P. marneffei lacks a defined sexual cycle but possesses all of the genes believed to be required for mating, including both mating type idiomorphs in a heterothallic arrangement among isolates (3). P. marneffei, like a number of other fungal pathogens, exhibits temperature-dependent dimorphic growth, hyphal at 25°C and yeast at 37°C. Exposure to an air interface at 25°C promotes the saprophytic hyphae to differentiate to produce asexual spores (conidia), the infectious agents (Fig. 2). Conidia inhaled into the host lung are phagocytosed by pulmonary alveolar macrophages. Within macrophages, conidia germinate into unicellular yeast cells, which divide by fission (4). This minireview focuses on the current understanding of the genes required for the morphogenetic control of conidial germination, hyphal growth, asexual development, and yeast morphogenesis in P. marneffei (Table 1). It should be noted that P. marneffei has recently been renamed Talaromyces marneffei on the basis of new molecular phylogenetic analyses (5).

Sexual reproduction occurs by mating of the opposite mating types to form the zygote. The zygote then undergoes meiosis to form ascus, which encloses the ascospores. Sexual reproduction in yeasts can be broadly divided into three types

1. Haplobiontic life cycle: This type of life cycle is found in *Schizosaccharomyces octosporus* and other yeasts. In this type of life cycle, the vegetative stage is predominantly haploid and diploid stage is short, represented by zygote, which undergoes meiosis immediately after nuclear fusion to form eight ascospores.

2. Diplobiontic life cycle: This type of life cycle is found in *Saccharomyces ludwigii* where the vegetative stage is predominantly the diploid phase and haploid phase is short. Here the ascospores are not liberated by the ascus and the spores copulate within the ascus to form diploid zygotes, which bud out to form diploid vegetative cells.

3. Haplo-diplobiontic life cycle: This type of life cycle is represented equally by the haploid and diploid stages. It is seen in budding yeast *Saccharomyces cerevisiae* where the haploid cells mate to form a diploid zygote, which undergoes meiosis to form four haploid vegetative cells belonging to two mating types.

Apart from these three types of mating, in certain yeasts such as fission yeast *S. pombe*, there is mating between two adjoining sister cells known as adelphogamy. Here the cells involved in copulation do not separate after fusion and remain united to form short chains (Bell and Koufopanou 1991).

Schizosaccharomyces pombe	*Saccharomyces cerevisiae*
Approximately 4,970 ORF	Approximately 5,600 ORF
About 5,000 introns	About 250 introns
3 chromosomes	16 chromosomes
Usually haploid	Often diploid
G2-M transition is tightly controlled	G1-S transition is tightly controlled
Large, repetitive centromeres more similar to mammalian centromeres, and degenerate replication origins of at least 1 kb	Small point centromere of 125 bp, and sequence defined replication origins of about the same size.

symbiotic association with algae and cyanobacteria, known as lichens. While the algae offer nutrition by photosynthesis, the fungus provides support and protection to algae by protecting them from harmful radiations and dehydration. Around 42% of Ascomycota form lichens.

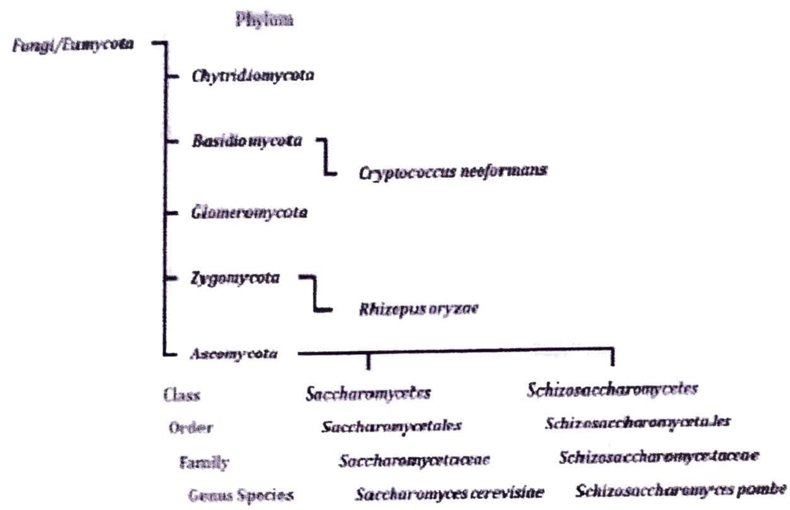


Figure I-1: Phylogenetic tree of budding and fission yeast along with well known examples from other phyla of kingdom Fungi. Digital resource at www.catalogueoflife.org/annual-checklist/2016.

Phylogenetic classification of yeasts

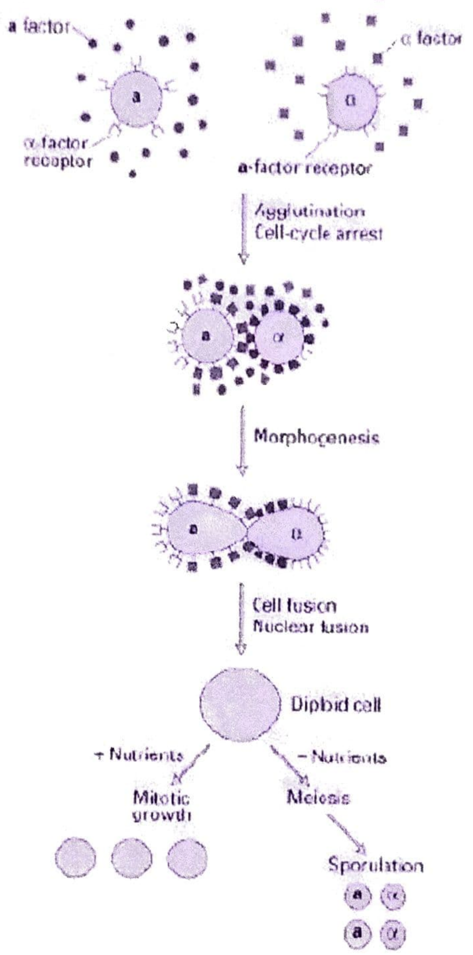
Yeasts do not form a single phylogenetic group, but are very diverse in nature. They are classified into two different phyla *Ascomycota*, *Zygomycota*, *Basidiomycota*, *Glomeromycota* and *Chytridiomycota*. The most important model yeasts *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe* belong to the phylum Ascomycota (Kurtzman 1994) (Digital resource at www.catalogueoflife.org/annual-checklist/2016) [Fig I-1]. They are the largest phylum of fungi with over 64,000 species. The members of this phylum are commonly called "sac fungi" due to characteristic sac like structures, called ascus, formed during sporulation. These asci contain non-motile spores called ascospores. This group is of particular relevance to humans since they are sources for medically important compounds, such as antibiotics and for making bread, alcoholic beverages and cheese. Many are also important as pathogens of humans and plants. For example, *Penicillium chrysogenum* produces the antibiotic penicillin, which created a revolution in the treatment of bacterial infections in the 20th century. Fungal species like *S. cerevisiae*, *S. pombe* and *Neurospora crassa* are well-known model systems. Many ascomycetes have

An Introduction to yeast

Yeasts are a group of eukaryotic, unicellular microorganisms classified under the Kingdom Eumycota. It is reported that yeasts originated hundreds of millions of years ago (Hoffman, Wood and Fantes 2015), evolving from multicellular ancestors (Yong 2012). In contrast to molds, which form hyphae, yeasts have a single celled growth habit. However, some species of yeasts show multicellular characteristics by forming strings of cells forming pseudo hyphae or false hyphae(Kim and Rose 2015). The size of yeasts varies depending on the species and environment ranging from 3-4 µm to as long as 40 µm (Walker, Skelton and Smith 2002). The usual method of reproduction is asexually by mitosis through budding or medial fission (Botstein and Fink 2011; Hoffman, Wood and Fantes 2015).

Being chemoorganotrophs, yeasts use organic compounds, majorly from hexoses such as glucose and fructose or disaccharides such as sucrose and maltose. Yeasts are either obligate aerobes or facultative anaerobes, but no known yeast species are obligate anaerobes. Growth conditions for yeast are usually in the neutral or slightly acidic pH and with temperatures ranging from -2 to 45 ^{0}C depending on the species. In laboratories, they are grown on solid growth media or in liquid broths. Most yeast species are non-pathogenic fungi, whereas other species, such as *Candida albicans* are opportunistic pathogens that can cause infections in humans.

Mating factors induce yeast mating



Lodish et al, 2000

UNIT 12 LICHENS

Structure

12.1 INTRODUCTION

In this last unit of this block you will study about lichens (pronounced as "lai-ken"), the organisms which are somewhat unusual in structure. They are composed of completely two different organisms – green algae or cyanobacteria (blue-green algae) and colourless fungal hyphae. The unique feature of fungi in lichens is the ability to form lichen thallus which they are incapable of individually. This group of organisms has a distinct morphology and a special character. They are found in all habitats including inhospitable tropical deserts, polar regions and even on the surface of granite boulders. In such regions they represent pioneer and dominant vegetation and are among the oldest living things on earth

In the following pages you will study the range of structure, anatomy and reproduction in lichens. We will also discuss the symbiotic relationship between fungal algal partners. Lichens are ecologically very useful. They are used for human consumption and for the production of chemicals. Therefore in the last section we will discuss various uses of lichens.

Objectives

After studying this unit you should be able to:

- describe the structure, distribution and anatomy of lichens,
- discuss the various types of reproduction in lichens,
- discuss the algal-fungal partnership in lichens,
- elaborate the role of lichens as pioneers of vegetation, and
- list the various uses of lichens.

12.2 RANGE OF STRUCTURE IN LICHENS

12.2.1 Lichens As Individual Organisms

Lichens represent symbiotic association of a fungal partner with an alga. Although the fungal component – **mycobiont** and the algal component – **phycobiont** can be grown separately lichen thallus develops only when they are together. As individual organisms, lichens show unique morphological and biochemical characters.

Now the term photobiont is used instead of phycobiont for the algal partner as the blue-green algae are in fact prokaryotic bacteria (cyanobacteria).

The mycobiont unlike the phycobiont is unique for each species of lichen. Nearly 98 per cent of lichen fungi are ascomycetes, the rest may have a basidiomycetes or deuteromycetes. The morphology of a lichen is believed to be determined by the fungal partner. Accordingly we have ascolichens, basidiolichens and deuterolichens.

The phycobiont is the photosynthetic partner, which is either a blue-green alga or a green alga.

There are nearly 37 algal genera found in lichens. The commonest partners are green algae *Trebouxia* (Chlorococcales) and – *Trentepohlia* (Chaetophorales) and the Cyanobacterium *Nostoc*. Sometimes more than two or even three algae may be found in the same lichen. Algae fix carbon dioxide by photosynthesis. The blue green algae in addition fix nitrogen and thus provide nutrition to the mycobiont. Laboratory studies show that the algal component can be grown in cultures without the fungus and it does not seem to depend on the fungal partner except for physical protection. The algal and fungal components of lichens can be separated and cultured in test tubes. Most attempts to recombine them were unsuccessful initially. However, it has been possible to reconstruct about 30 species of lichens successfully in the laboratory (Fig. 12.1).

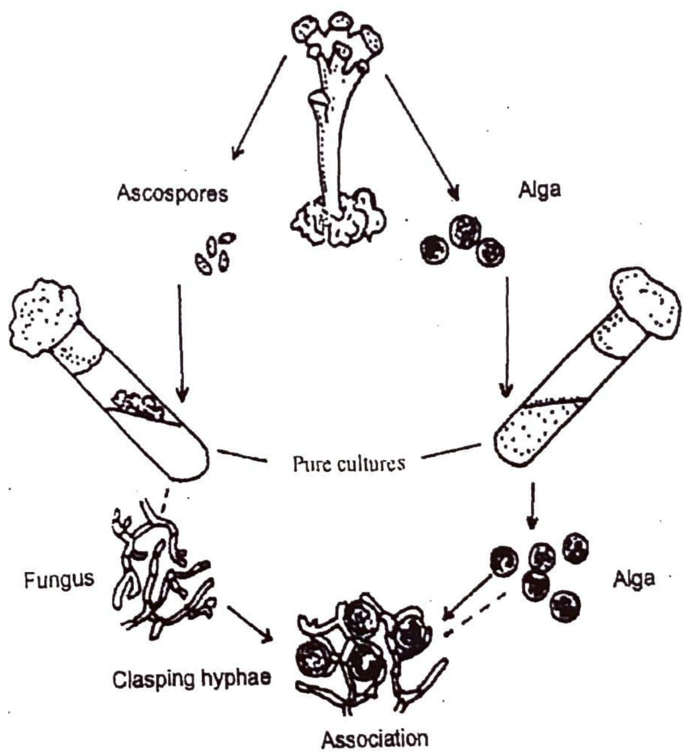


Fig. 12.1: Diagrammatic representation showing separation and culture of lichen components and the reconstruction of lichen from them.

12.2.2 Structure and Anatomy of Lichens

Structure

The plant body in lichen is a thallus that lacks differentiation into stem, roots or leaves. The thalli are generally round in outline between 1 cm to 30 cm in diameter. They may either be scattered or clustered together occupying a large area of substrate. Distinct growth forms and colours can identify the type of lichen.

There are three major morphological forms of lichens.

i) **Crustose** forms like *Graphi, Lecidea* and *Haematomma*. Thallus is a crust-like (Fig. 12.2.a) coloured patch growing on bare rocks and tree trunks.
ii) **Foliose** forms genera like *Parmelia, Peltigera, Collema, Parmotrema* and *Gyrophora*. Thallus is leaf-like, flat and dorsiventral with lobed or irregular margins (Fig. 12.2 b). It is loosely attached to the substrate. In cross section it appears differentiated into layers.
iii) **Fruticose** forms like *Usnea, Cladonia* and *Ramalina*. Thallus is branched bush-like, shrubby and (Fig. 12.2 c to i) sometimes several metres long hanging from tree branches. It is internally differentiated into layers.

The majority of lichens are of the crustose type.

Besides variable morphology lichens also show striking colours such as grey, yellow, orange, yellowish or bluish green, black or white because of the presence of pigments.

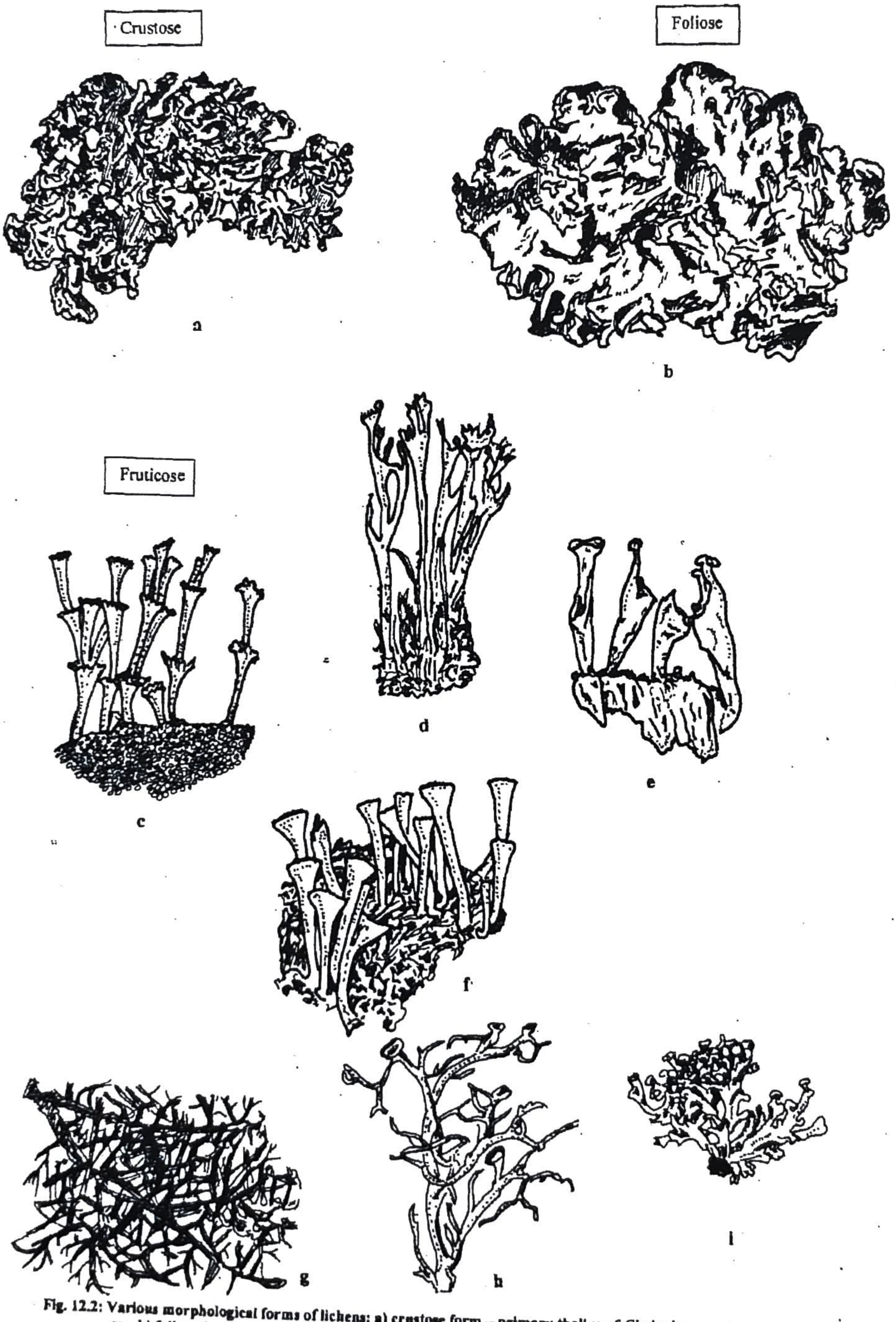


Fig. 12.2: Various morphological forms of lichens: a) crustose form – primary thallus of *Cladonia* sp., b) foliose form – *Parmotrema* sp., c to i) fruticose form – *Cladonia* sp. (i to c), *Usnea* sp. (i to e), *Usnea* sp. (g), *Ramalina* sp. (h and i).

Anatomy

The ability to form thallus is a unique feature of lichen fungi. A vertical section of a foliose lichen when examined under a microscope shows upper and lower **cortex** containing tightly packed fungal hyphae and a central medulla of loose hyphae (Fig. 12.3a). Below the upper cortex are algal cells surrounded by fungal tissue forming a distinct layer. Similar algal layer may also be found on the basal side, above the lower cortex. Rhizoids grow from the lower cortex and attach the thallus to soil, bark or rocks.

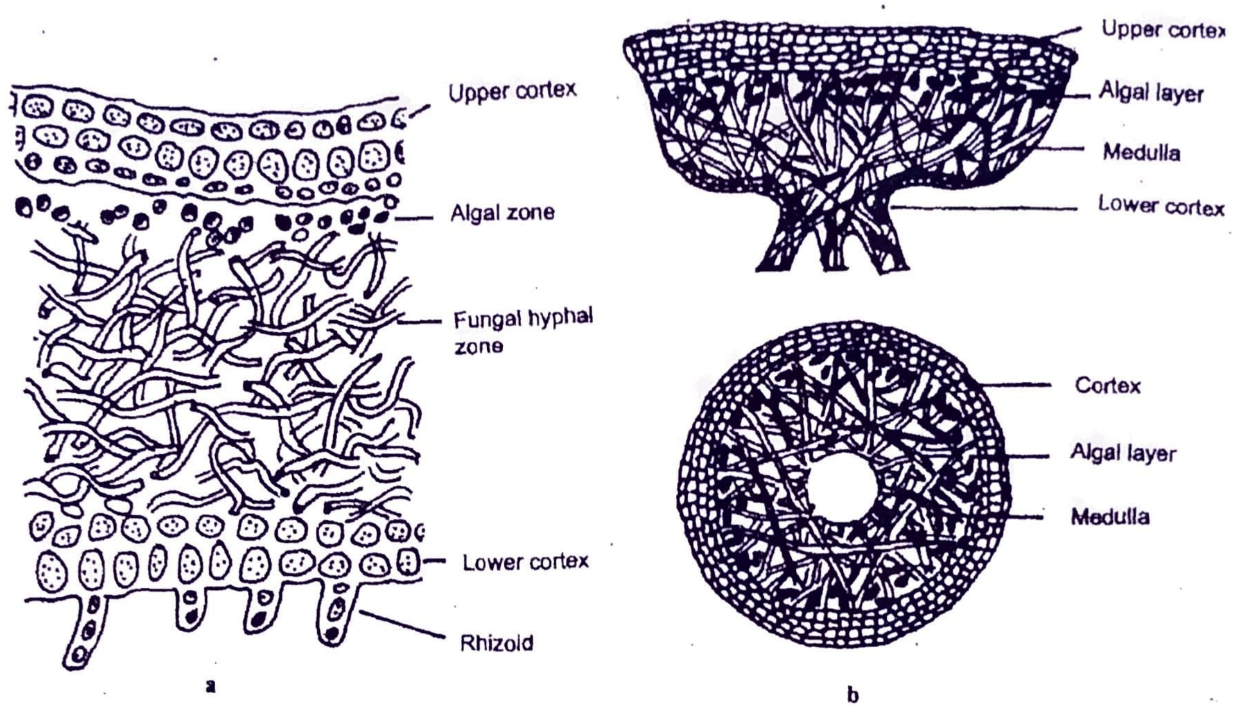


Fig. 12.3: Lichen thalli in cross section, (a) crustose (b) foliose (c) fruticose.

SAQ 12.1

a) In the following statements fill in the blank spaces with appropriate words.

i) The fungal partner in lichen is called .... and the algal ....

ii) In 98% of the lichen the fungal partners belongs to ....

iii) The algal partner of lichens could be .... or ....

iv) The upper and lower hyphae of fungal partners in lichen thallus are called .... and the central loose hyphae are called ....

v) The two most common algae in lichen symbiosis are .... and ....

vi) The cyanobacteria involved in symbiosis in lichen is ....

b) Indicate which of the following statements are true or false. Write T for true or F for false in the given boxes.

i) The fungal partner of lichen can be grown separately but not the algal partner. ☐

ii) A single lichen may have 2 or 3 algal partners. ☐

iii) Fungal and algal partners can be cultured in the laboratory separately and reconstructed into lichen again. ☐

iv) Lichens are not capable of fixing CO_2. ☐

v) When a lichen has *Nostoc* as an algal partner it can fix CO_2 as well as nitrogen. ☐

12.3 REPRODUCTION IN LICHENS

12.3.1 Vegetative Reproduction

New patches of lichens grow when small pieces of lichen are broken from the main thallus. In addition, a variety of vegetative structures **soredia**, **cephalodia** and **isidia** arise from the main thallus containing partners, the phycobiont and the mycobiont.

a) **Soredia:** Each soredium consists of algal cells surrounded by fungal hyphae. These can develop into a new thallus (Fig. 12.4 a).
b) **Cephalodia :** These are dark-coloured gall-like outgrowths of the thallus (Fig. 12.4 b).
c) **Isidia:** These are cylindrical finger-like outgrowths on the thallus (Fig. 12.4 c).

Besides the above important structures lichens produce many other specialised bodies for vegetative propagation. It is interesting to note that such structures are absent in the life cycle of the fungal or algal component when grown separately but are produced only when they grow together as lichen.

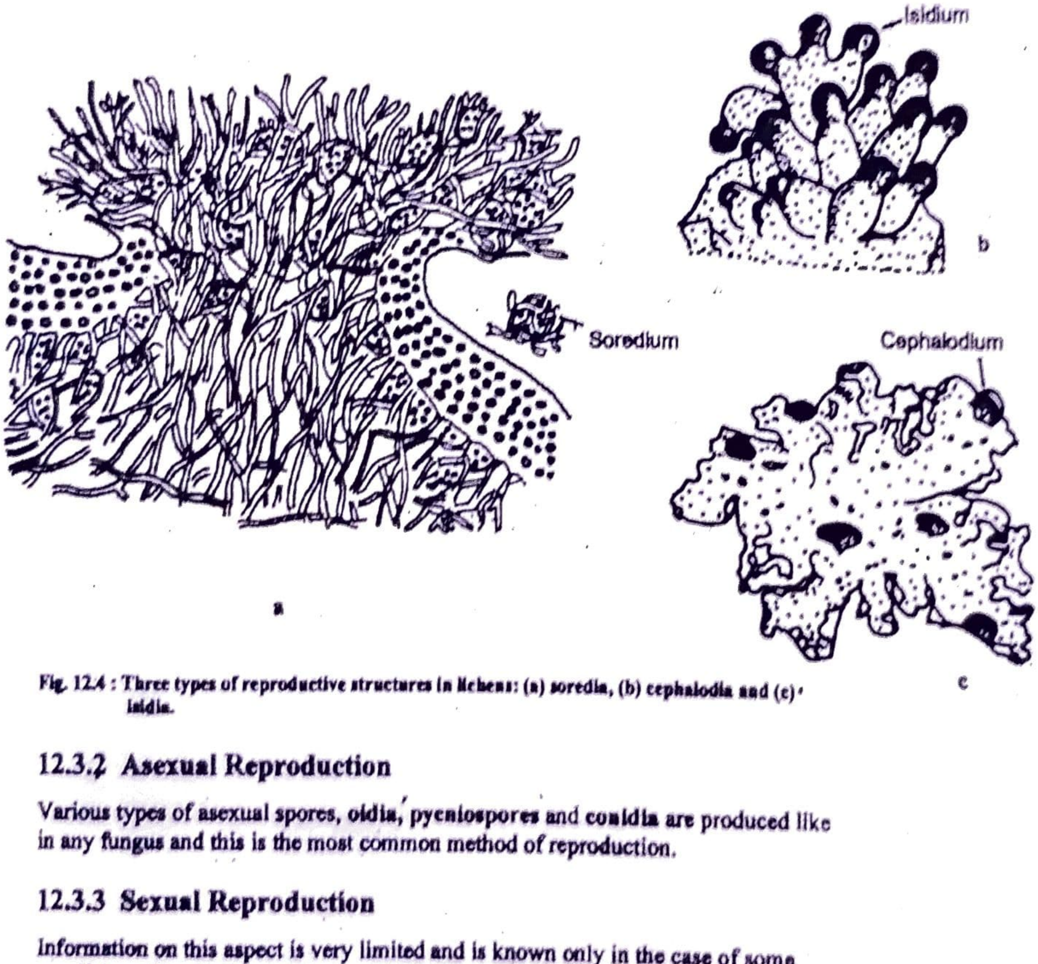


Fig. 12.4 : Three types of reproductive structures in lichens: (a) soredia, (b) cephalodia and (c) isidia.

12.3.2 Asexual Reproduction

Various types of asexual spores, oidia, pycniospores and conidia are produced like in any fungus and this is the most common method of reproduction.

12.3.3 Sexual Reproduction

Information on this aspect is very limited and is known only in the case of some ascolichens like *Collema*. It is very similar to the sexual process of an ascomycete fungus (recall sexual reproduction in *Neurospora*, ref. to unit 9, section 9.3.3 of this block).

The male sex organs are known as **spermagonia**, which produce small non-motile male cells called **spermatia**.

Reproductive structures in lichens are shown in Fig. 12.5. The female sex organs are called **ascogonia**, which develop from the medulla of the lichen thallus. The ascogonium has terminal long multicellular hair like projection called **trichogyne** and a basal portion which acts as **oogonium**. Fertilisation occurs by the transfer of spermatium to the tip of trichogyne after which it passes down to the basal portion. A number of ascogenous hyphae (Fig. 12.5 b) are produced which form the ascocarp. The ascocarp is a dish-shaped – **apothecium**. Each ascus produces eight **ascospores**. Ascospores germinate and when the hyphae come in contact with suitable algal cells they develop into new lichen thalli.

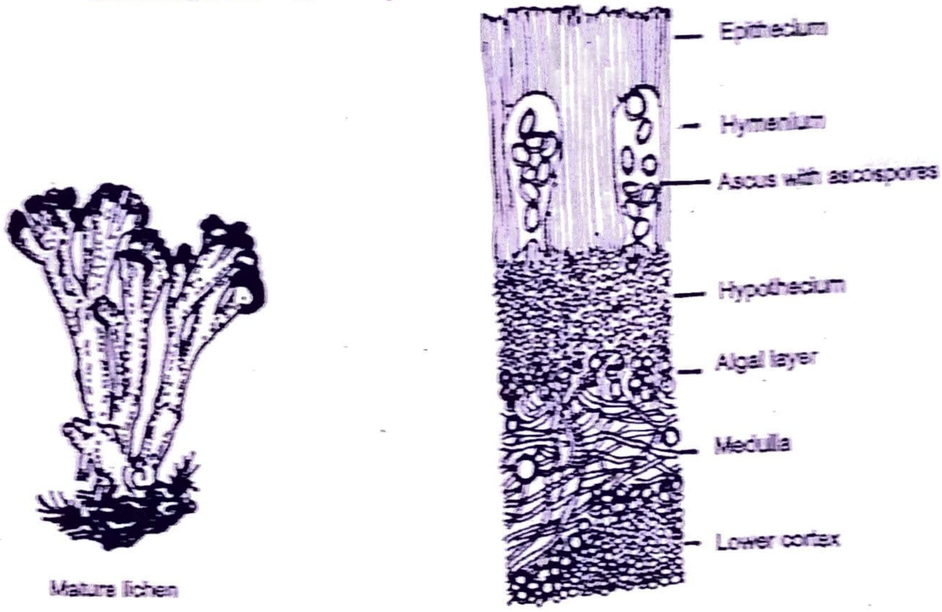


Fig. 12.5: Reproductive structures in lichens: a) apothecia, b) cross section of a typical apothecium.

SAQ 12.2

a) Fill in the blank spaces with appropriate words.
   i) The specialised structures in lichens for vegetative reproduction are ...., ... and ....
   ii) The dark-coloured gall-like outgrowths of lichen thallus that can give rise to new thalli are called ....
   iii) The cylindrical finger-like outgrowths on the lichen thallus that give rise to new thalli are called ....
   iv) The asexual spores produced in lichens may be ...., ..., or ....
   v) The sexual reproduction in ascolichens is similar to ....

12.4 LICHEN – A MODEL OF SYMBIOTIC SYSTEM

The nature of fungal algal association in a lichen is considered as symbiosis where both the partners derive equal benefit from each other, also known as mutualism. Though in some lichen it is observed that the algal cells are penetrated by haustoria (as in parasitic fungi) they are not killed or weakened. There seems to be a balance or give and take between the partners.

It has been shown by experiments that nearly 70 to 80 per cent of the total carbon compounds synthesised by the alga (ribitol, mannitol and arabitol) during photosynthesis are passed on to the fungus.

In *Peltigera* where the algal partner is a cyanobacterium (*Nostoc*) which also fixes nitrogen, in addition to carbon compounds, the nitrogen compounds like ammonia are also supplied to the mycobiont. However, it is difficult to say what the alga receives from the fungus in return. Probably the fungal hyphae provide house to the algal cells and protect them from drying, excessive light and other adverse environmental conditions. The loosely interwoven hyphae of the medulla facilitate gas exchange for photosynthesis. However, the opinion about the nature of this association is controversial. Some scientists regard algae as the victims rather than partners imprisoned by the fungal tissue. They consider this association as 'controlled parasitism'. Others believe that it is unique and the finest example of mutualism because of the healthy appearance and long life of algal cells.

12.5 IMPORTANCE OF LICHENS

12.5.1 Ecology of Lichens

Lichens are found growing in many places where other organisms might perish. They are found on bare rocks in tropical, sub-tropical, temperate and freezing polar regions. Some are found to survive on rocks where temperature may reach 50°C.

Most lichens are slow-growing, at the rate of about 1 mm per year but are long-lived. In arctic regions lichen thalli even 4500 years old are found. They have been found on the highest mountains in Himalayas.

On the newly exposed rocks and volcanic regions lichens are the pioneer vegetation as they are the first to inhabit these regions. By their activity they cause the weathering of rocks, build up organic debris, and make the surface suitable for the growth of higher plants. The cyanobacterial lichens contribute nitrogenous compounds also.

Lichens are most abundant in tropical rain forests. Lichens profusely cover tree trunks, branches, and leaves of all plants.

The association between a heterotrophic fungus and a photosynthetic alga is variously termed mutualism or symbiosis. Such an association is highly successful and productive in the ecological sense, and this is reflected in the distribution of lichens in diverse habitats all over the earth.

12.5.2 Lichens as Food

In many inhospitable areas like polar regions, rocks and deserts, the only vegetation available to animals is lichen. *Cladonia rangifera*, known as reindeer moss is widely eaten by arctic animals such as reindeer and caribou. Sheep and land snails browse much on fruticose lichens growing on the soil.

In some countries like the Libyan desert lichen *Lecanora* is collected and eaten by people. In Japan, foliose rock lichen *Umbilcaria* is eaten as salad. In Iceland and Lapland many local lichens are consumed as food.

12.5.3 Lichens as Indicators of Pollution

Lichens can absorb not only water vapour from the atmosphere but also various pollutants including fluoride, ozone, NO_2, PAN and herbicides. They are particularly sensitive to sulfur dioxide and radioactive element strontium and caesium. Nitrogen fixation is most sensitive to SO_2 followed by photosynthesis, and respiration. Consequently, the size of the thallus is reduced, fruiting is suppressed and the colour is also affected. Because of this sensitivity, detailed examination of lichens in an area can determine the degree of atmospheric pollution including radioactive fall-out during nuclear tests.

12.5.4 Other Uses of Lichens

The medicinal value of lichens was recognised in folk medicine long ago and is still being used widely. *Lobaria pulmonaria* is useful for lung diseases, also *Peltigera canina* for hydrophobia.

Many lichen contain antibiotic properties. Usnic acid from *Usnea* is effective against fungi, bacteria and other pathogens of man.

Substances obtained from lichens can also control plant diseases like tomato canker and tobacco mosaic virus.

Before the advent of synthetic dyes. lichens were the source of coloured substances used for dying textiles. *Rocella, Parmelia, Ochrolechia, Evernia* are some of the lichens used for the extraction of dyes like orchil which can be used to gives shades of red, purple and brown to wool.

Orcein, derived from lichens is used in biological laboratories for staining nucleus in plant and animal cells. Likewise litmus, the acid-base indicator is extracted from the lichen *Rocella*.

Lichens contain various types of essential oils, which are used in the manufacture of perfumes.

SAQ 12.3

a) In the following sentences fill in the blank spaces with appropriate words..
   i) Lichens can survive temperature as high as ....
   ii) Lichens are slow-growing. They may grow at the rate of about .... per year.
   iii) In arctic regions lichen thalli as old as .... years are found.
   iv) Lichens are sensitive to pollutants like .... and .... element .... and caesium.
   v) The lichen commonly known as moss reindeer eaten by reindeer, caribou and sheep is ....

b) Indicate which of the following statements are true or false with regards to lichens. Write **T** for true or **F** for false in the given boxes and also write the correct statement..
   i) In some lichens when algal cells are penetrated by fungal haustoria they get killed. ☐
   ii) In lichens the algal partner passes carbon compounds to the fungal partner. ☐
   iii) Sexual reproduction in ascolichen is similar to that of ascomycetes fungi. ☐
   iv) The fungal partner provides food and water to the algal partner. ☐
   v) In some lichens *Anabaena* is the algal partner.

12.6 SUMMARY

- In lichens, the heterotrophic non-photosynthetic fungus forms a symbiotic association with green alga or blue-green alga and constitutes a new thallus. The green-thallus thus formed has no resemblance to either fungus or an alga growing separately.
- Lichens can be identified by their striking colours and distinct growth forms. Lichen thallus consists of interwoven hyphae which shelter algal cells and derive nutrition from them. If the fungal partner is a cyanobacterium, it provides nitrogen nutrition in addition to photosynthates..
- Lichens reproduce by special vegetative reproductive structures – soredia, isidia or cephalodia. The asexual spores formed are oidia pycniospores and conidia. In ascolichens sexual reproduction also takes place and it is similar to the fungi belonging to ascomycetes.
- Lichens are ecologically important and pioneer vegetation. They can colonise harsh habitats.
- Lichens are eaten by arctic animals. In some countries they are used as food for humans. Dyes and some other chemicals were formerly extracted from lichens. Lichens are also used for medicinal purposes.
- Lichens are very sensitive to air pollutants and therefore can be used as indicators of pollution for the area where they grow.

12.7 TERMINAL QUESTIONS

1. Write the fungal partners of the following type of lichens
   a) Ascolichen -
   b) Basidiolichen -
   c) Deuterolichens -

2. Give an example of each of the following morphological types of lichen
   1. Crustose -
   2. Foliose -
   3. Fructose -

3. Write the various uses of lichen under the headings listed below.

   Food

   ....

   ....

   Medicine

   ....

   ....

   Dyes

   ....

   ....

4. Explain the role of lichens as pioneers of vegetation.

   ....

   ....

   ....

   ....

5. Name one lichen eaten by human beings.

   ....

12.8 ANSWERS

Self-assessment Questions

12.1a) i) mycobiont, phycobiont/photobiont
ii) ascomycetes
iii) green alga, cyanobacteria
iv) cortex, medulla
v) Trebouxia, Trentepohlia
vi) Nostoc

b) (i) F (ii) T (iii) T (iv) F (v) T

12.2 i) soredia, insidia, cephalodia
ii) cephalodia
iii) isidia
iv) oidia, conidia, pycniospores
v) ascomycetes

12.3a) i) 50°C
ii) 1 mm
iii) 4500
iv) SO_2, PAN, radioactive strontium
v) *Cladonia rangiferia*

GLOSSARY

Basidiospore: A haploid spore produced externally on a basidium in basidiomycete fungi, usually after karyogamy and meiosis.

Basidium: An enlarged sexual reproductive cell in basidiomycete fungi in which meiosis occurs, resulting in the formation of basidiospores.

Clamp connection: In basidiomycete fungi, a loop-like structure that connects adjacent hyphal cells and is produced during the formation of new cells by the binucleate hyphae.

Cleistothecium: A spherical ascocarp-type fruting body with no opening in which asci are produced that occurs in some ascomycete fungi.

Dikaryotic hypha: Binucleate filament of fungal cells arising through fusion of plus (+) and minus (–) hyphae without nuclear fusion.

Dikaryotic phase: Phase in the life cycle of some fungi, such as ascomycetes, in which each cell is binucleate as a consequence of the fusion of plus (+) and minus (–) hyphae.

Haustorium: A structure produced by fungal hyphae that penetrates host cells and is adapted for the absorption of water, nutrients, and metabolites from the host cell.

Karyogamy: The fusion of two sex nuclei following the fusion of their protoplasts (plasmogamy).

Karyokinesis: The process of nuclear division that occurs during mitosis.

Perithecium: A flask-shaped fruiting body in which asci are produced in ascomycete fungi.

Pycnidium: A flask-shaped structure in which asexual spores called conidia are formed in some ascomycete fungi and in imperfect fungi.

Scutellum: An appendage of the embryo of a grass, located adjacent to the endosperm in the seed.

Spermagoium: A flask-like structure that bears small, spore-like spermatia (male gametes) in some ascomycetes and rust and smut fungi.

Sterigma: A stalk on the outer surface of a basidium which bears basidiospores in basidiomycete fungi.

Uredospore: One of many binucleate spores produced in a uredosorus-type fruiting body in basidiomycetes known as rusts.

Further Reading

1) Alexopoulos, C.J. and C.W. Minis. 1979, Introductory Mycology, third edition, Wiley Eastern Limited, New Delhi.

2) Ingold, C.T. 1973, The Biology of Fungi, third edition, ELBS low-priced textbook.

3) Vashishta, B.R. 1993, Botany (For Degree Students), Part II Fungi, S. Chand and Company Ltd. New Delhi.

b) i) F
   ii) T
   iii) T
   iv) F
   v) F

Terminal Questions

1. The fungal partner would belong to the class
   a) Ascomycetes
   b) Basidiomycetes
   c) Deuteromycetes
2. See section 12.2.2
3. See section 12.5 and list the uses below.
4. When lichen grow on bare rocks and by their activity weathering of rocks takes place. Consequently they build up organic debris which is necessary for the growth of vegetation.
5. *Umbilcaria.*

Life history of Vaucheria

Systematic position

Division - Thallophyta: Algae

Class - Xanthophyceae

Order - Vaucheriales

Family - Vaucheriaceae

Genus - *Vaucheria*

Habitat - Vaucheria is predominantly freshwater, but marine (six species) and terrestrial (moist soil) forms also exist. Vaucheria is represented by 54 species. Common species are *V. sessilis*, *V. terrestris*, *V. amphibia*, *V. geminate* etc.

Plant Body - Plant body is thalloid and thallus is composed of long, cylindrical branched filaments. Filaments are aseptate, multinucleate and coenocytic in structure resulting into siphonaceous structure. Plant body remains attached to the surface of the substratum with the help of branched hold fast called haptera. In *V. mayyanadensis*, plant body is differentiated into branched rhizoidal system and an erect aerial system. Some of the *Vaucheria* sp (*V. debaryana*) shows calcium carbonate incrustations. Althogh filaments are aseptate, but septa develop during reproduction or Gongrosira formation or injury.

Cell structure – Cell or thallus is surrounded by cell wall enclosing protoplasm within its boundary. Cell wall is made up of two layers viz. outer pectic layer and inner cellulosic layer. Cell consists of a large vacuole filled with cell sap that continues from one end of filament to another end forming a tube-like structure called canal or siphon. Hence, thallus is called siphonaceous. Chloroplast without pyrenoids is present in peripheral part of the protoplasm. Pyrenoids contain chromatophores possessing chlorophyll a, chlorophyll e, carotenoids and xanthophylls. Pigmentation in Vaucheria is similar to members of Xanthophyceae as it doesn't consist of cahlorophyll b. As filament is coenocytic, it consists of many small nuclei positioned below the chloroplast. Other membrane bound organelles include mitochondria, golgi body, ribosomes, lysosomes, small vesicles, food reserves etc. Reserve food material in *Vaucheria* present in cytoplasm is oil. Growth in filament occurs by apical cell.

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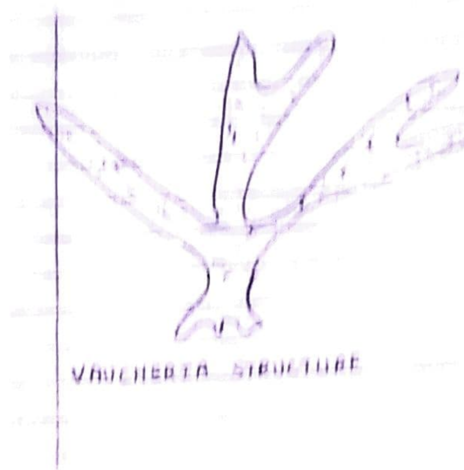


Reproduction

Vaucheria reproduces by vegetative, sexual and asexual methods.

Vegetative Reproduction

Vegetative reproduction in Vaucheria takes place by means of fragmentation. In this case, the thallus breaks into fragments due to mechanical stress or injury and each fragment develop a septum at the breakage point. Following septum formation, thick layer is formed by fragments and ultimately mature thallus of Vaucheria develops.

Asexual Reproduction

There are three means of asexual reproduction viz. zoospores, aplanospores and akinetes in *Vaucheria* sp.

i. **Asexual reproduction by zoospores** -

Asexual reproduction by the formation of zoospores is the common among aquatic plants. In terrestrial forms, zoospores are formed during flood. Zoospores are formed under favourable condition and may be induced by transferring them from light to dark or from running water to stagnant water.

Zoospores develop singly in an elongated club-shaped zoosporangium which develops with club-shaped swelling at the tip of side branch. Swelling is followed by entry of large number of nuclei and chloroplast with cytoplasm. Colourless protoplasm separated from cytoplasm is now clearly visible. Each separated protoplast secretes thin layer membrane outside it and separates itself from rest of the cell. Zoosporangium becomes dense, size of vacuole decreases and change in nuclei position from inner to chloroplast (peripheral) to periphery (nuclei) occurs. Now, contraction of zoospore protoplasm occurs resulting into development of oval zoospore. Now, two flagella corresponding to each nucleus result into development of multi-flagellate zoospore. A terminal aperture is produced due to gelatinization that supports in liberation of zoospores in the morning.

Each zoospore is large, oval and yellow green with a central vacuole with cell sap. Protoplasm outer to vacuole has many nuclei towards the walls and chromatophore towards the vacuoles. Pair of flagella attached to the tip of the nuclei of zoospore is heterokontic and whiplash type. Zoospore consists of vacuole, mitochondria, chlorophyll etc in their cytoplasm.

After liberation from zoosporangium, zoospores swim for few minutes (5-15 minutes) attaches itself to substratum, withdraws flagella and secrete thin layer wall around it and proceeds for germination without going resting period.

Now, two tube like outward projection develop of which one develops into colourless lobed holdfast and another develop into yellow-green coenocytic filament.

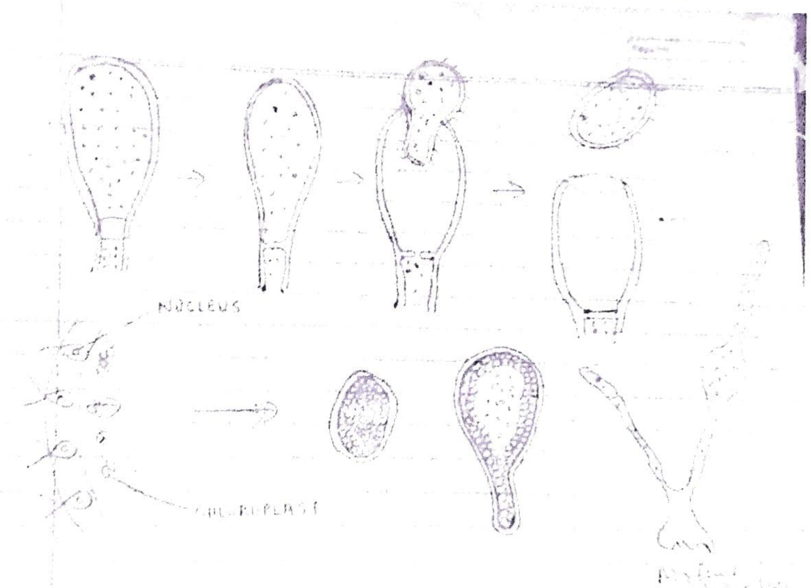


Fig Asexual Reproduction (Zoospore)

ii. **Asexual reproduction by aplanospores**

Asexual reproduction by aplanospores generally occurs in terrestrial species of *Vaucheria* such as *V. geminata, V. uncinata* etc., marine species like *V. pitoboloides* and in aquatic forms under unfavourable condition. Aplanospores are non-motile asexual spores that develop into aplanosporangia. Aplanosporangia develop singly at the apical end of terminal or short lateral branch. Protoplasm of aplanosporangium is transformed into single spherical aplanospores and is liberated outside with rupturing of sporangial wall. Developmental process of aplanospore formation is similar to zoospore except flagella. Aplanospore germinate and develop into new thalli.

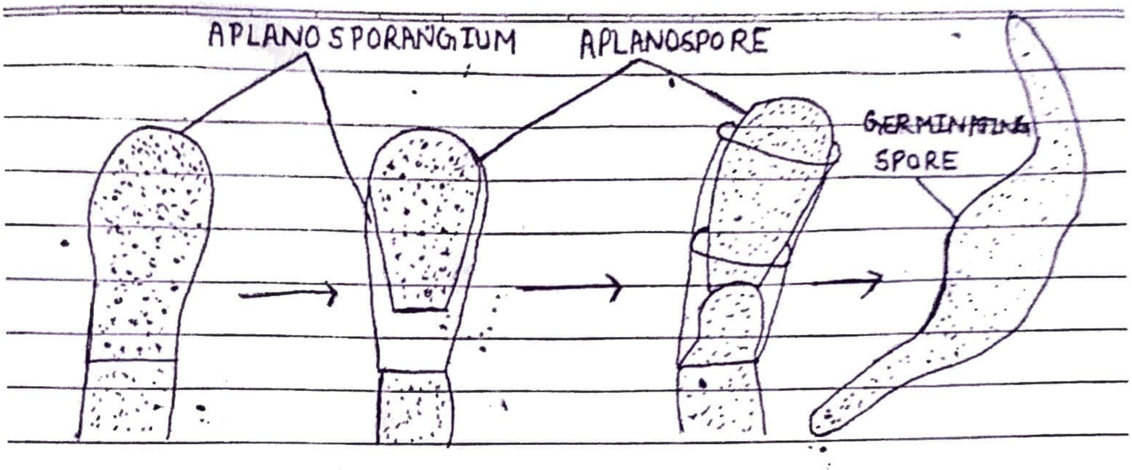


Fig - VAUCHERIA : APLANOSPORE FORMATION, LIBERATION AND GERMINATION

iii. Asexual reproduction by Akinetes

Akintes are thick-walled structures formed on the apical part of the lateral branches during unfavourable condition. In this case, protoplasm moves to the tips of the branches, forms cross wall to separate itself and develops thick walls around it.Such multinucleate thick walled cells are called akinetes or hypnospores. Akinetes divides and forms many thin walled cysts. When many akinetes remains attached to plant body, it appears like algae Gongrosira. On onset of faviurable condition, akinetes or cysts give rise to mature thallus.

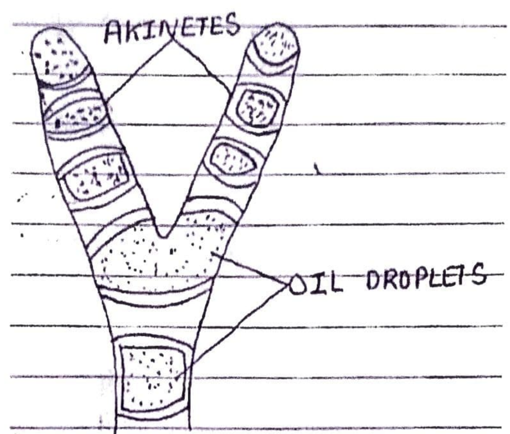


Fig - VAUCHERIA : AKINETES

Sexual reproduction in Vaucheria

Sexual reproduction in Vaucheria is advanced oogamous type and takes place by means of antheridia (male sex organ) and oogonia (female sex organ). Most of the freshwater species are monoecious or homothallic whereas certain species are dioecious or heterothallic.

Antheridia and oogonia develop on special lateral adjacent branches close to each other with terminal antheridium and lateral oogonium.

Structure and development of Antheridia

Young antheridium is usually green whereas mature one is curved, tubular, straight or cylindrical and yellow in colour. Antheridium arises as a lateral outgrowth either simultaneously with oogonium or before development of oogonium. Many nuclei along with cytoplasm move into outgrowth and forms a septum to separate it from rest of the filament. Now, it grows and become curved forming a upper main antheridium and lower stalk. Nuclei of the antheridium get surrounded by cytoplasm and forms biflagellate and yellow colour spindle-shaped antherozoids. These antherozoids are liberated outside through apical pore.

Structure and development of Oogonia

Development of oogonia starts with movement of colourless multinucleate cytoplasm near the antheridial branch. Such accumulated mass is termed as 'wanderplasm' and ouygrowth with accumulated mass is called oogonial initial. Large amount of cytoplasm and nuclei move intolarge globule structure called oogonium. On maturity, oogonium gets separated from main filament by developing septum at the base. Mature oogonium consists of single nucleus which develops into a single egg. Some of the phycologist proposed that all other nuclei (except egg nuclei) migrate back to filament whereas some other suggest that all other nuclei except egg nuclei degenerate or fuse to form large single nuclei. Mature oogonium is either globose, obvoid, pyriform or hemispherical in structure with or without stalk. Protoplasm with single nucleus is called oosphere or ovum. Mature oogonium consists of receptive spot opposite to vertical/oblique beak developed in the apical part. Pore is formed opposite to receptive spot.

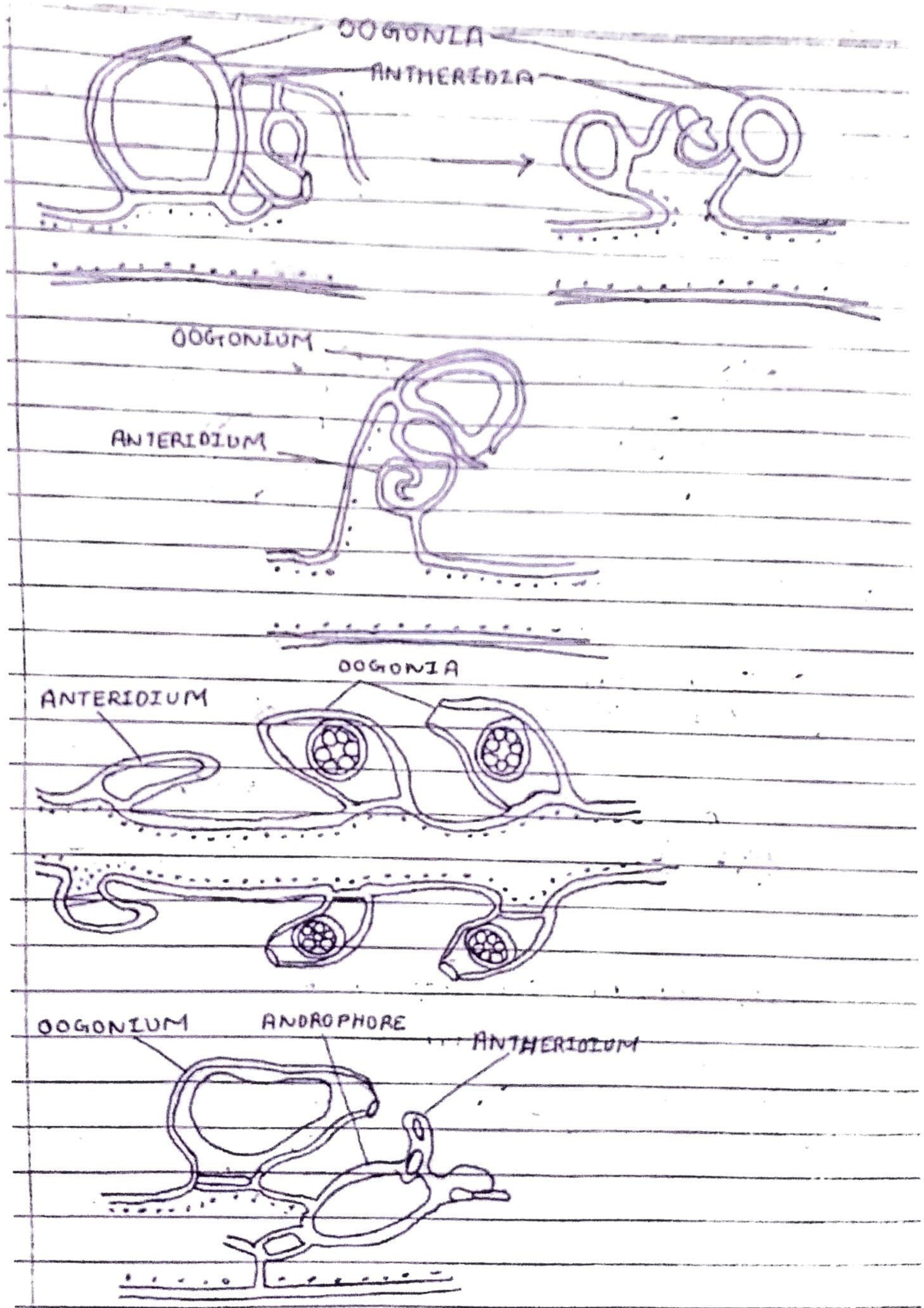


Fig : VAUCHERIA : ARRANGEMENT OF ANTHERIDIA AND OOGONIA

Fertilization

Antherozoids stick to the oogonium with gelatinous substances secreted by oogonium at the beak. Many antherozoids try to enter into the oogonium but only one succeeds. Male nucleus fuses with egg nucleus and forms zygote (2n). Zygote secretes 3-7 thick layer membrane and forms a oospore.

Germination of oospore

Oospore enters into dormant stage and on reaching favourable condition, oospore is liberated, goes through meiotic division and germinates into new filaments.

In this way, *Vaucheria* completes its life cycle.

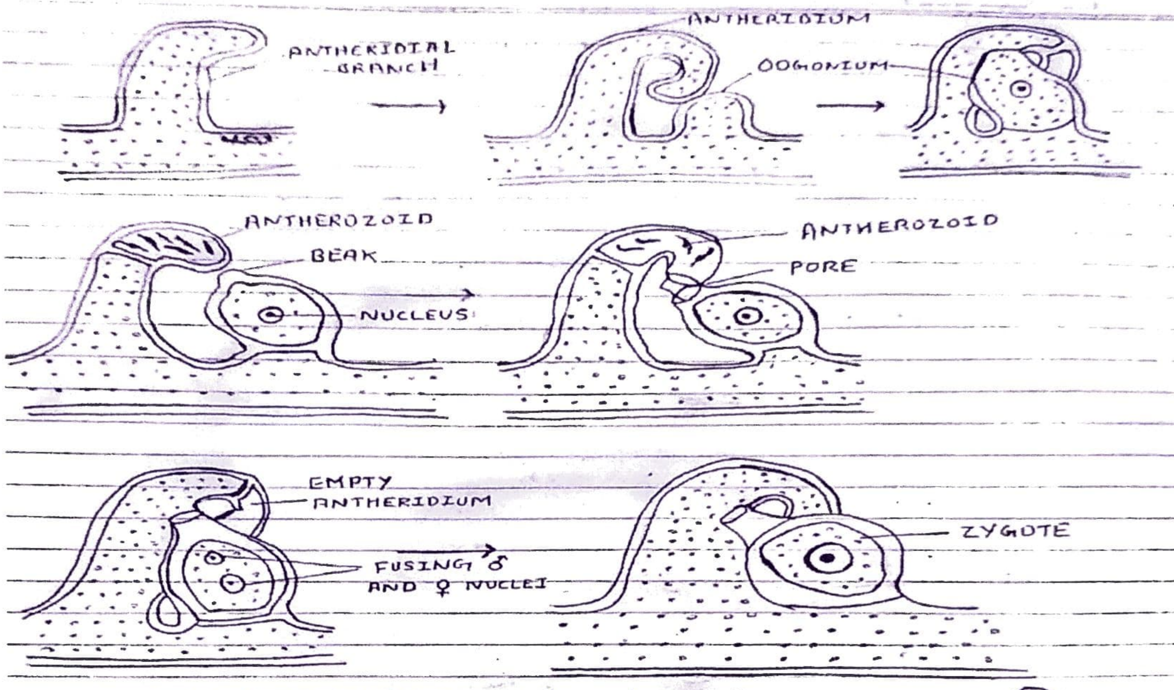


Fig : VAUCHERIA : Sexual Reproduction

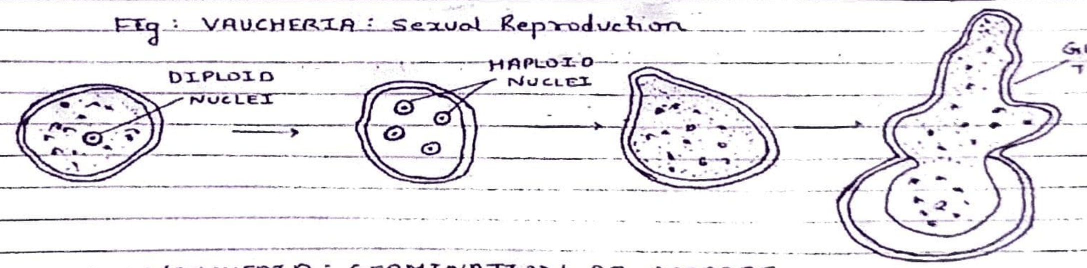
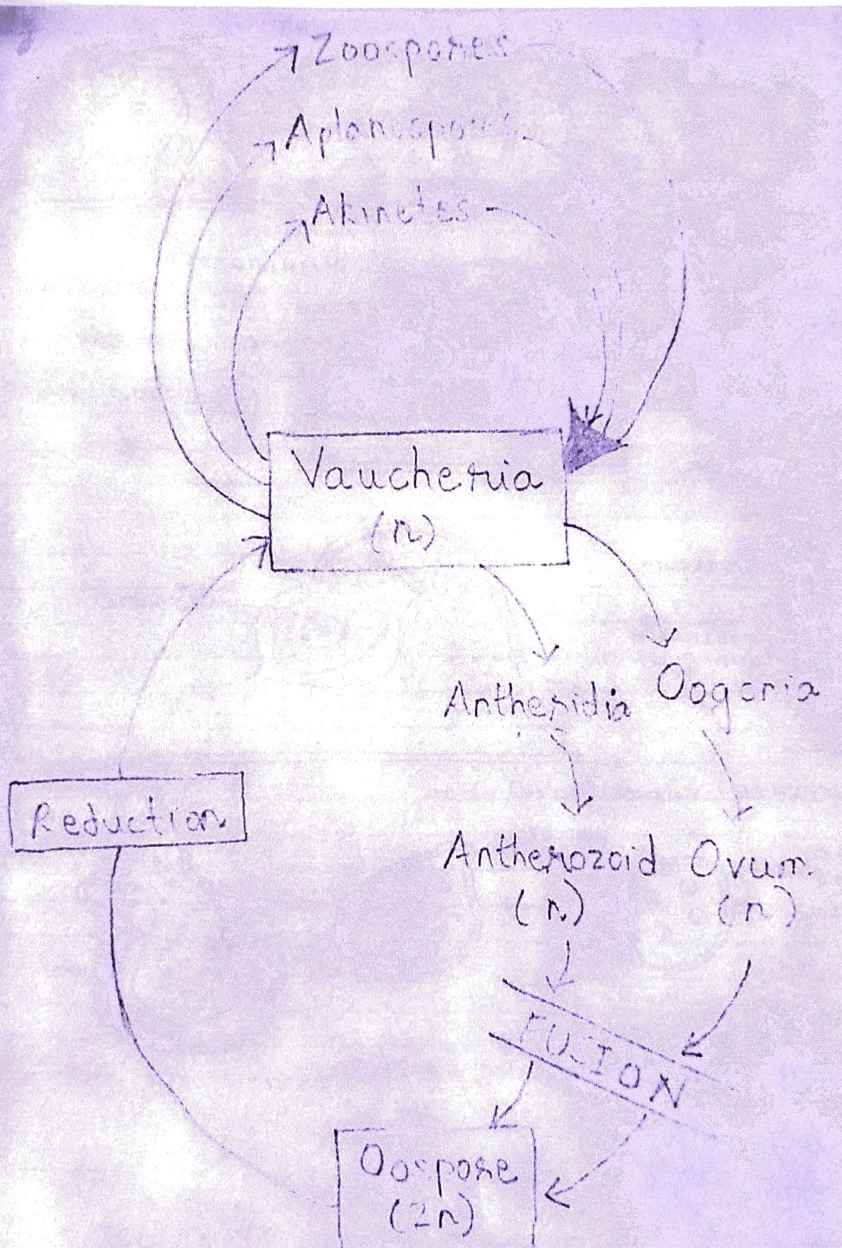


Fig : VAUCHERIA : GERMINATION OF OOSPORE



Life Cycle of Vaucheria