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ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY

B.Sc (Ag)

COURSE NO. PATH 171
Credit hours 3 (2+1)

DETAILED
THEORY STUDY MATERIAL

INTRODUCTION TO PLANT PATHOGENS

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DEPARTMENT OF PLANT PATHOLOGY

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FOREWORD

Plant Pathology is being taught as a compulsory subject in Under Graduate Programme and as a specialized subject at the Post G raduate level in the Agricultural Universities.The importance of Plant pathogens in different crops is well recognized.The detailed study material for the course PATH 171 is prepared in accordance with the revised course curriculam as suggested by the IV D eans committee which helps in easy understanding about the Plant Pathogens, fungi,bacteria,viruses etc.

The attempt has been made by the authors in the study material to emphasize the important char acteristics of Plant Pathogens viz; fungi, bacteria, fastidious vascular bacteria, viruses, viroids,phytoplasmas and spiroplasmas as per the revised syllabus.

The detailed study material in course No.PATH 171 entitled 'Introduction to Plant Pathogens'has been prepared to im part basic knowledge on Plant Pathogens to Under Graduate students of Agriculture.The information contained in the study material is appropriate and reliable.The study material consists of 32 lecture notes and each lecture explains the characteristics of Plant Pathogens.

I congratulate the efforts of Dr.V.Krishna Rao, Dr.R.Sarada Jayalakshmi, Dr.P.Kishore Varma and Dr.V.Damodara Naidu in compiling the valuable information in the study material according to the syllabus framed by the Acharya N.G.Ranga Agricultural University.I feel that this detailed study material provides basic knowledge and training in identifying and understanding of Plant Pathogens.

(T.YELLAMANDA REDDY)

DEPARTMENT OF PLANT PATHOLOGY

1. Course No. : PATH 171
2. Course Title : **Introduction to Plant Pathogens**
3. Credit Hours : 3(2+1)
4. General Objective : To impart knowledge to the students on pathogens that cause diseases in plants
5. Specific Objectives:

a) Theory :

By the end of the course the students will be able to

i. study different pathogens causing plant diseases
ii. understand the morphological characters and taxonomic keys associated with the identification of pathogens

b)Practical:

By the end of the practical exercises, the students will be able to

i. identify the plant pathogens
ii. know the modes of transmission of viruses

A) Theory Lecture Outlines :

1.Introduction- importance of plant pathogens - important phytopathogenic organisms, *viz.,* fungi, bacteria, fastidious vascular bacteria (RLO's), phytoplasmas (MLO's), spiroplasmas, viruses, viroids, algae and protozoa. History - contributions of scientists - Micheli, Tillet, Prevost, Persoon, Fries, Smith, Burril, Bejierinck, Stanley, Bawden , Pirie , Doi ,Diener,Ricketts and Bove.

2. General characteristics of fungi - fungus - definition - somatic structures -types of fungal thalli - plasmodium, unicellular and filamentous, eucarpic, holocarpic mycelium - ectophytic, endophytic, intercellular, intracellular and vascular - septation in fungi - fungal tissues - plectenchyma (prosenchyma, pseudoparenchyma)

3. Modifications of mycelium (rhizomorphs, rhiz oids, sclerotium, stroma, haustoria and appressorium) – Fungal cell, nutrition,groups of fungi based on nutrition-Reproduction - asexual reproduction - fragmentation,fission, budding and sporulation

4 Sexual reproduction – planogametic copulation, gametangial contact, gametangial copulation, spermatization, somatogamy, parasexual cycle -various life cycle patterns displayed by fungi - haplobiontic and diplobiontic with examples

*5.*Taxonomy and nomenclature of fungi - Classification of fungi - important characteristics of divisions -Myxomycota and Eumycota and Sub-divisions - Mastigomycotina, Zygomycotina, Ascomycotina,Basidiomycotina and Deuteromycotina

6. Division - Myxomycota - important characteristics of Class Plasmodiophoromycetes, Order Plasmodiophorales and Family Plasmodiophoraceae - differences in the characteristics of *Plasmodiophora* and *Spongospora* and diseases caused by them

7. Division Eumycota - Sub-division Mastigomycotina - important characteristics of Class Chytridiomycetes, Order Chytridiales and Family Synchytriaceae - diseases caused and transmitted by *Synchytrium*

8 Important characteristics of Class Oomycetes, Order Peronosporales and Family Pythiaceae - *Pythium* and *Phytophthora*

9. Family Albuginaceae - disease caused by *Albugo Candida* - Family Peronosporaceae - *Sclerospora, Peronospora, Peronosclerospora, Plasmopara, Pseudoperonospora* and *Bremia* (sporangiophore branching and sporangia and example of a disease caused by each genus)

10. Sub-division Zygomycotina - important characteristics of Class Zygomycetes, Order Mucorales - diseases caused by *Rhizopus*

11. Sub-division Ascomycotina - typical life cycle - *Pyronema omphalodes*

12 Important characteristics of Class Hemiascomycetes, Order Taphrinales, Family Taphrinaceae - diseases caused by *Taphrina deformans* and *T. maculans*

13. Important characteristics of Class Plectomycetes, Order Erysiphales, Family Erysiphaceae - *Erysiphe, Leveitlula, Phyllactinia, Uncinula, Sphaerotheca, Podosphaera* and *Microsphaera* (characteristics of ascocarps and their conidial stages)

14. Important characteristics of Class Pyrenomycetes, Order Hypocreales, Family Clavicipitaceae - diseases caused by *Claviceps purpurea*

15 Important characteristics of Class Loculoascomycetes, Order pleosporales, Family Venturiaceae - disease caused by *Venturia -inaequalis* - Family Pleosporaceae - diseases caused by *Cochliobolus miyabeanus.*

16 Important characteristics of Order Myriangiales, Family Myriangiaceae - diseases caused by *Elsinoe awcetti* - Important characteristics of Order Dothideales, Family Dothideaceae - diseases caused by *Mycosphaerella arachidicola, M.berkeleyi* and *M. musicola* - imperfect stages for the genera of Loculoascomycetes

17 Sub-division - Basidiomycotina - important characteristics of Class Teliomycetes, Order Uredinales, Family Pucciniaceae – distinguishing characteristics of Genera - *Puccinia, Uromyces* and *Hemileia* – disease caused by *Puccinia graminis tritici, Uromyces appendiculatus* and *Hemileia vastatrix.*

18. Life cycle of *Puccinia graminis tritici* - important characteristics of Family Melampsoraceae Genus *Melampsora* - disease caused by *Melampsora ricini.*

19 Important characteristics of Order - Ustilaginales, Family Ustilagenaceae – distinguishing characteristics of *Ustilago, Sphacelotheca* and *Tolyposporium* - diseases caused by *Ustilago tritici, Sphacelotheca sorghi* and *Tolyposporium ehrenbergii*

20. Important characteristics of Family Tilletiaceae - distinguishing characteristics of *Tilletia, Neovossia* and *Urocystis* - diseases caused by *Tilletia caries, Neovossia indica* and *Urocystis cepulae*

21 Important characteristics of Class Hymenomycetes,Order Aphyllophorales, Family Ganodermataceae - diseases caused by *Ganoderma lucidum*

22.Sub-division Deuteromycotina - Saccardoan spore group system -important characteristics of Class Coelomycetes, Order Sphaeropsida|es, Family Sphaeropsidaceae - distinguishing characteristics of *Phomopsis, Macrophomina, Phyllosticta, Septoria, Diplodia* and *Botryodiplodia*

23.Important characteristics of Family Excipulaceae and Family Nectrioidaceae important characteristics of Order Melanconiales, Family Melanconiaceae - distinguishing characteristics of *Colletotrichum, Gloeosporium,Pestalotiopsis and pestalotia.*

24.Important characteristics of Class Hyphomycetes, Order Moniliales, Family Moniliaceae - distinguishing characteristics of *Aspergillus, Penicillium, Pyricularia, Botrytis* and *Verticillium*

25. Important characteristics ot Family Dematiaceae - distinguishing characteristics of *Alternaria, Helminthosporium, Bipolaris* , *Cercospora and Phaeoisariopsis.*

26.Important characteristics of Order Tubercullariales, Family Tuberculariaceae - distinguishing characteristics of *Fusarium* - important characteristics of Order Stilbellales, Family Stilbellaceae - distinguishing characteristics of *Graphium* - important characteristics of Order Agonomycetales, Family Agonomycetaceae - distinguishing characteristics of *Sclerotium* and *Rhizoctonia*

27 . Prokaryotes - Classification (Bergey's Manual of Systematic Bacteriology, 1984) into divisions - Gracilicutes, Firmicutes, Tenericutes and Mendosicutes with examples

28. Bacteria - important characterstics of phytopathogenic bacteria with key for identification of important Genera - *Streptomyces* (common scab), *Pseudomonas* (wild fire of tobacco) and *Ralstonia* (wilt of solanaceous crops)

29. Bacteria - important characterstics of phytopathogenic bacteria with key for identification of important Genera - *Xanthomonas* (citrus canker), *Agrobacterium* (crown gall), *Erwinia (* fire blight of apple) and *Clavibacter* (tundu disease of wheat)

30. Fastidious vascular bacteria (RLOs) - important characteristics of *Leifsonia xyli* (sugarcane ratoon stunt), *Candidatus liberobacter asiatieus* (citrus greening) and *Xylella fastidiosa* (Pierce's disease of grapes) –vectors

31. Phytoplasmas and Spiroplasmas - important characteristics of Phytoplasmas and Spiroplasmas - little leaf of brinjal, sesamum phyllody, corn stunt and citrus stubborn – vectors

32 Viruses and viroids - important characteristics of plant viruses and viroids - classification of viruses - single stranded (ss) RNA, double stranded (ds) RNA, ss DNA and ds DNA - methods of transmission - examples of important plant viral diseases - Tobacco Mosaic Virus (TMV) and Rice Tungro Virus (RTV); Examples of important viroid diseases - potato spindle tuber viroid and coconut cadang cadang

B) Practical Class Outlines:

1. Study of vegetative structures of fungi and their modifications

2. Study of reproductive (sexual and asexual) structures of fungi

3. Study of *Pythium* and *Phytophthora*

4. Study of *Albugo*

5. Study of downy mildew fungi - *Sclerospora, Peronosclerospora*

6. Study of downy mildew fungi - *Pseudoperonospora, Peronospora, Plasmopara* and *Bremia* and Zygomycetes fungi - *Rhizopus*

7. Study of powdery mildew fungi - *Oidium, Oidiopsis, Ovulariopsis*

8. Study of ascocarps of *Erysiphe, Phyllactinia, Uncinula, Podosphaera* and *Microsphaera*

9. Study of rust fungi - *Puccinia* (different stages), *Uromyces* and *Hemileia*

10. Study of smut fungi - *Sphacelotheca, Ustilago, Tolyposporium* ;
    - Study of *Ganoderma*

11. Study of imperfect fungi - *Septoria, Colletotrichum* and *Pestalotiopsis*

12. Study of imperfect fungi - *Aspergillus, Penicillium* and *Pyricularia*

13. Study of imperfect fungi - *Drechslera, Helminthosporium, Alternaria, Cercospora* and *Phaeoisariopsis*

14. Study of imperfect fungi - *Fusarium, Rhizoctonia* and *Sclerotium*

15. Isolation of phytopathogenic bacteria (locally available diseased plant material) and study of colony characteristics and Gram's staining

16. Demonstration of mechanical transmission of plant viruses

References:

Alexopoulos, C.J., Mims C.W. and Blackwell M. 1996. *Introductory Mycology.* Wiley Eastern Ltd, New York.

Mandahar, C.L. 1987. *Introduction to Plant Viruses.* Chand and Co Pvt Ltd, New Delhi.

Mehrotra, R.S. and Aneja, K.R. 1990. *An Introduction to Mycology.* New Age International (P) Ltd, New Delhi.

Singh, R.S. 1982. *Plant Pathogens - The Fungi. Oxford* & IBM Publishing Co. Pvt. Ltd., New Delhi.

Singh, R.S. 1989. *Plant Pathogens - The Prokaryotes.* Oxford & IBM Publishing Co. Pvt. Ltd., New Delhi.

1. INTRODUCTION

Plant Pathology/Phytopathology(Phyton= plant,Pathos=suffering,ailment, Logos=study / discourse/knowledge) ie., the study of nature, development and management of plant diseases.

Definition: A branch of Agricultural science which deals with cause,etiology,resulting losses
and management of plant diseases.

Pathogen is an entity usually a micro organism that can incite disease in susceptible plants. It is also referred to as incitant, causal agent or causal organism.

Plant Disease: (dis-ease ie.,not at ease): It is the malfunctioning of host cells and tissue that results from continuous irritation by a pathogenic agent and leads to development of symptoms.

Symptoms: External or internal reactions or alterations of a plant as a result of disease.

Importance of plant pathogens :

1.Plant diseases caused by micro organisms are of paramount importance to humans because they damage plants and plant products on which human depend for food, clothing, furniture and housing.

2. Millions of people all over the world still depend on their own plant produce for their survival.

3. Plant diseases reduce the quality and quantity of plant produce. Eg.Wheat bunt caused by *Tilletia* sp.

4. Results in increased prices of products to consumer.

5. Results in severe pathological effects on humans and animals that eat plant products.

6. Destroy beauty of environment by damaging plants around home, park, streets and forests.

7. The pesticides used to control disease, pollute the water and environment.

8. Reduce crop yields.

9. Cause financial loss ie.,the money spent for plant protection chemicals.

10.Changes agricultural pattern.

11.Influences the industries ie.,lack of raw material .

12.Some plant diseases even change food habits of human population.

Examples of serious diseases that lead to famines:
Irish famine (1845) - lateblight of potato by *Phytophthora infestans* destroyed million hectares of potato fields thus people switched over to other food crops.

Bengal famine - *Bipolaris oryzae* (1942), West Bengal, India

Coffee rust - *Hemileia vastatrix* (1868), Srilanka

Wheat rust - *Puccinia graminis f.sp.tritici* (1940) U.S.A

Southern corn leaf blight - *Helminthosporium maydis*, U.S.A

Important Phytopathogenic organisms :

1.Fungi 2.Bacteria 3.Fastidious vascular bacteria (RLO's) 4.Mollicutes (phytoplasma and spiroplasma) 5.viruses 6.viroids 7.Algae 8.Flagellated protozoans.

1.Fungi: Fungi are eukaryotic, spore bearing, achlorophyllous organisms that generally reproduce sexually and asexually and whose filamentous, branched somatic structures are typically surrounded by cell walls consisting chitin or cellulose or both with many organic molecules.

2.Bacteria: Bacteria are extremely minute, rigid, essentially unicellular organisms free of true chlorophyll and generally devoid of any photosynthetic pigment, most commonly multiplying asexually by simple transverse fission, the resulting cell, being of equal or nearly equal in size.

3.Fastidious vascular bacteria (RLO's). Fastidious vascular bacteria are similar to bacteria in most respects but are obligate parasites or can not be grown on routene bacteriological media.

4.Mollicutes (phytoplasma and spiroplasma) :

Phytoplasma: Phytoplasmas are pleomorphic, wall less prokaryotic micro organisms, that can infect plants and can not yet to be grown in culture.

Spiroplasma: Spiroplasmas are helical, wall less prokaryotic micro organisms that are present in phloem of diseased plants, often helical in culture and are thought to be a kind of mycoplasma and can be cultured on artificial medium.

5.Virus: A sub-microscopic, obligate parasite consisting of nucleic acid and protein that multiplies only intracellularly and is potentially pathogenic.

6. Viroids*:* Small, low molecular weight ribonucleic acids(RNA) that can infect plant cells, replicate themselves and cause disease in plants.

7.Algae: Algae are eukaryotic,photosynthetic, uni or multicellular organisms, containing chlorophyll and a few algae mainly green algae cause plant diseases.

8.Flagellated protozoans : Protozoa are microscopic,non-photosynthetic,eukaryotic,flagellate motile,single celled animals.

HISTORY:

Mycology (Mycetology- Greek grammer): It is the Science which deals with study of fungi.

Term Mycology derived from 2 Greek words. Mykes= mushroom / fungus, logos= discourse or study.

Term Fungus is derived from a Latin word fungor = to flourish.

Study of fungi started with study of mushrooms because of their macroscopic size and brilliant color.

Mushrooms attracted the attention of ancient people,and they started studying them out of curiosity.

Old Romans had interest in mushrooms and named one of their city name as ' Mycenean'.

CONTRIBUTIONS OF SCIENTISTS:

1.PIER ANTONIO MICHELI ;

Italy botanist , recognised as '**Founder and father of mycology'**.

He published a book in 1729 ' Nova Plantarum Genera' in latin- a classic in mycology in which he gave 1900 descriptions in latin. Out of which 900 were of fungi, which include *Mucor, Aspergillus niger, Botrytis, Tuber*, *Polyporus* etc.

He also proved that,if spores are placed on a freshly cut piece of a fruit,they grow in to new thallus of a fungus.

He was the first scientist who in 1729 studied the fungi and observed fungal spores for the first time and conducted spore germination tests.

First scientist who described asci and ascospores and observed basidiospores and cystidia on the lamellar edge or hymenial layer of *Agaricales.*

2.MATHIEU TILLET ;

French botanist, In 1755 published a paper on bunt or stinking smut of wheat.Established role of fungi in plant disease.

He proved that wheat seeds that contained black powder on their surface produced more diseased plants than clean seeds.

He emphasized contagious nature of wheat bunt disease .He believed that the disease was caused by some toxin produced by the black powder.

He reported that the chemical treatment of seeds with common salt and lime inhibited the contagious activity.

3.BENEDICT PREVOST :

French scientist,first proved that diseases are caused by micro-organisms.

Proved *Tilletia caries* as causal organism of wheat bunt, observed germination of bunt spores & discovered life cycle of bunt fungus.

Studied and confirmed Tillet's findings .Suggested control of bunt disease by seed treatment with Cu so_4 solution.

Published classic paper 'memoir on the immediate cause of bunt or smut of wheat and of several other diseases of plants and on preventives of bunt' in 1807.

Studied fungicidal and fungistatic properties of chemicals .

4.CHRISTIAN HENDRIK PERSOON :

South African .First published observations Mycologicae.

In 1801 published 'Synopsis Methodica Fungorum' for nomenclature of uredinales,ustilaginales and Gasteromycetes.

In 1822 published 'Mycologia Europica'.

He gave the name '*Puccinia graminis*' to wheat rust fungus in 1794. .

5.ELIAS MAGNUS FRIES ;

He published three volumes of 'Systema Mycologicum' for the nomenclature of Hymenomycetes and Ustilaginales.

Persoon and Fries first time introduced binomial system of nomenclature to classify the fungal organisms.

6.PIER ANDREA SACCARDO :

Professor at Padua university in Italy.

Developed spore group system for Ascomycotina and Deuteromycotina fungi in 1899.Wrote a book in 1882 Sylloge Fungorum Omnium Hucusque Cognitorum in 25 volumes.

Systematically compiled and grouped all fungi and wrote description in latin.

This book brought uniformity in naming fungi, thus initiated systematic grouping of fungi.

7.E.F.SMITH (U.S.A):

He gave the final proof of the fact that bacteria could be causal organisms of plant diseases.In 1920 wrote a book 'Bacterial diseases of plants.'

He also worked on the bacterial wilt of cucurbits and crown gall disease.

He is also called as "**Father of Phytobacteriology".**

In 1981, he demonstrated for the first time that budding or grafting could be another method of transmission of plant viruses.He showed the contagious nature of peach yellows.

8.T.J.BURRILL (U.S.A): First scientist to relate bacterium as cause of plant disease. He proved for the first time that fire blight of apple and pear was caused by a bacterium, *Erwinia amylovora*.

9.M.K PATEL:

started plant bacterial research at pune. – 1948.
Reported about 40 bacterial plant diseases.
Introduced post of " plant bacteriologist " at IARI, in 1955

10.M.W.BEIJERINCK (Dutch):Father of virology. More extensively studied Tobacco Mosaic disease.

He proved that the virus causing Tobacco mosaic is not a living microorganism. He named the infectious agent as '*contagium vivum fluidum'* (infectious living fluid).Subsequently called the agent as 'virus.'

11.W.M.STANLEY (U.S.A): Initiated 'Biochemical nature of virus'.

In 1935,he proved that viruses can be crystallized .**He was awarded Nobel prize**.He treated the sap from diseased leaves of tobacco with ammonium sulphate and obtained a crystalline protein which ,when placed on healthy tobacco leaves ,could reproduce the disease.Isolated proteinaceous crystalline substance from diseased tobacco plants.Considered it as globular protein.

He finally proved that viruses are not living microorganisms because no living form can be chemically treated and crystallized and still remain viable.

12.F.C.BAWDEN (plant virologist) and N.W.PIRIE (Biochemist) (Britain):

Established complete chemical nature of Tobacco Mosaic Virus. Purified TMV. Characterised TMV chemically as Nucleoproteins containing Nucleic acid 5 %, proteins 95%.Also worked on Turnip mosaic virus &Tobacco bushy stunt virus.

13.DOI : In 1967,Doi and his colleagues in Japan observed mollicutes.,i.e.,wall-less mycoplasma like organisms in the phloem of plants exhibiting yellows and witches' broom symptoms.

First identified phytoplasmas as causal agent of Aster yellows and Mulberry dwarf in phloem sieves .

They showed that the mycoplasmas like organisms and symptoms disappeared temporarily when the plants were treated with tetracycline antibiotics.

14.DIENER: Discovered the potato spindle tuber was caused by small naked ssRNA which he called as viroid.

15. HOWARD TAYLOR RICKETTS : 1916- First discovered Rickettsia.In1972 first observation in phloem of clover and periwinkle causing clover club leaf disease.

In 1973 observed in xylem causing pierce's disease of grapes.

16.BOVE: Bove et al.,in 1968 first time identified spiroplasmas as causal agent of corn stunt.

2. GENERAL CHARACTERISTICS OF FUNGI

FUNGI: Fungi are eukaryotic, spore bearing, achlorophyllous, heterotrophic organisms that generally reproduce sexually and asexually and whose filamentous, branched somatic structures are typically surrounded by cell walls containing chitin or cellulose or both with many organic molecules and exhibiting absorptive nutrition.

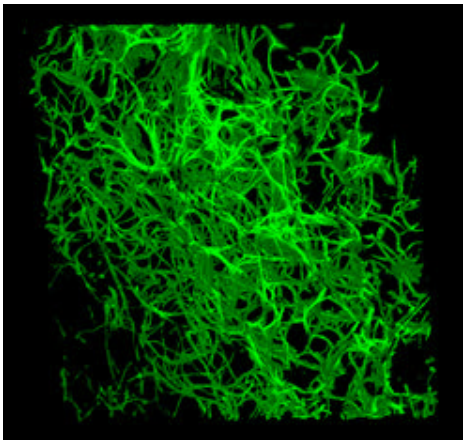
Somatic structures:

Thallus/ Soma Commonly called as vegetative body or fungal body. A thallus(pl. thalli) is a simple, entire body of the fungus devoid of chlorophyll with no differentiation into stem, roots and leaves lacking vascular system.

Hypha (hypha=web) (pl. hyphae) : Hypha is a thin, transparent, tubular filament filled with protoplasm.It is the unit of a filamentous thallus and grows by apical elongation.

Mycelium(pl. mycelia): A net work of hyphae (aggregation of hyphae) constituting the filamentous thallus of a fungus.It may be colourless i.e., hyaline or coloured due to presence of pigments in cell wall.The mycelium may be ectophytic or endophytic.

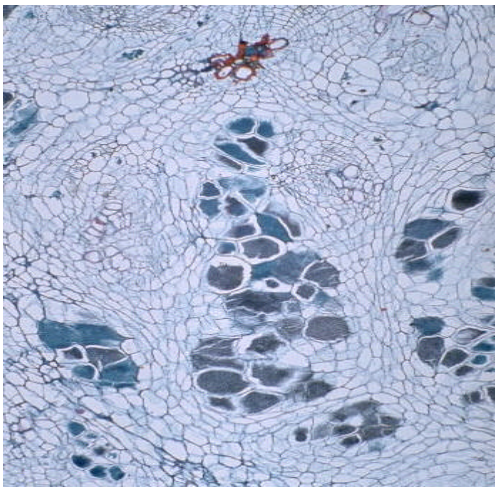
image of fungal mycelia



Types of fungal thalli:

1.Plasmodium (plasma = moulded body): It is a naked,multinucleate mass of protoplasm moving and feeding in amoeboid fashion . Eg. *Plasmodiophora brassicae.*

Plasmodiophora brassicae in host cell



2.Unicellular thallus: consisting of a single cell. Eg.Chytrids, *Synchytrium*

3.Multi cellular or filamentous thallus: Majority of fungi i.e., a true fungi are filamentous, consisting of a number of branched, thread like filaments called hyphae.Eg.Many fungi,*Alternaria.*

Fungi based on reproductive structures:

Holocarpic (holos=whole+karpos=fruit): If the thallus is entirely converted into one or more reproductive structures, such thallus is called holocarpic thallus. Eg.*Synchytrium*

Eucarpic(Eu=good+karpos=fruit): If the thallus is differentiated into a vegetative part which absorbs nutrients and a reproductive part which forms reproductive structures, such thallus is called eucarpic thallus**.** Eg.*Pythium*

Ectophytic fungus: If the fungal thallus is present on the surface of the host plant, it is called ectophytic.Eg. *Oidium* .

Endophytic fungus: If the fungus penetrates into the host cell / present inside the host, it is called endophytic.Eg. *Puccinia*. Endophytic fungus may be **intercellular** (hypha grows in between the cells), or **intra cellular** (hypha penetrates into host cell).Eg.Ustilago, or **vascular** (xylem vessels) Eg. *Fusarium oxysporum*

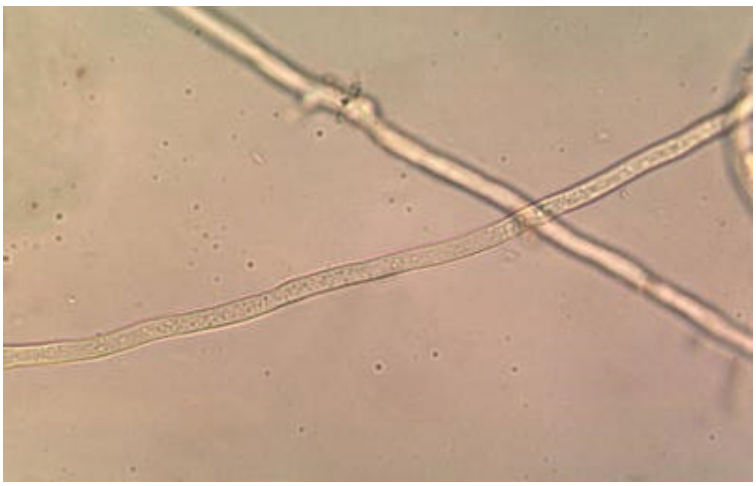
Inter cellular hyphae produce special organs called haustoria which penetrate the host cell and absorb food. These are absent in intracellular hyphae. Endophytic intra cellular mycelium absorb food directly from protoplasm with out any specialized structures.

In ectophytic mycelium, haustoria are produced in epidermal cells.

Septation in Fungi :(septum=hedge/partition) (pl.septa)

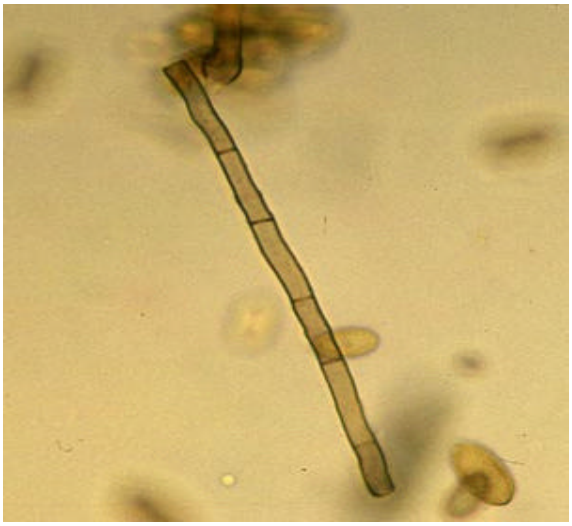
Some fungal hyphae are provided with partitions or cross walls which divide the fungus into a number of compartments /cells. These cross walls are called septa.

Aseptate hypha/coenocytic hypha: (Koinos=common,kytos=hollow vessel) A hypha with out septa is called aseptate /non-septate/ coenocytic hypha wherein the nuclei are embedded in cytoplasm.Eg. lower fungi like Oomycetes and Zygomycetes.



Septate hypha: A hypha with septa or cross walls is called septate hypha.

Eg.common in higher fungi like Ascomycotina, Basidiomycotina and Deuteromycotina



General types of septa:

1.Based on formation:

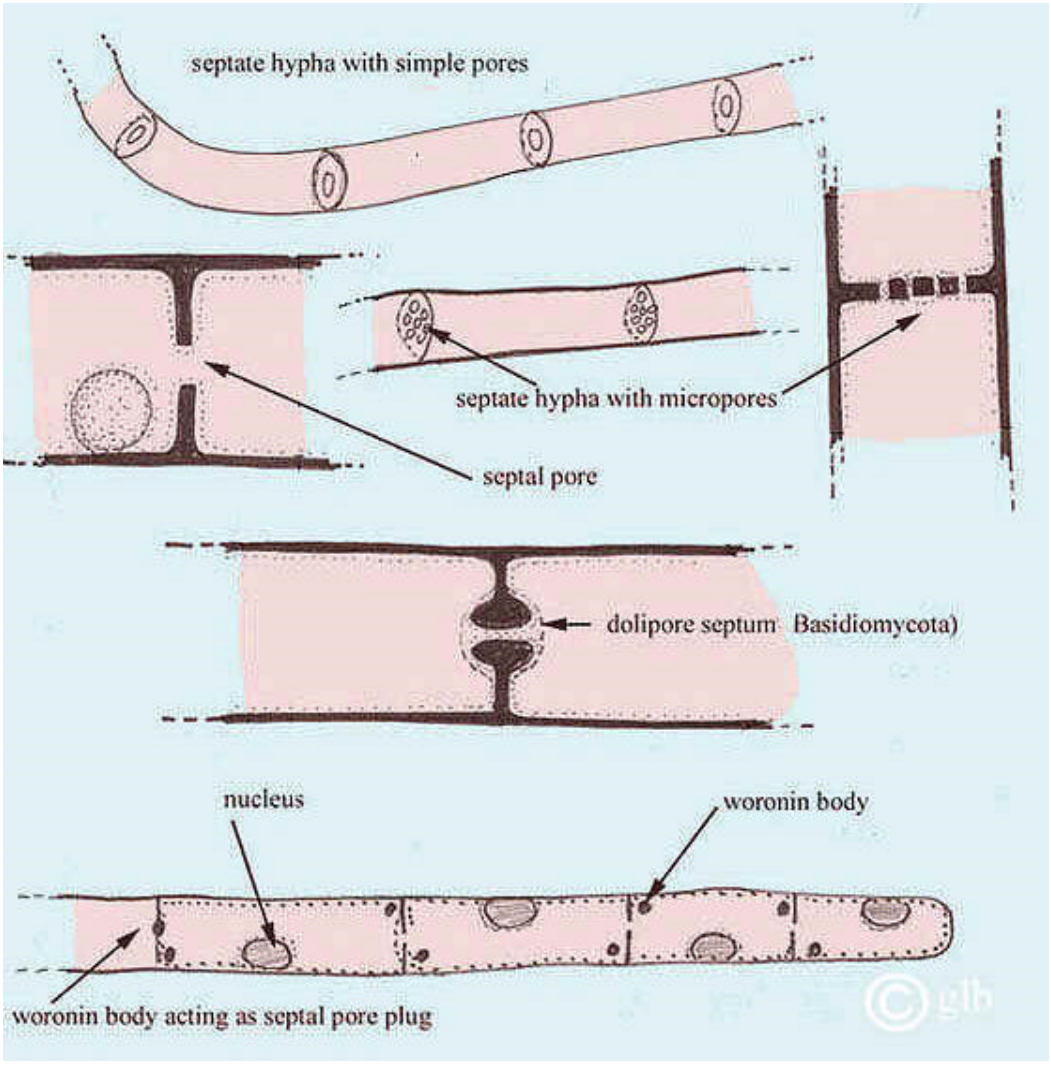
a)Primary septa: These are formed in direct association with nuclear division (mitotic or meiotic) and are laid down between daughter nuclei separating the nuclei /cells. Eg. Higher fungi like Ascomycotina and Basidiomycotina.

b)Adventitious septa: These are formed independent of nuclear division and these are produced to delimit the reproductive structures. Eg. lower fungi like Oomycetes and Zygomycetes in which septa are produced below gametangia (sex organs) which separate them from rest of the cells.

2. Based on construction:

a)Simple septa: It is most common which is a plate like, with or without perforation.

b)Complex septa: A septum with a central pore surrounded by a barrel shaped swelling of the septal wall and covered on both sides by a perforated membrane termed the septal pore cap or parenthosome. Eg. Dolipore septum in Basidiomycotina.



3.Based on perforation:

a)Complete septa: A Septum is a solid plate without any pore or perforations. Eg. Adventitious septa in lower fungi.

b)Incomplete septa: A septum with a central pore.

Fungal tissues: Plectenchyma :(plekein=to weave+enchyma=infusion**)**

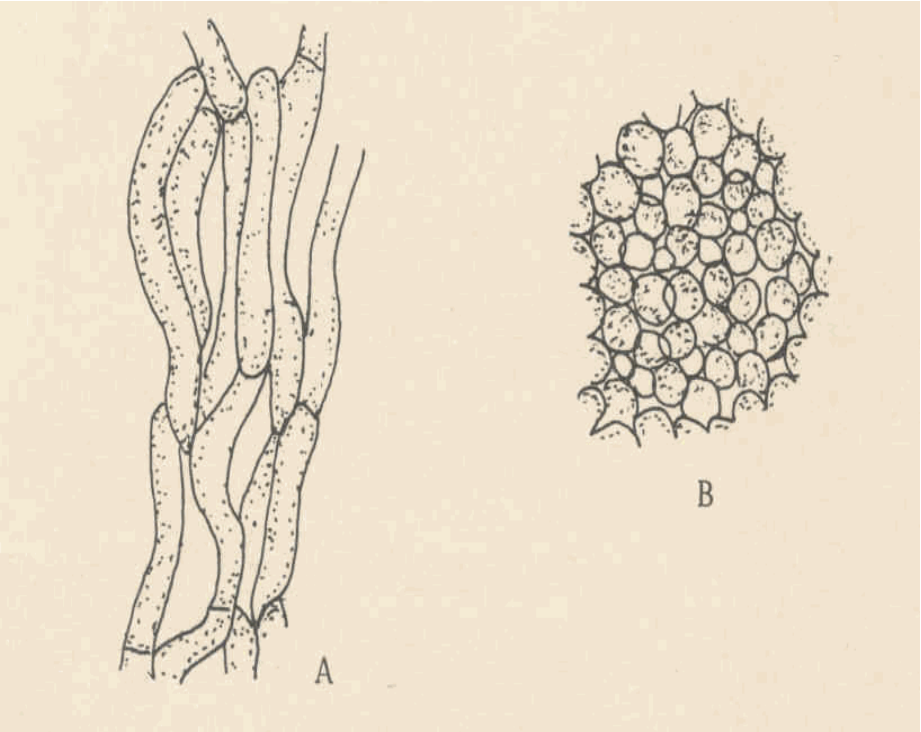
Fungal tissues are called plectenchyma i.e., mycelium becomes organized into loosely or compactly woven tissue. This tissue compose various types of vegetative and reproductive structures.

Types of plectenchyma:

1.Prosenchyma: It is a loosely woven tissue. The component hyphae retain their individuality which can be easily distinguishable as hyphae and lie parallel to one another.Eg. Trauma in *Agaricus.*

2. Pseudoparenchyma:It is compactly woven tissue. It consists of closely packed cells which are isodiametric or oval in shape resembling parenchymatous cells of plants and hence the name. The component hyphae loose their individuality and are not distinguishable as hyphae. Eg. Sclerotial bodies of *Sclerotium* and rhizomorph of *Armillariella.*

A.Prosenchyma B.Pseudoparenchyma



3. MODIFICATION OF MYCELIUM/ SPECIALISED SOMATIC STRUCTURES

Purpose:

1. to obtain nourishment i. e., for nutrition .
2. to resist or tolerate unfavourable conditions for their survival i.e., over wintering, over summering.
3. for reproduction.

1.Rhizomorphs: (rhiza=root, morph=shape) Thick strands of somatic hyphae in which the hyphae loose their individuality and form complex tissues that are resistant to adverse conditions and remain dormant until favourable conditions return. The structure of growing tip of rhizomorphs res emble that of a root tip, hence the name rhizomorph. Eg. *Armillariella mellea.*

2. Sclerotium: (skleron=hard) pl.sclerotia: It is a hard, round (looks like mustard seed)/ cylindrical or elongated (*Claviceps*) dark coloured (black or brown)resting body formed due to aggregation of mycelium, the component hyphae loose their individuality , resistant to unfavourable conditions and remain dormant for a longer period of time and germinate on the return of favourable conditions.

Eg*. Sclerotium, Rhizoctonia* .

3. Stroma: (stroma=mattress) pl.stromata. It is a compact somatic structure looks like a mattress or a cushion on which or in which fructifications (spores or fruiting bodies) are usually formed.

a. Sub stomatal stroma: cushion like structure formed below epidermis in sub stomatal region from which sporophores are produced. Eg. *Cercospora personata.*

b. Perithecial stroma: When reproductive bodies like perithecia of some fungi are embedded characteristically throughout periphery of stroma, such stroma are called perithecial stroma. Eg.*Claviceps, Xylaria.*

4. Haustorium: (hauster=drinker) pl.haustoria.It is a outgrowth of somatic hyphae regarded as special absorbing organ produced on certain hyphae by parasitic fungi for obtaining nourishment by piercing into living cells of host. They may be knob like(*Albugo),* elongated *(Erysiphe, Uncinula),* finger like (*Peronospora)*.

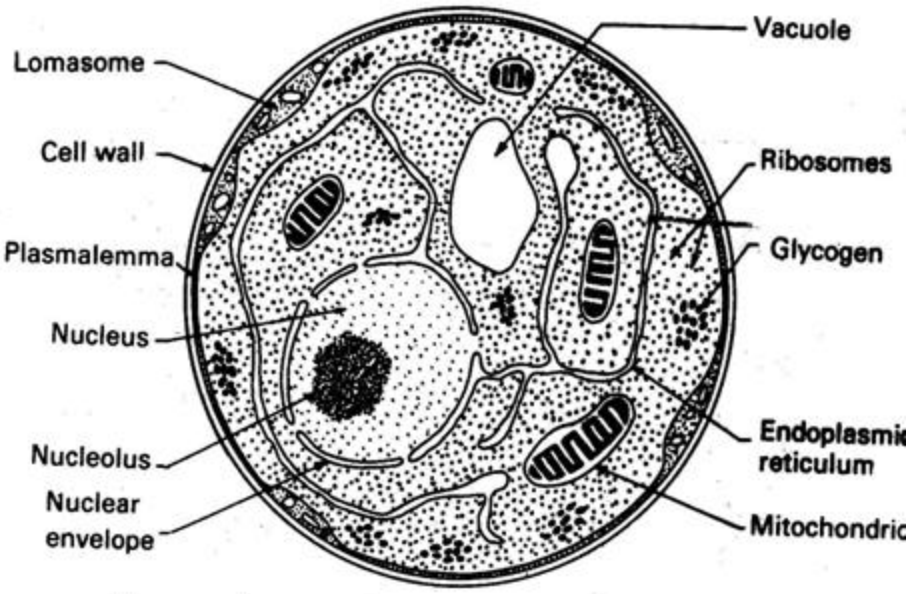
5.Rhizoids: (rhiza=root, oeides=like) These are slender root like branched structures found in the substratum produced by some fungi which are useful for anchoring the thallus to substratum and for obtaining nourishment from the substrate.Eg. *Rhizopus stolonifer.*

6. Appresorium: (apprimere=to press against) pl.appressoria A flattened tip of hyphae or germ tube acting as pressing organ by attaching to the host surface and gives rise to a minute infection peg which usually grows and penetrates the epidermal cells of the host. Eg. *Puccinia, Colletotrichum, Erysiphe.*

Fungal cell :

Fungal cells are typically eukaryotic and lack chloroplasts.

Cell is bounded by cell wall, which provides rigidity and shape to the cell is the outermost membrane of cell consisting of more than one layer with fibrous structure and made up of chitin or cellulose or both.



Diagrammatic representation of the ultrastructure of a cross section of a typical fungus cell.

The layer surrounding the cytoplasm is called cytoplasmic membrane or plasmalemma. Protoplasm contains a true nucleus surrounded by two layered membrane with nucleolus, cytoplasm and other inclusions.

Endoplasmic reticulum is not well developed, and it may be rough atudded with ribosomes or smooth with out ribosomes.

Vacuoles in which metabolic products are accumulated are bounded by a membrane called tonoplast .

Ribosomes are protenaceous bodies scattered all over cytoplasm, play a role in protein synthesis.

Mitochondria are the sites of respiratory activities.

Lomasomes are the swollen membranous structures of plasmalemma.

Cytoplasm also contains fat particles, calcium oxalate crystals, resins, glycogen.

Fungal nutrition:

Fungi are heterotrophic with holophytic nutrition(absorptive type). The essential elements for fungi are, C, H, O, N, P, K, S, Zn, Fe, Mg, Mn, Mo, Cu and Ca. Reserve food material in the cell may be either fat or carbohydrates. Fats may be present in the form of oil drops and carbohydrates in the form of glycogen or sugars. Starch is never present in the fungal cell.

Groups of fungi based on mode of nutrition:

1. Saprophytes: (sapros=rotten, phytos=plant) Organisms which obtain nutrition on from dead organic matter either completely or for a part of their life. A large number of fungi fall under this category.

Eg. *Saprolegnia, Rhizopus, Mucor, Alternaria.*

a. **Obligate saprophytes:** (obligare =to bind it self) Organisms which can never grow on living organisms or can never obtain their food from living source. They get their food only from dead organic matter.

Eg. *Mucor, Agaricus* .

. **b. Facultative parasite:** (facultas=ability) Organisms which are usually saprophytic but have ability to become as parasites.

Eg. *Pythium aphanidermatum, Fusarium solani, Rhizoctonia solani.*

2.Parasites: Organisms which live within or out side another organisms for their nutrition either completely or for a part of their life .

Pathogen : If a parasite damages the host then they are called as pathogens..

All pathogens are not parasites and all parasites need not be pathogens .

a. Obligate parasites: (Organisms which obtain food only from living organisms (living protoplasm) and can never derive their food from dead organic matter or artificial medium. Eg. *Puccinia graminis* , *Plasmopara viticola* .

b. Facultative saprophytes: Organisms which are usually parasites but have ability to become saprophytes .Eg. *Ustilago maydis*

Reproduction in fungi :

Reproduction is the formation of new individuals having all the characteristics of the species.

Types of reproduction: 1. Asexual /non-sexual / vegetative / somatic reproduction 2. Sexual reproduction.

1.**Asexual reproduction :**

Asexual reproduction stage is also known as imperfect stage and technically called as anamorphic stage. There is no union of nuclei /sex cells/ sex organs. It is repeated several times during the life span of a fungus producing numerous asexual spores. Hence, it is more important for fungi than sexual reproduction.

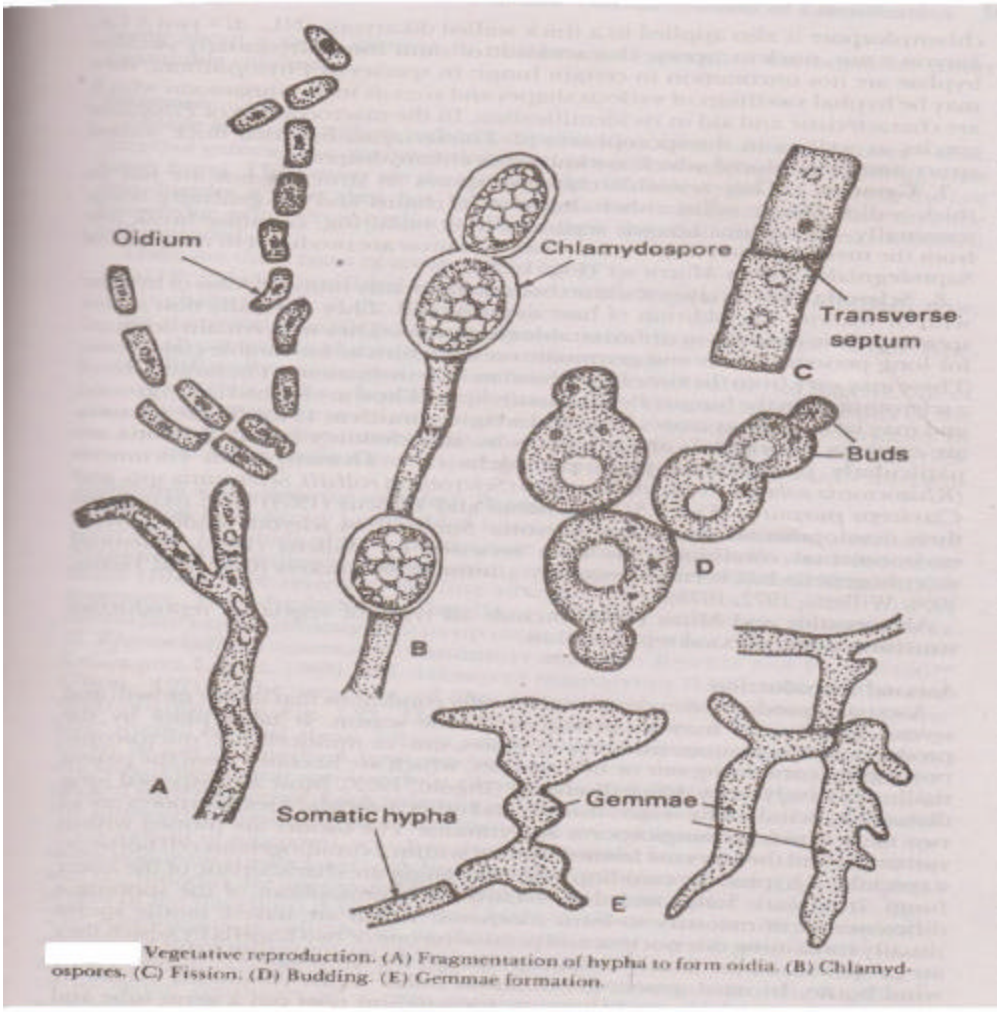
Asexual spores are formed after mitosis ,hence also called mitospores.

Methods of asexual reproduction :

1. Fragmentation 2. Fission. 3. Budding 4. Sporulation (production of spores)

1. Fragmentation : It is the most common method. Hypha of fungus breaks into small pieces, each broken piece is called a fragment, which function as a propagating unit and grows into a new mycelium.The spores produced by fragmentation are called **arthrospores** (arthron=joint) (spora=seed) or oidia.. Eg. *Oidium, Geotrichum.* Sometimes, the contents of intercalary cells or terminal cells of hypha rounded off and surrounded by thick wall and formed as **chlamydospores** which are thick walled resistant spores produced either singly or in chains. Eg. *Fusarium oxysporum, Ustilago tritici.*

2. Fission / Transverse fission: The parent cell elongates,nucleus under go mitotic division and forms two nuclei, then the contents divide into equal halves by the formation of a transverse septum and separates into two daughter cells.Eg.*Saccharomyces cerevisiae.*



Vegetative reproduction. (A) Fragmentation of hypha to form oidia. (B) Chlamydospores. (C) Fission. (D) Budding. (E) Gemmae formation.

3.Budding: The spores formed through budding are called **blastospores**. The parent cell puts out initially a small out growth called bud / blastos ie.,sprout or out growth which increases in size and nucleus divides, one daughter nucleus accompanied by a portion of cytoplasm migrates into bud and the other nucleus remains in the parent cell. Later, the bud increases in size and a constriction is formed at the base of bud, cutting off completely from parent cell . Bud, when separated from parent cell, can function as an independent propagating unit.Sometimes multiple buds are also seen i.e., bud over bud and looks like pseudomycelium. Eg. *Saccharomyces cerevisiae.*

4. Sporulation (spores): The process of production of spores is called sporulation.

Spore: It is a minute, simple propagating unit of the fungi, functioning as a seed but differs from it in lacking a preformed embryo that serves in the reproduction of same species.

Spores vary in colour,size,number of cells and the way in which they are borne.

There are 2 main types of spores.

1. Sporangiospores 2. Conidia

1.Sporangiospores: When the asexual spores are produced internally, within the sporangia,such spores are called sporangiospores.The sac like structure which produces sporangiospores is called sporangium. The special hypha bearing sporangium is called sporangiophore which may or may not be distinguishable from hypha. A small sporangium with or without columella containing a few or single spore is called as sporangiolum.

Eg. *Choanephora trispora* .

Sporangium which is cylindrical in shape is called as merosporangium.

Eg. *Syncephalastrum racemosum.*

Sporangium with columella is called as columellate sporangium.

Eg.*Rhizopus stolonifer.*

Sporangiospores are of 2 types.

a. Zoospores /planospores b.Aplanospores

a.Zoospores / planospores: sporangiospores which are motile by flagella are called zoospores.Also known as planospores.Eg. *Pythium, Phytophthora.*

b.Aplanospores: Sporangiospores which are non motile with out flagella are called aplanospores Eg*. Rhizopus stolonifer, Mucor.*

Flagellation in fungi:

Flagella : (sing.flagellum)Flagella are thin, hair like delicate structures attached to a basal granule called blepharoplast in cytoplasm and these are the organs of motility in lower fungi and aquatic fungi.

Types of flagella : Flagella of zoospores are of **2** types**.**

a.Whiplash b.Tinsel

a)Whiplash : A flagellum with long, thick, rigid basal portion and with a short, narrow, flexible, upper portion .It gives a whip like appearance to flagellum.

b)Tinsel : It is a feathery structure consisting of a long rachis with lateral hair like projections called mastigonemes or flimmers on all sides along its entire length.

The number, position and nature of flagella play an important role in the classification of lower fungi.

Uniflagellate zoospore : A zoospore with a single flagellum, may be placed at anterior or posterior end of spore.

Biflagellate zoospore:A zoospore with two flagella, situated laterally or anteriorly on zoospore.

One whiplash,one tinsel type flagella and equal in size.Eg. *Pythium aphanidermatum, Phytophthora infestans*,

Both whiplash flagella,unequal in size (heterokont).Eg .*Plasmodiophora brassicae.*

2. Conidia / Conidiospores: (konis=dust; oides=like) Conidia are non- motile asexual spores which may arise directly from somatic hyphae or from specialized conidiogenous cells (a cell from which conidia are produced) or on conidiophore (hypha which bear conidia).Conidia are produced freely on conidiophore ie.,at the tips or sides of conidiophore or may be produced in specialized asexual fruiting bodies viz., pycnidium, acervulus, sporodochium and synnemata.

Asexual fruiting bodies :

(a) Pycnidium: (pl.pycnidia) It is a globose or flask shaped fruiting body lined inside with conidiophores which produce conidia. It may be completely closed or may have an opening called ostiole.

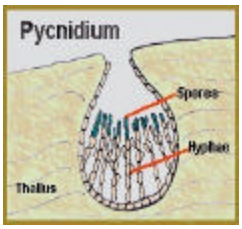
Pycnidium may be provided with small papillum or long neck. Eg.*Phomopsis.*

(b) Acervulus: (pl.acervuli) A flat or saucer shaped fruiting body with a stromatic mat of hyphae producing conidia on short conidiophores.An acervulus lacks a definite wall structure and not having an ostiole or definite line of dehiscence. Eg.*Colletotrichum,Pestalotiopsis.*

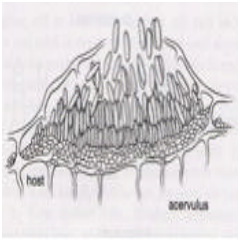
(c) Sporodochium : (pl.sporodochia**)** A cushion shaped asexual fruiting

body.Conidiophores arise from a central stroma and they are woven together on a mass of hyphae and produce conidia.Eg.*Fusarium.*

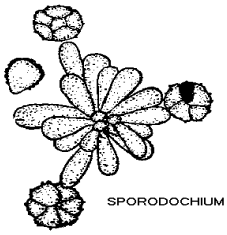
(d) Synnemata: (pl.synnema) A group of conidiophores often united at the base and free at the top. Conidia may be formed at its tip or along the length of synnema, resembling a long handled feather duster.Eg.*Graphium.*



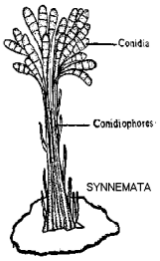
Pycnidium



Acervulus



Sporodochium



Synnemata

4. SEXUAL REPRODUCTION

Sexual reproduction involves union of two compatible nuclei or sex cells or sex organs or somatic cells or somatic hyphae for the formation of new individuls. Sexual stage is perfect stage and technically called as teleomorphic stage. Sexual cycle normally occurs once in the life span of the fungus. Sexual spores or sexual structures which contain sexual spores are thick walled, resistant to unfavourable conditions and are viable for longer period and thus these spores help the fungus to perpetuate from one season to another , hence these are called as resting spores.Sexual spores are definite in number.

Sex organs of fungi :

Gametangia: Sex organs of fungi are called gametangia containing gametes or gamete nuclei. **Gametes**: Sex cells are called as gametes .

Antheridium: (pl.antheridia) Male gametangium is called as antheridium. Male gametangium is small and club shaped.

Oogonium / Ascogonium:(pl.oogonia/ascogonia):The female gametangium is called Oogonium (oomycetes) or ascogonium (ascomycotina).Female gametangium is large and globose shaped.

Male gametes are called antherozoids or sperm or spermatozoids .

Female gametes are called egg or oosphere.

Planogametes: If gametes are motile, they are called planogametes.

Isogametangia: If gametangia are morphologically similar or identical i.e.,indistinguishable as male and female , they are called as isogametangia.

Isogametes: If gametes are similar morphologically, they are called as isogametes.

Heterogametangia: If gametangia differ morphologically in size and structure, they are called as heterogametangia.

Heterogametes: If gametes differ morphologically, they are called heterogametes.

+ or – signs: In some sexually undifferentiated fungi, male and female are symbolically designated as ' + ' (male) and ' – ' (female).

Classification of fungi based on sex :

1. Monoecious fungi / hermaphroditic fungi: (mono=single,oikos=home)

The fungi which produce distinguishable male and female sex organs on the same thallus, which may or may not be compatible are called monoecious/ hermaphroditic fungi. Eg. *Pythium aphanidermatum*.

2. Dioecious fungi: (di=two, oikos=home) The fungi which produce distinguishable male and female sex organs on two different thalli ie., there will be separate male and female thalli . Eg. *Phytophthora infestans.*

Classification of fungi based on compatibility ;

Homothallic fungi: Fungi in which both sexes occur on same thallus, which can reproduce sexually by it self with out the aid of another thallus ie., self compatible / self fertile are called homothallic fungi.
Eg. *Pythium aphanidermatum.*

Heterothallic fungi: A fungal species consisting of self sterile (self incompatible) thallus requiring the union of two compatible thalli for sexual reproduction, regardless of the possible presence of both male and female organs on the same thallus. Heterothallic fungi are dioecious
Eg. *Phytophthora infestans.*.

Phases in Sexual reproduction:. There are 3 phases in sexual reproduction.

1. **Plasmogamy**: union of two protoplasts takes place.As a result of it the two nuclei come together within the same cell.
2. **Karyogamy**: union of 2 sexually compatible nuclei brought together by plasmogamy to form a diploid nucleus (2n) i.e., zygote.

3. **Meiosis**: This is reduction division . The number of chromosomes is reduced to haploid (n) i.e., diploid nucleus results into haploid nucleus..

In lower fungi (Phycomycetes -Mastigomycotina and Zygomycotina) plasmogamy, karyogamy and meiosis occurs at regular intervals / sequence i.e.,karyogamy follows immediately after plasmogamy. In higher fungi (Ascomycotina, Basidiomycotina), karyogamy is delayed, as a result the nuclei remain in pairs (dikaryotic phase- n+ n condition), which may be brief or prolonged.

Dikaryon : A pair of genetically different nuclei, lying side by side with out fusion for a considerable period of time is called dikaryon.A cell containing dikaryon is called **dikaryotic cell**. And the process is known as **dikaryogamy**.

Methods of sexual reproduction : 5 methods.

1. Planogametic copulation. 2. Gametangial contact 3. Gametangial copulation 4. Spermatisation 5. Somatogamy .

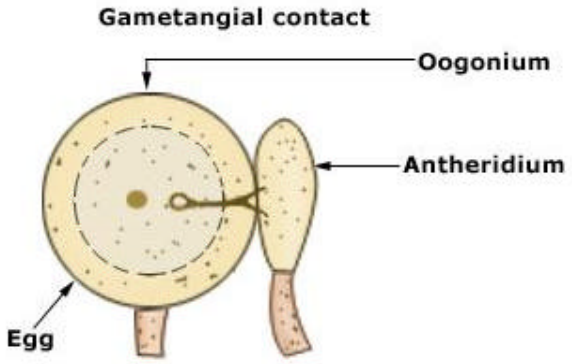
1.Planogametic copulation (gametogamy): This involves the union of 2 naked gametes one or both of which are motile.

a.Isogamy (Isogamous planogametic copulation) : If both gametes are motile and similar.Eg. *Plasmodiophora brassicae.*

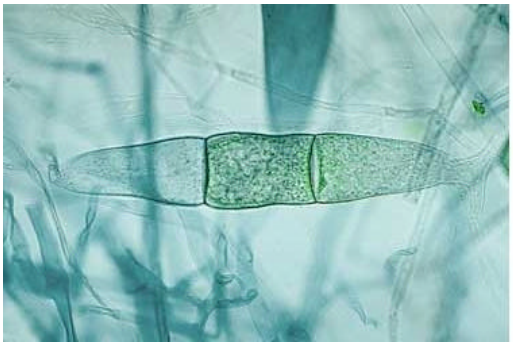
b. Anisogamy (Anisogamous planogametic copulation) : If both gametes are motile but dissimilar.Eg. *Allomyces macrogynus*

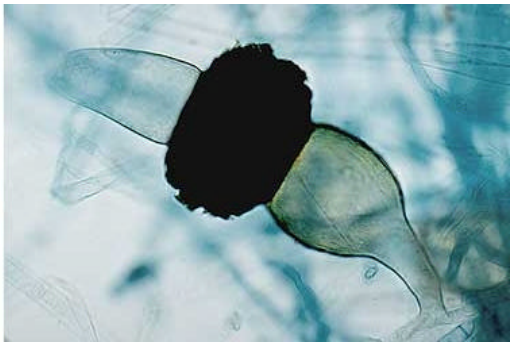
c.Heterogamy: If gametes are dissimilar, one motile, another is non motile. Eg. *Monoblepharis polymorpha.*

2.Gametangial contact (gametangy / oogamy): Male and female gametangia come in contact . At the place of contact, dissolution of wall occurs and a fertilization tube is formed. The contents of male gametangium migrate into female gametangium through a pore or fertilization tube developed at the point of contact. The gametangia do not loose their identity. Eg. *Pythium aphanidermatum.*

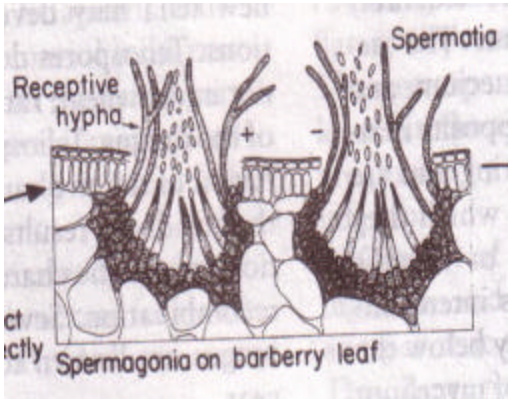


3.Gametangial copulation (gametangiogamy): The isogametangia come in contact, their intervening wall dissolves leading to fusion of entire contents of two contacting gametangia to form a single unit.Gametangia loose their identity.The protoplasts fuse and the unit increases in size. Eg. *Rhizopus stolonifer.*





4.Spermatiz ation: Minute, uninucleate male cells called as spermatia which are produced on spermatiophores in a fruiting body (pycnium) are carried to female reproductive structures called receptive hyphae. Spermatia and receptive hyphae come in contact and contents of male spermatium migrate into female receptive hypha, thus making the cell binucleate. This process is called dikaryotization. Eg. *Puccinia graminis tritici.*



5.Somatogamy: Many higher fungi do not produce sex organs.In such cases somatogamy takes place.It is the union of 2 somatic hyphae or somatic cells representing opposite sexes to form sexual spores .Eg. *Agaricus campestris*

Parasexual cycle / Parasexuality :Parasexual cycle is a process in which plasmogamy, karyogamy and haploidisation (non meiotic process) takes place in a sequence but not at specified points in the life cycle of a fungus. It was first discovered in 1952 by Pontecorvo and Roper in *Aspergillus nidulans*, the imperfect stage of *Emericella nidulans*.It is of importance in heterokaryotic fungi(a fungi in which genetically different nuclei are associated in the same protoplast or mycelium) .This is one of the methods of producing variability of fungal pathogens. In majority of Deuteromycotina,true sexual cycle is absent but derive many of the benefits of sexuality through this cycle.

Different types of sexual spores : Sexual spores are formed after meiosis,hence also called meiospores.

1.Oospores 2.Zygospores 3.Ascospores 4.Basidiospores

1**.Oospore:** A thick walled sexual resting spore produced by the union of two morphologically different gametangia.

Eg.*Pythium, Phytophthora* , members of class Oomycetes.

2. Zygospore: A thick walled sexual resting spore produced by the fusion of two morphologically similar gametangia.

Eg.*Rhizopus* , members of sub-division Zygomycotina

3. Ascospore:Sexual spore produced in a specialized sac like like structure known as ascus. Generally 8 ascospores are formed.

Eg.*Erysiphe,*members of sub-division Ascomycotina.

4.**Basidiospore:**Sexual spore produced on a club shaped structure known as basidium.Generally 4 basidiospores are formed.

Eg.*Puccinia,* members of sub-division Basidiomycotina.

Various Life cycle patterns displayed by fungi:

1. Haplobiontic life cycle 2. Diplobiontic life cycle

1. **Haplobiontic life cycle**: If there is only one free living thallus, which is haploid or diploid in life cycle of a fungus, it is called as haplobiontic life cycle.

(long haploid somatic phase and short diploid phase confined to zygote cell, which undergoes meiosis immediately after karyogamy and develop ascospores)

Eg. *Schizosaccharomyces octosporus.*

2. **Diplobiontic life cycle:** If haploid thallus alternates with a diploid thallus, the life cycle is called diplobiontic life cycle, which has a long diploid somatic phase and a very short haploid phase. Eg. *Saccharomyces ludwigii.*

5. TAXONOMY AND NOMENCLATURE OF FUNGI

Taxonomy : The science of classification. It is concerned with pricnciples of classification.

Classification: Grouping of organisms into classes,orders,families,genera, species etc.

Nomenclature : Art of naming living organisms.

Importance of taxonomy and nomenclature;

1. for study of fungi
2. for scientific communication between mycologists and plant pathologists throughout the world.

Binomial system of nomenclature was originally introduced by Carl Linnaeus for higher plants. Later, this classification was adopted to fungi by his students C.H.Persoon amd E.M. Fries.

Some important rules of nomenclature :

1.According to International code of Botanical Nomenclature, the names of organisms should be binomial i.e., 2 parts.The first part is noun designating genus and the first letter of the genus name should be in capital. The second name is often an adjective, describing the noun which denotes the species, and the first letter should be in small letter. Eg. *Puccinia graminis.*

2.Binomials are usually derived from Greek or Latin.

3.Binomials when hand written should be underlined and when printed italicised.

Eg.. Puccinia graminis (hand written)

Puccinia graminis (printed)

4. Citation of authors name: The full name or abbrevation name of scientist who described fungus first, follows the species name.Eg. *Puccinia graminis* Persoon or Pers.

5. Citation of two authors names: If name of species is transferred to another genus from original (*Botrytis infestans*), the name of first author who first described species must be kept in parenthesis followed by name of second author who gave present status of species. *i.e., Phytophthora infestans.* Eg. *Phytophthora infestans* (Mont.) de Bary.

6. The taxa (groups) used in classification are Kingdom, Division, Class, Order, Family, Genus and Species.Each category may be sub divided into sub groups like Sub- Division,Sub- Class, Sub- Order.

7. Species is the unit of classification or basic taxonomic category (taxon).

8. Species some times broken into variety / formae speciales (f.sp.) and varieties into races and races into biotypes.

Standard endings of TAXA:

Division ends with **mycota**
Sub- Division ends with **mycotina**
Class with **mycetes**
Sub- class with **mycetidae**
Order with **ales**
Family with **aceae**
No special ending for genus and species.

TAXA:
Kingdom
Division
Sub-division
Class
Sub-class
Order
Sub-order
Family
Genera
Species

Eg. *Puccinia graminis tritici* race 1

Kingdom :Fungi
Division : Eumycota
Sub-division : Basidiomycotina
Class : Teliomycetes
Order : Uredinales
Family : Pucciniaceae
Genus : Puccinia
Species : graminis
Variety : tritici
Race : 1

CLASSIFICATION OF FUNGI

(CLASSIFICATION BY AINSWORTH, 1973)

KINGDOM: MYCOTA

DIVISIONS

MYXOMYCOTA

CLASS

PLASMODIOPHOROMYCETES
ORDER: PLASMODIOPHORALES
FAMILY:PLASMODIOPHORACEAE
Eg.*Plasmodiophora*

EUMYCOTA

SUB DIVISIONS

1. MASTIGOMYCOTINA
2. ZYGOMYCOTINA
3. ASCOMYCOTINA
4. BASIDIOMYCOTINA
5.DEUTEROMYCOTINA

S.D : 1. MASTIGOMYCOTINA
CLASSES
1.CHYTRIDIOMYCETES
ORDER: CHYTRIDIALES
FAMILY: SYNCHYTRIACEAE
Eg. *Synchytrium*
2.OOMYCETES
ORDER: PERONOSPORALES
FAMILY:PYTHIACEAE
Eg: *Pythium, Phytophthora*
FAMILY: ALBUGINACEAE
Eg. *Albugo*
FAMILY: PERONOSPORACEAE
Eg: *Sclerospora. Peronospora,Peronosclerospora Plasmopara, Pseudoperonospora, Bremia*
S.D :2**.** ZYGOMYCOTINA
CLASS :ZYGOMYCETES
ORDER: MUCORALES
FAMILY: MUCORACEAE
Eg. *Rhizopus, Mucor*
S.D 3. ASCOMYCOTINA
CLASSES
1.HEMIASCOMYCETES
ORDER: PROTOMYCETALES
FAMILY: PROTOMYCETACEAE
Eg. *Protomyces and Protomycopsis*
ORDER: TAPHRINALES
FAMILY: TAPHRINACEAE
Eg. *Taphrina*
2.PLECTOMYCETES
ORDER: EUROTIALES
FAMILY: EUROTIACEAE

Eg. *Eurotium, Talaromyces*

ORDER: ERYSIPHALES

FAMILY:ERYSIPHACEAE

Eg. *Erysiphe, Leveillula, Phyllactinia, Uncinula, Sphaerotheca,Podosphaera, Microsphaera*

3.PYRENOMYCETES

ORDER: HYPOCREALES

FAMILY: CLAVICIPITACEAE

Eg. *Claviceps*

4.DISCOMYCETES

ORDER: TUBERALES

FAMILY: TUBERACEAE

Eg. *Tuber*

ORDER: PEZIZALES

FAMILY: MORCHELLACEAE

Eg. *Morchella*

5.LOCULOASCOMYCETES

ORDER: PLEOSPORALES

FAMILY: VENTURIACEAE

Eg. *Venturia*

FAMILY: PLEOSPORACEAE

Eg. *Cochliobolus*

ORDER: MYRIANGIALES

FAMILY: MYRIANGIACEAE

Eg. *Elsinoe*

ORDER: DOTHIDIALES

FAMILY: DOTHIDIACEAE

Eg. *Mycosphaerella*

S.D 4. BASIDIOMYCOTINA

CLASSES

1.TELIOMYCETES

ORDER: UREDINALES

FAMILY: PUCCINIACEAE

Eg.*Puccinia, Uromyces, Hemileia*

FAMILY: MELAMPSORACEAE

Eg. *Melampsora*

ORDER: USTILAGINALES

FAMILY: USTILAGINACEAE

Eg. *Ustilago, Sphaecelotheca,Tolyposporium*

FAMILY: TILLETIACEAE

Eg. *Tilletia, Neovossia, Urocystis*

FAMILY: GRAPHIOLACEAE

Eg. *Graphiola*

2.HYMENOMYCETES

SUB CLASS: HOLOBASIDIOMYCETIDAE

ORDER: AGARICALES

FAMILY: AGARICACEAE

Eg. *Agaricus, Volvariella, Pleurotus*

ORDER: APHYLLOPHORALES

FAMILY: POLYPORACEAE

Eg. *Polyporus, Fomes, Peria*

FAMILY: GANODERMATACEAE

Eg. *Ganoderma*

S.D 5 DEUTEROMYCOTINA

CLASSES

1.COELOMYCETES

ORDER: SPHAEROPSIDALES

FAMILY: SPHAEROPSIDACEAE

Eg. *Phoma, Phomopsis, Macrophomina, Phyllosticta, Diplodia,Botryodiplodia*

FAMILY:EXCIPULACEAE

Eg*. Ephelis*

FAMILY: NECTRIOIDACEAE

Eg. *Zythia*

FAMILY: LEPTOSTROMATACEAE

Eg. Leptostroma

ORDER: MELANCONIALES

FAMILY: MELANCONIACEAE

Eg. *Colletotrichum, Gloeosporium, Pestalotiopsis, Pestalotia*

2.HYPHOMYCETES

ORDER: HYPHOMYCETALES / MONILIALES

FAMILY: MONILIACEAE

Eg. *Pyricularia, BotrytIs, Verticillium,*

FAMILY: DEMATIACEAE

Eg. *Alternaria ,Bipolaris, Cercospora, Phaeosariopsis*

ORDER: STILBELLALES

FAMILY: STILBELLACEAE

Eg. *Graphium*

ORDER: TUBERCULARIALES

FAMILY: TUBERCULARIACEAE

Eg. *Fusarium, Myrothecium*

ORDER: AGONOMYCETALES

FAMILY: AGONOMYCETACEAE

Eg. *Sclerotium,Rhizoctonia*

IMPORTANT CHARACTERISTICS OF DIVISIONS AND SUB-DIVISIONS

DIVISIONS :

1. **MYXOMYCOTA:** Plasmodial forms with out cell wall. Plasmodium is a naked multinucleate mass of protoplasm which moves and feeds in an amoeboid direction.Also calledcas slime molds.

2. **EUMYCOTA**: True fungi. Thallus is typically filamentous with cell wall. Plasmodium absent.

SUB DIVISIONS OF EUMYCOTA:

1. **MASTIGOMYCOTINA** :

Thallus is unicellular or aseptate mycelium.Asexual spores are zoospores (motile spores).Sexual spores are oospores. Sexual reproduction by gametangial contact.

2. **ZYGOMYCOTINA** :

Thallus is aseptate mycelium. Motile spores are absent. Asexual spores are sporangiospores (aplanospores).Sexual spores are zygospores.Sexual reproduction through gametangial copulation.

3. **ASCOMYCOTINA :**

Thallus is septate mycelium. Rarely unicellular. Motile spores are absent. Asexual spores are conidia.Sexual spores are ascospores produced endogenously in an ascus.Sexual reproduction mainly by gametangial contact .

4. **BASIDIOMYCOTINA:**

Thallus is septate mycelium.Motile spores are absent.Clamp connections and dolipore septum are present.Sexual spores are basidiospores produced exogenously on basidium.Sexual reproduction is by spermatization and somatogamy.

5. **DEUTEROMYCOTINA:**

Thallus: septate mycelium . Motile spores are absent. Sexual spores are absent. Asexual spores called conidia are present.

6. DIVISION - MYXOMYCOTA

IMPORTANT CHARACTERISTICS OF

CLASS :PLASMODIOPHOROMYCETES,ORDER:PLASMODIOPHORALES

FAMILY:PLASMODIOPHORACEAE

1. These are obligate endoparasites.Commonly called as endoparasitic slime molds. Thallus is a plasmodium,
2. There are 2 types of plasmodia.
   a. **Sporangiogenous plasmodium** - formed asexually containing many thin walled zoosporangia and each zoosporangium produce a single or many secondary zoospores or sporangial zoospores.
   b. **Cystogenous plasmodium** - formed sexually consisting of thick walled cysts and each cyst gives rise to a single primary zoospore / cyst zoospore. Cysts may be free or united.Cysts act as resting spores.
3. Zoospores are anteriorly biflagellte, whiplash type,unequal in size which are called as Heterokont zoospores. After swimming for some time, the zoospore

encysts on the root hair of the host. A cylindrical sharp pointed body, called **satchel**, is formed in a specialized pouch or sheath called **Rohr**.

4.Nuclear division is by cruciform division.

5. Sexual reproduction is by isogamous planogametic copulation.

6. Members cause abnormal enlargement and multiplication of host cells i.e., hypertrophy and hyperplasia. Eg: *Plasmodiophora ,Spongospora*

Differences between *Plasmodiophora* and *Spongospora* :

***Plasmodiophora* :** Resting spores / cysts lie freely with in the host cell, but not in cystosorus.

Spongospora : Resting spores form balls and appear like sponge.

Diseases :*Plasmodiophora brassicae* : club root / finger & toe disease of cabbage / crucifers.

Spongospora subterranea : powdery scab of potato

7. DIVISION :EUMYCOTA

... **SUB - DIVISION: MASTIGOMYCOTINA**

IMPORTANT CHARACTERISTICS OF CLASS CHYTRIDIOMYCETES:

1. Thallus (a) primitive members - unicellular, advanced members with coenocytic mycelium.

(b) endobiotic (fungus which lives with in the cells of host) or epibiotic (reproductive organs of the fungus on surface of the host, part or entire thallus with in the host cell).

(c) holocarpic or eucarpic.

2 .Zoospores are posteriorly uniflagellate whiplash type. Inside the zoospore, around the nucleus cell ribosomes cluster together to form a nuclear cap.

3. Asexual reproduction is by zoospores produced in zoosporangia.

4.Sexual reproduction is by (a) planogametic copulation (isogamy, anisogamy, heterogamy). (b)gametangial copulation.

5. Zygote is converted into resting sporangium / resting spore. Zoospores produced from this resting spore infect host cell and produces prosorus which is thick with golden-brown chitinous wall. Prosorus eventually gives rise to sorus. Eg.*Synchytrium*

Important characteristics of Order: Chytridiales

1.Thallus is epibiotic or endobiotic, monocentric or polycentric, vegetative parts are rhizoidal .

2.Zoosporangium is operculate or inoperculate (operculum present or absent).
3.Zoospore germination is unipolar.
4.Resting spore on germination functions as a sporangium or prosporangium

Important characteristics of Family: Synchytriaceae :
Includes only single genus - *Synchytrium*, species - *endobioticum*.
Thallus is unicellular, endobiotic and holocarpic. Warts contain resting sporangia. Thallus behaves as a prosorus.
Disease: Causes black wart of potato. It is prominent in hilly regions like Darjeeling.
Epidermal cells of tubers are infected by the fungus. Hypertrophy and hyperplasia takes place, as a result, out growths appear on tubers.

Diseases transmitted : *Synchytrium endobioticum* transmits potato virus - x .

8. IMPORTANT CHARACTERISTICS OF CLASS OOMYCETES

1. Members may be aquatic or terrestrial ,saprophytes or obligate parasites.
2. Thallus - mostly eucarpic ,coenocytic
3. Cell wall consists of cellulose. Chitin is absent.
4. Asexual reproduction is by zoospores produced in zoosporangia. Zoospores are biflagelte (whiplash and tinsel), anteriorly or laterally positioned, equal in size.
5. Sexual reproduction is oogamous type ie.,gametangial contact/ gametangy.. Heterogametangia come in contact, contents of antheridium (male gametangium) passes into oogonium(female gametangium) containing oosphere (egg) through fertilization tube.
6. Zygote resulting from sexual reproduction is called oospore.
7. Oospore is the sexual resting spore which is the characteristic of oomycetes.
8. This zygote/ oospore is diploid.Oospore which gives rise to mycelium/ gametangia is also diploid.
9. Meiosis occurs in gametangia instead of zygote.

IMPORTANT CHARACTERISTICS ORDER PERONOSPORALES:

1.Many species are destructive pathogens causing very serious diseases in some important crop plants.The diseases caused by these members include white rusts, downy mildews, damping off, leaf blights and seedling blights.
2.Members are mostly terrestrial.
3.Mycelium is coenocytic, produce inter and intra cellular hyphae.If inter – cellular produce haustoria.

4.Sporangia are produced on well developed, distinct sporangiophores and sporangia are deciduous (fall off at maturity).

5.Sporangiophores may be indeterminate / indefinite type (sporangiophores continue to grow indefinitely producing sporangia at the tip as they grow.ie.,sporangia of different ages are seen on sporangiophores) or determinate/definite type (sporangia are not produced until sporangiophores complete their development and maturity and all the sporangia are produced at one time.ie.,single crop of sporangia are produced.)

6.Zoospores are monomorphic (producing morphologically one type of zoospores i.e., reniform zoospores) and monoplanetic (only one swarming period.).

7.Zoospores are reniform ie., kidney shaped and biflagellate.
Some species exhibit highly specialized parasitism i.e., obligate parasites.

8.Oogonium produces a single oosphere / egg surrounded by conspicuous periplasm except in Family: Pythiaceae in which periplasm is inconspicuous. Periplasm serves as a source of nutrients to oosphere.

ORDER PERONOSPORALES :

Families: 1.Pythiaceae 2.Albuginaceae 3.Peronosporaceae

These three families are distinguished based on characteristics of sporangiophores and sporangia.

IMPORTANT CHARACTERISTICS OF FAMILY 1. PYTHIACEAE :

1.Species may be saprophytes or facultative parasites.Commonly called water molds.

2.May be inter or intra cellular mycelium.If inter cellular, produce haustoria, if intra cellular, no haustoria are produced.

3.Sporangiophores generally not distinguished from somatic hyphae unless sporangia are present.

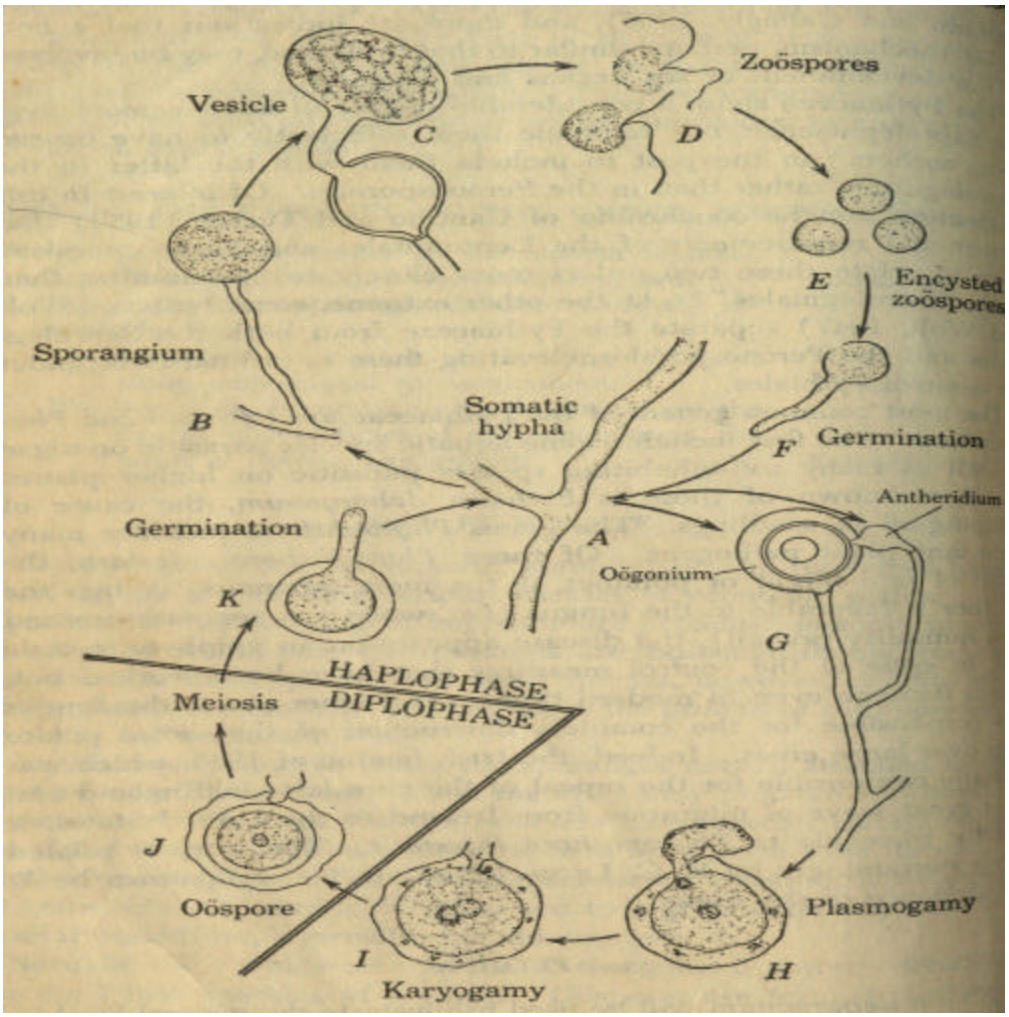
4.Sporangiophores are indefinite or indeterminate type .

5.In oogonium ,Periplasm is inconspicuous (not visible).

Eg. *Pythium* and *Phytophthora*

Genus **PYTHIUM :**Fungus is facultative parasite and lives in soil on dead organic matter or parasitically on young seedlings of crop plants .Mycelium well developed,branched,coenocytic,hyaline,intracellular mycelium without haustoria. Thallus is homothallic.Asexual reproduction is through zoospores produced in zoosporangia . Sporangia are large globose(*P. debaryanum*) or irregularly lobed *(P.aphanidermatum)* produced terminally or intercalary on somatic hyphae.Zoospores are produced in a vesicle which emerge out of sporangium.ie.,zoospore differentiation takes place in vesicle.Sexual reproduction is by gametangial contact.**Paragynous** antheridium(Antheridium is by the side of oogonium).Oospores are smooth,thick walled,round,light brown and aplerotic (oospore wall do not fuse with oogonial wall) or plerotic (oospore wall fuses with oogonial wall).

Diseases: Damping off of vegetable seedlings of solanaceous crops caused by *Pythium debaryanum* or *P.aphanidermatum*.



Genus **PHYTOPHTHORA :** (Phyto=plant,Phthora=destructor)

Fungus lives in soil on dead organic matter or parasitically on potato tubers.

Mycelium is well developed,branched,coenocytic,hyaline,intercellular mycelium with haustoria.Thallus is heterothallic.

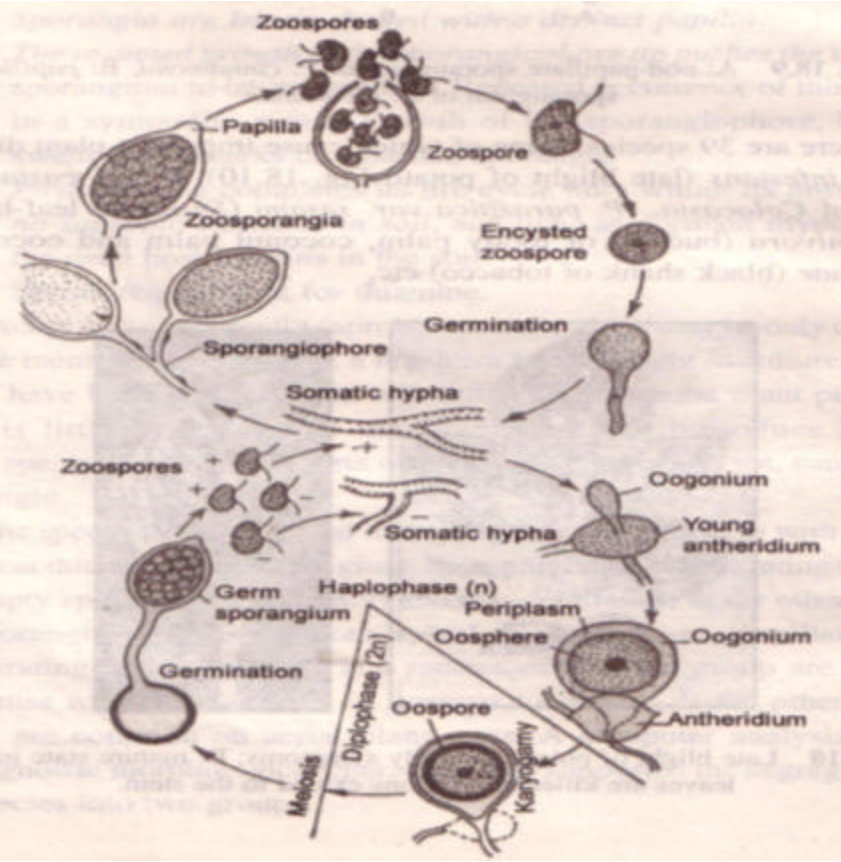
Asexual reproduction is by zoospores produced in sporangia.Sporangia are lemon or pear shaped,thin walled,papillate,formed terminally on sympodially branched sporangiophore (sympodium is with a more or less zig zag growth and characteristic swellings at nodes).Sporangiophores are distinct ie.,easily distinguished from somatic hyphae.Vesicle is not formed, zoospores are differentiated in zoosporangium it self.

Sexual reproduction is by gametangial contact.Antheridium is **amphigynous** (Oogonium penetrates the antheridium) or paragynous.Oospores are smooth,thick walled,round ,dark brown and plerotic.

Also produces resting spores called chlamydospores.

Diseases: *Phytophthora infestans* - Late blight of Potato

P. parasitica var. nicotianae - black shank and leaf blight of tobacco



Differences between *Pythium* and *Phytophthora*

Pythium	*Phytophthora*
1.Mycelium is both inter and intracellular.When intracellular, no haustoria are produced.	Only intercellular. Haustoria are produced.
2. Production of sporangia on somatic hyphae. Sporangiophores are indistinct from hyphae.	Sporangiophores can be distinguished by sympodial branching and nodal swellings.
3.Sporangia are globose or elongated or lobed. They are produced intercalary or Terminally. No papillum.	Sporangia are lemon or pear or oval shaped. Produced terminally. Papillum is present.
4.Sporangia germinate by forming vesicle. Differentiation of zoospores takes Place in the vesicle.	No vesicle is seen. Zoospores differentiate in the sporangium .
5. Antheridium is of paragynous type.	Amphigynous type.
6. Homothallic	Heterothallic.
7.Asexual reproduction is by Zoospores in sporangia. 8.Oospores are plerotic / aplerotic.	Zoospores in sporangia and chlamydospores. Oospores are aplerotic
9.Appresorium not formed	Formed
10.Oospore hyaline,smooth	Brown,warty

9.FAMILY ALBUGINACEAE - IMPORTANT CHARACTERISTICS

1. Members are obligate parasites.
2. Mycelium is intercellular producing knob shaped haustoria.
3. Sporangiophores are specialized which are short, unbranched and club shaped.They are of indeterminate type.Sporangiophores are borne in close proximity to one another in compact layers or beds under the epidermis of the host.
4. Each sporangiophore gives rise to several aporangia which are produced in succession,one below the other,so that a chain of sporangia is formed with the oldest at the tip and youngest at the base (basipetal manner).
5. Sporangia are globose.Successive sporangia are connected by isthmus or disjunctor cell or separation disc.
6. Periplasm is conspicuous.
7. Single genus under the family i.e*., Albugo.*

The diseases caused by this genus are called white rusts. The term rust is restricted normally for the fungi belonging to the order Uredinales of class Teliomycetes of sub division Basidiomycotina and the diseases they cause. Since these white pustules resemble the pustules caused by true rusts in order Uredinales, the term white rust was coined to the group of diseases caused by *Albugo* sp. The white rusts also cause floral malformation and tumors on stems, leaves, petioles etc. due to hypertrophy of infected tissue.

Genus **ALBUGO:**

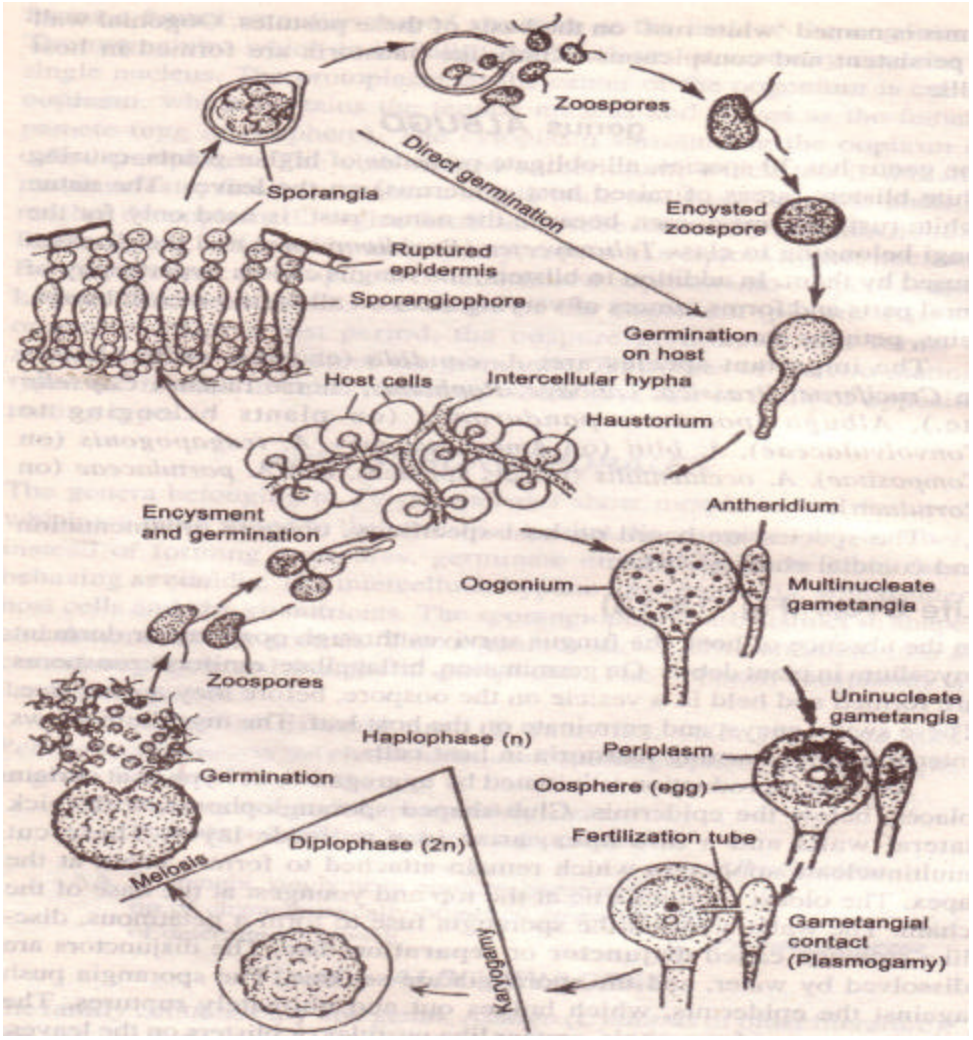
Fungus is an obligate parasite on crucifers and lives in soil in the form of oospores or parasitically on plants.

Mycelium iscoenocytic,hyaline,endophytic,intercellular with knob shaped haustotia.

Asexual reproduction is by zoospores produced in sporangia.Sporangiophores are unbranched,hyaline clavate,bears sporangia in chains in basipetal succession.Sporangia are spherical,thin walled,sessile, hyaline and germinate by zoospores.

Sexual reproduction is by gametangial contact.Oospores are round ,thick walled,dark brown and outer wall warty.

Diseases:White rust on mustard caused by *Albugo candida*



IMPORTANT CHARACTERISTICS OF FAMILY:3.PERONOSPORACEAE

1. All the members are obligate parasites of plants causing diseases called downy mildews.

2. Mycelium is coenocytic and intercellular with haustoria

3.Sporangiophores are well developed, specialized , characteristically branched and determinate type.Sporangiophores attain maturity and later produce sporangia at one time. ie.,single crop of sporangia are produced.

4.Sporangia deciduous, may be papillate (also called operculum) or may not be papillate. In most genera, sporangia germinate by zoospore. However, in some species they germinate by germ tube and function as conidia depending on environmental conditions.

5.Oospores may be plerotic or aplerotic.

6.Periplasm conspicuous.

The name downy mildews(downy= feathery or soft + mildew= superficial growth) is given because of soft feathery growth observed on the lower side of affected foliage consisting of sporangiophores of these fungi.

The members are further divided into different genera and distinguished based on two characteristics viz., 1. morphology of sporangiophore (branching pattern) 2. method of germination of sporangia.

Eg. *Peronospora, Pseudoperonospora, Peronosclerospora, Sclerospora, Plasmopara, Bremia, Sclerophthora.*

DISTINGUISHING CHARACTERISTICS OF DOWNY MILDEW GENERA:

1.***SCLESPORA***:Sporangiophores are stout ,having upright branches, bearing sporangia on sterigmata.Sporangia are h yaline ,ovoid,smooth walled,papillate and germinate by zoospores.Oospore is plerotic.
Eg.*Sclerospora graminicola –downy mildew of bajra*.

2.*PERONOSPORA:*Sporangiophores are dichotomously branched 2-7 times at acute angles and tips of branches are curved and pointed bearing sporangia on sterigmata.Sporangia are hyaline ,ovoid ,non-papillate and always germinate by germ tube. i.e.,sporangia behave like conidia.
Eg;*Peronospora destructor-downy mildew of onion.*

3.*PERONOSCLEROSPORA :* Fungus possess characteristics of both *Peronospora* and *Sclerospora.*Sporangiophores are erect,short,stout,widening towards upper portion,dichotomously branched 2-5 times at apex bearing sporangia on sterigmata.Sporangia are hyaline,elliptical or ovoid,thin walled, non-papillate and germinate by germ tube like *Peronospora.* Oospore is plerotic type like *Sclerospora.*
Eg.*Peronosclerospora sorghi*-downy mildew of jowar
P.philippinensis-downy mildew of maize

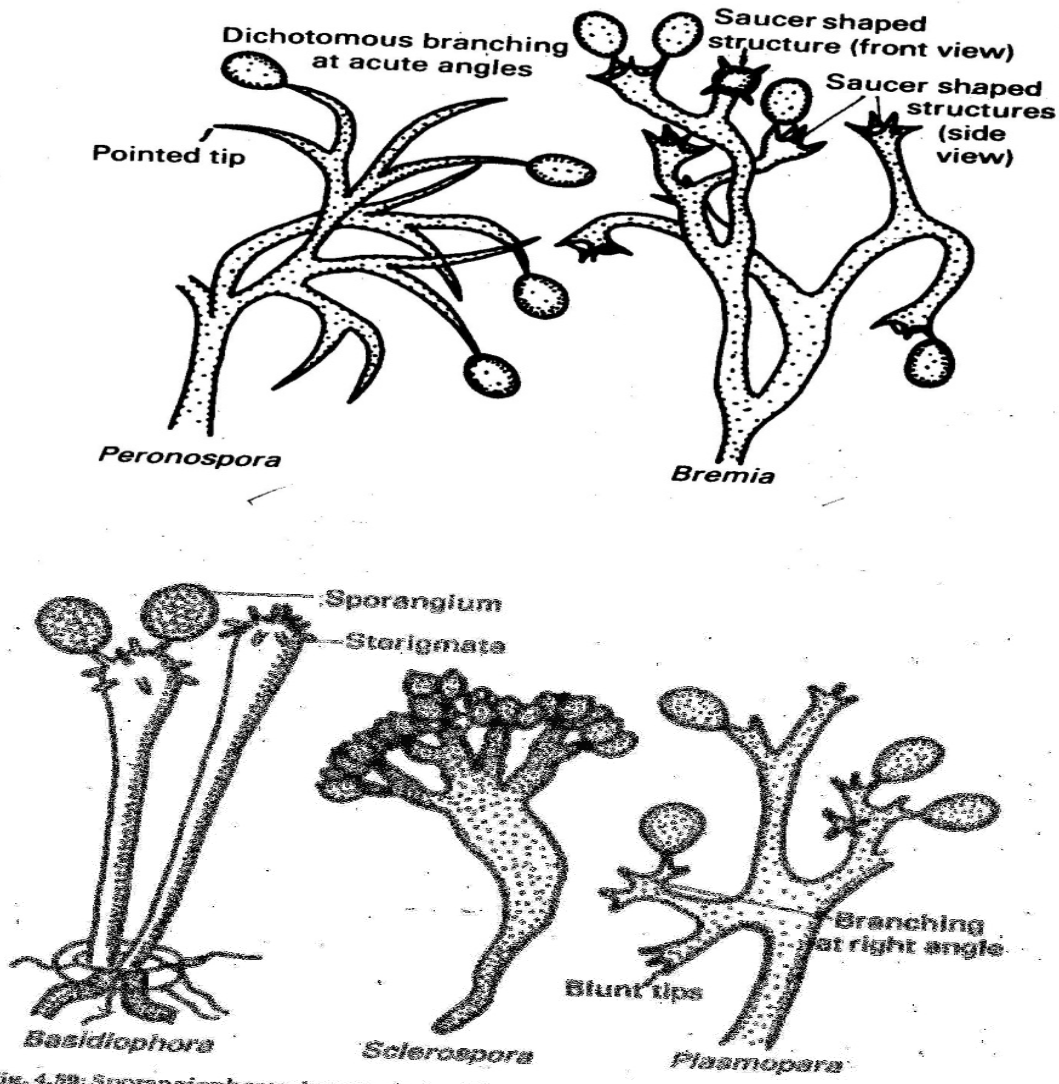


Fig. 4.59: Sporangiophores characteristic of five genera of the Peronosporaceae (Redrawn from Alexopoulos and Mims, 1979).

4.***PSEUDOPERONOSPORA:***Sporangiophores are branched at acute angles with curved,blunt tips,bearing sporangia on sterigmata.Sterigmata are unequal (1 big and 1 small).Sporangia are greyish,ovoid,papillate and germinate by zoospores.
Eg.*Pseudoperonospora cubensis -downy mildew of cucurbits*

5.***PLASMOPARA***;Sporangiophores are branched at right angles to the main axis at regular intervals.Monopodial branching is observed.Subsequent branches are 3-6 which end in blunt sterigmata of 3 in number.Sporangia are ovoid and germinate by zoospores.
Eg.*Plasmopara viticola-downy mildew of grapes.*

6.***BREMIA*** :Sporangiophores are dichotomously branched ,tips of branches are expanded to cup shaped apophysis with four sterigmata bearing sporangia.Sporangia are ovoid,papillate and germinate by zoospores.
Eg:*Bremia lactucae*-downy mildew of lettuce.

10. SUB-DIVISION: ZYGOMYCOTINA
CLASS: ZYGOMYCETES

IMPORTANT CHARACTERISTICS OF CLASS: ZYGOMYCETES, ORDER:MUCORALES:

1.Absence of motile zoospores (planospores) and production of non- motile sporangiospores (aplanospores).

2.Production of thick walled resting spore-zygospore

3.Well developed , coenocytic mycelium and cell wall with chitin

4.Asexual reproduction is by sporangiospores though some species produce Chlamydospores.

5.Sexual reproduction is by gametangial copulation of isogametangia or heterogametangia.

FAMILY:MUCORACEAE:

Eg.Rhizopus stolonifer

Genus:*Rhizopus:*

Rhizopus stolonifer, commonly called as bread mold is a general contaminant of several food materials. The fungus is mostly saprophytic but is a weak parasite.

1.Well developed coenocytic mycelium.Mycelium is differentiated into rhizoids, stolons and sporangiophores

2.Rhizoids / holdfast are a cluster of brown, slender, branched root like structures which arise from the lower side of stolons and penetrate into the substrarum. These are useful for anchoring the thallus into the substratum and for absorption of nutrients.

3.Stolons or runners are aerial hyphae which grow on the surface of substratum horizontally and connect the two nodal points (the junction of stolon and rhizoid or the point from which rhizoids are produced is called node).

4.Sporangiophores are erect, unbranched hyphae usually produced in fascicles (groups) only from the nodes during asexual reproduction. Each sporangiophore bears a single sporangium at its tip. Sporangia are large, globose , many spored with a sterile structure called columella.

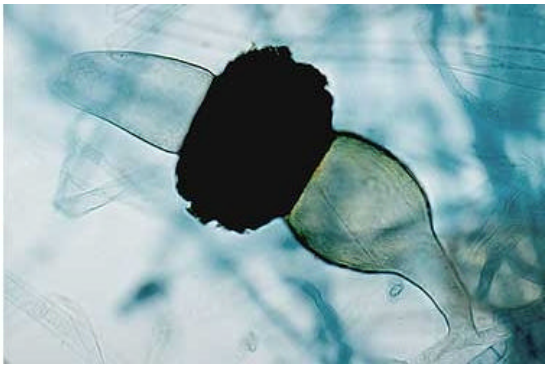
5.Asexual reproduction is by non-motile sporangiospores which are uninucleate,globose,brown,smooth walled and are produced inside columellate

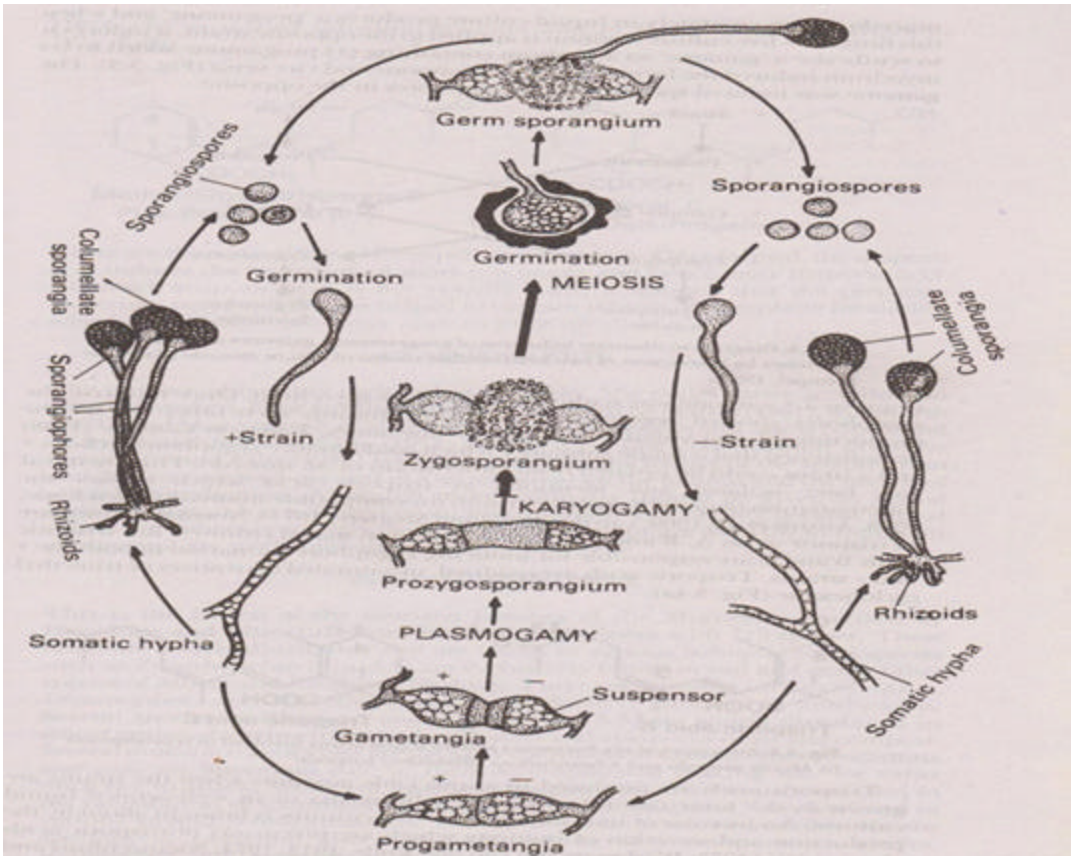
sporangium.The sporangiospores are liberated by rupture of sporangial wall.The spores germinate under favourable conditions and gives rise to mycelium,

6.Fungus is heterothallic.Phenomenon of Heterothallism was discovered by in 1904 by A.F.Blakeslee.Heterothallism is favoured by sexual harmones called gammones or trisporic acid.

7.Sexual reproduction is by isogametangial copulation.Zygospores are thick walled,dark,warty sexual resting spores which develops in a zygosporangium.

Diseases: Soft rot of sweet potato, fruits and vegetables.





11.SUB DIVISION: ASCOMYCOTINA

The members of sub division Ascomycotina are commonly called as sac fungi, because of production of sexual spores, ascospores in a sac like structure called ascus. The members of sub divisions Ascomycotina, Basidiomycotina and Deuteromycotina are also considered as higher fungi. The members are found in a variety of habitats . Some are parasitic on plants, some saprophytes living in soil or on decaying vegetable matter or grow on dung.

IMPORTANT CHARACTERISTICS OF SUB-DIVISION ASCOMYCOTINA :

1. Produce definite number (usually eight) of sexual spores (ascospores) in a sac like structure called ascus.
2. Mycelium is septate,branched and organized into tissues known as plectenchyma.
3. Production of sexual fruiting body called ascocarp in which asci are produced.
4. Absence of motile spores and presence of asexual spores called conidia.
5. Presence of a short dikaryotic phase in ascogenous hypha or ascogenous cell.

1. **Somatic characteristics**: Mycelium is septate and organized into fungal tissues. Some consists of septate hyphae except in a few cases like yeasts which are single celled. Mycelium is profusely branched (except in yeasts) and the hyphal walls containing chitin.In few species cellulose is also reported. The septum is simple, incomplete, perforated and have a central pore/ septal pore through which cytoplasm and nuclei move from one cell to another cell thus, cytoplasmic continuity is maintained.
2. **Fungal tissues**: Mycelium is mostly organized into fungal tissues known as plectenchyma. These tissues are chiefly associated with fruiting bodies called ascocarps viz.,cleistothecium,perithecium,apothecium and ascostroma.
3. **Asexual reproduction:Asexual stage is also called as anamorph or imperfect stage.** Asexual reproduction occurs by fission (Yeasts), budding (blastospores) (Yeasts),fragmentation(majority of fungi) chlamydospore and conidia. Conidia are short lived, indefinite(enormous) in number,may be produced directly from somatic hyphae, or from conidiogenous cells or from specialized hyphae called conidiophores. Conidiophores may be short or long,branched or

unbranched or may form complex asexual fruiting bodies viz., pycnidium, acervulus, sporodochium and synnemata and the method vary with species and environmental conditions.

4. **Sexual reproduction**: Sexual stage is also called as teleomorph or perfect stage or ascigerous stage / state. Sexual spores are called ascospores which are produced in a sac like structure called ascus. The methods of sexual reproduction are gametangial copulation, gemetangial contact, spermatiz ation and somatogamy. The gametangia are antheridium (male sex organ) and ascogonium(female sex organ). Ascogonium is provided with a hair like structure called trichogyne

(receptive neck of ascogonium), which is often long and functions as a fertilization tube.

5. **The asci may be formed by any of the following methods**.

A.**Direct** development of zygote into ascus - eg. In yeasts, the compatible nuclei brought together during plasmogamy, fuse (karyogamy) and the cells containing single diploid nucleus (zygote) directly develops into ascus.

B.**Indirect Development** of asci from ascogenous hyphae- eg. sexual reproduction and ascus development as exemplified by general life cycle pattern in *Pyronema omphalodes*.

6.Short dikaryotic phase is seen.Plasmogamy and karyogamy are separated both by space and time.

DEVELOPMENT OF ASCUS INDIRECTLY FROM ASCOGENOUS HYPHAE OR LIFE CYCLE OF *PYRONEMA OMPHALODES*:

1.The male sex organ is known as antheridium and the female sex organ is known as ascogonium.

2.During sexual reproduction,the male nuclei from the antheridium pass through the trichogyne into the ascogonium and pairs up with female nuclei to form dikaryon. (they do not fuse thus delaying karyogamy) .

3. The sexual act stimulate the ascogonium to produce a number of swellings/ papillae just opposite to groups of nuclei located in the periphery of the ascogonium.

4. The dikaryons in ascogonium multiply by conjugate division and as these swellings enlarge, the daughter nuclear pair from ascogonium begin to pass into swellings one by one.

5. Eventually, the swellings elongate into ascogenous hyphae. The nuclear pair or dikaryon in ascogenous hyphae undergoes conjugate divisions.Later, septa are formed in ascogenous hyphae in such a way that each cell of ascogenous hyphae is dikaryotic,except the terminal cell which is uninucleate.Thus,the dikaryotic phase in Ascomycotina is represented by ascogenous hyphae where in one nucleus is ascogonial origin and the other antheridial.

6.The penultimate binucleate cell of ascogenous hypha elongates and bends over to form a hook like cell called as ' hook cell ' or 'crozier '. The two nuclei in crozier cell undergoes conjugate division to form 4 nuclei.

7. Now septa are formed in hook cell in such a way that basal and apical cells consist of single nucleus each,and the middle cell consists of two nuclei.This binucleate middle cell is known as 'Crook cell '.

8.Crook cell enlarges and converted into 'Ascus mother cell '. Karyogamy takes place in ascus mother cell fusing two nuclei and forms diploid nucleus (2 n). Thus, plasmogamy (in ascogonium) and karyogamy (in ascus mother cell) occur at different places.Meanwhile ascus mother cell elongates and develops into ascus.

9.The diplod nucleus undergoes meiosis resulting in the formation of 4 haploid nuclei.

10.These 4 haploid nuclei further undergo mitosis forming 8 haploid nuclei.

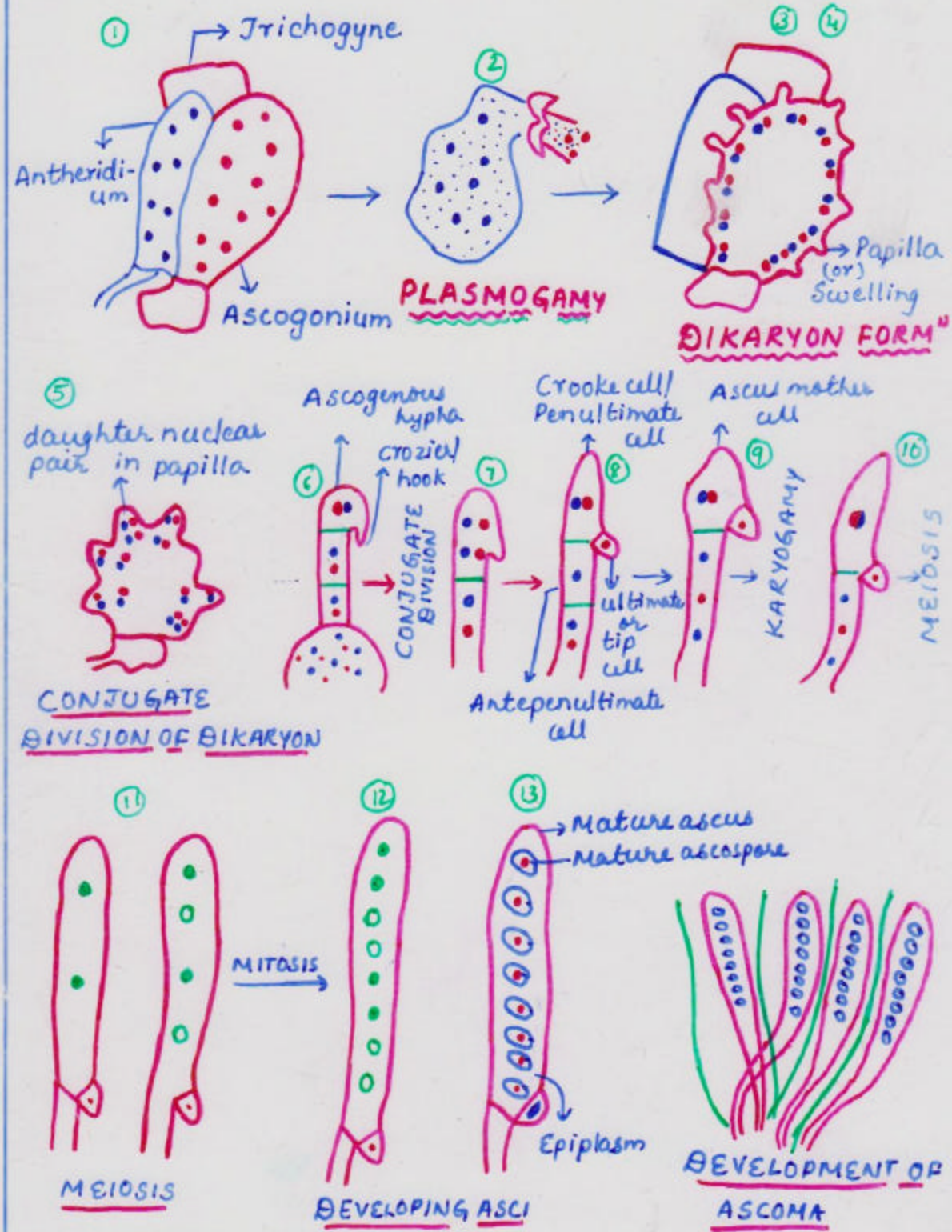
11.The nuclei develop in to ascospores by free cell formation.The process of formation of ascospores is called 'Free cell formation' or 'Ascosporogenesis'. The ascospores are formed by aggregation of cytoplasm of the ascus around the nucleus forming definite walls. Epiplasm is the portion of cytoplasm left over, out side the ascospore walls , which supplies nutrients to the developing ascospores.

12. The number of ascospores may be 8, 16, 32, 64, or even more depending on the number of mitotic divisions following meiosis. The ascospores vary in shape, size and some times in color also.

13. Based on compatibility, the members may be homothallic(eg. *Aspergillus,* powdery mildew fungi) or heterothallic(Eg.*Saccharomyces cerevisiae*).

GENERALISED LIFE CYCLE OF ASCOMYCOTINA

Eg: Pyronema omphalodes



ASCOSPOROGENESIS = FREE CELL FORMATION

MORPHOLOGY OF ASCI:

Ascus is a sac like structure usually containing a definite number of ascospores (typically eight) formed by a process called free cell formation after karyogamy and meiosis. In majority members of ascomycotina shape of ascus may be elongated, cylindrical , clavate or club shaped,except in some groups where they are globose or ovoid. Asci may be stalked or sessile. Generally ascus represents a single cell but in some ascus may be septate.

Origin of asci:

Asci may arise from a common place called fascicle and spread out like a fan or they may arise singly and distributed irregularly at various levels in the fruiting body. They may also form at the base of the fruiting body in a definite layer called as hymenium. In some cases they are not produced in any fruiting body and remain exposed and are called as naked asci.Eg.*Taphrina.*

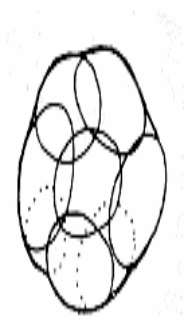
Types of asci based on structure of ascus wall:

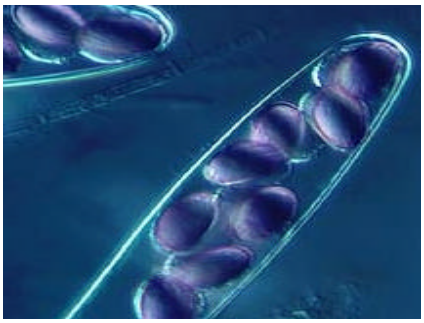
The wall structure plays an important role in classifying the species.There are three types of asci based on structure of ascus wall.

1. **Prototunicate ascus**: This is the primitive type.The wall is very thin, dissolves at maturity and spores are released. The ascospores are released in a mucilaginous substance. Eg. *Eurotium*

2. **Unitunicate ascus:** The ascus wall consists of 2 layers which are rigid and unite together through out length and existence of the ascus. . The outer wall is called exotunica or exoascus and the inner wall is called endotunica or endoascus and not separated during spore release. The spores are released through a terminal pore, slit or operculum.Eg. *Claviceps.*

3. **Bitunicate ascus**: The ascus wall consists of 2 layers.At the time of spore release,the exotunica bursts and the endotunica expands up to twice or more of its original length separating from exotunica while exotunica remains as originally formed. The spores are released through a pore at the tip of endotunica. In this,the walls are separated. The behavoiur of bitunicate ascus during discharge of spores is described as Jack- in – a box.Eg. *Venturia.*





ASCOCARPS:

Ascocarps are the fruiting bodies of members of Sub-division Ascomycotina which produce the asci containing the ascospores. In some members such as yeasts, *Taphrina* fruiting bodies are not produced and the asci are naked.

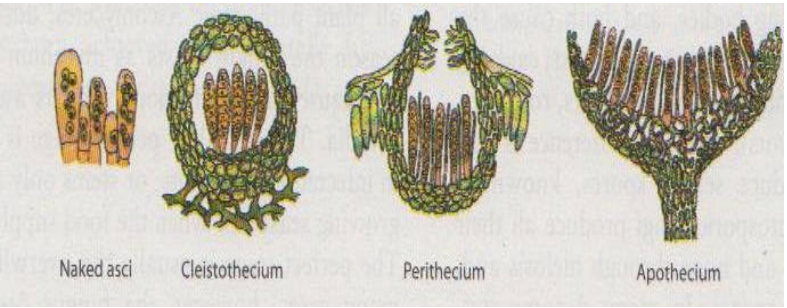
Types of ascocarps : 4 types.

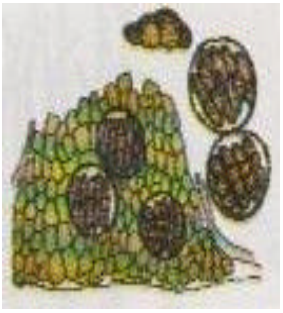
1. **Cleistothecium**: It is a completely closed ball like(globose) ascocarp and it is made up of a wall with pseudoparenchymatous tissue called as peridium. In some species these are provided with outer appendages. Asci are scattered or distributed at different levels in ascocarp.When the asci are matured, ascospores are released by disintegration of peridium. Eg. *Eurotium, Erysiphe.*
2. **Perithecium**; It is a flask shaped more or less closed ascocarp but provided with a pore or opening at the tlp called true ostiole through which ascospores are released at maturity.Ostiole is lined inside with sterile structures called as periphysis. The wall is called peridium . The asci are arranged in definite layer called hymenium. In between the asci,there are sterile thread like structures called paraphyses which help in liberation of ascospores.Eg. *Claviceps, Xylaria.*

3. **Apothecium.:** It is an open cup shaped ascocarp with a wall peridium. The asci are arranged in a layer called hymenium , either exposed from the beginning or later exposed. The sterile structures called paraphyses
(tips free / not fused) are also present intermingled with asci which help in liberation and dispersal of ascospores.**Epithecium** is a layer on the surface of hymenium of an apothecium formed by fusion of tips of paraphyses over the asci.Eg. *Peziza, Tuber.*

4. **Ascostromata**: The asci are formed directly in cavities called locules with in stroma. The stroma itself serves as wall of ascostroma. Sterile structures called pseudoparaphyses are present in ascostromata.Eg.Elsinoe

If the ascostromata is with a single locule ie., An unilocular ascostroma which resembles perithecium with pseudoparaphyses is called as pseudothecium.Eg.*Venturia.*





ascostroma

STERILE THREAD LIKE STRUCTURES IN ASCOCARP:

Ascocarps contain sterile thread like structures of various types.

1.Paraphyses: These are elongated, cylindrical , club shaped or sometimes branched threads arising from bottom of ascocarp. They may be septate or aseptate. They grow among asci in hymenium and remain free at their tips. However, in Discomycetes, the tips fuse together forming a layer known as epithecium. Paraphyses help in liberation and dispersal of ascospores.
Eg. Perithecium (*Claviceps)* , Apothecium(*Peziza).*

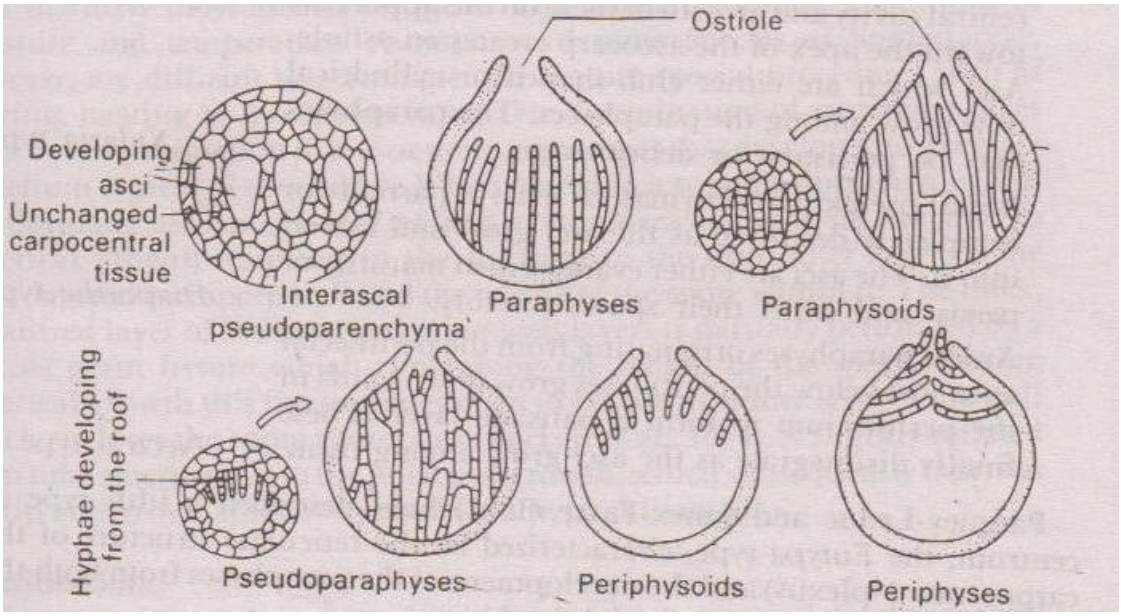
2.Paraphysoids:These are inter ascal tissue that stretch and resemble pseudoparaphyses,but remotely septate,very narrow,anastomose and tips remain free.

3.Periphyses: These are short, hair like threads lining in side of an ostiole of perithecium or pseudothecium. Their function is to direct the asci towards ostiole at the time of ascospore release.

Eg. Perithecium(*Claviceps)* , Pseudothecium(*Venturia).*

4.Periphysoids: These are the lateral periphyses which are short and originate above the level of developing asci but do not reach base of cavity and curve upwards towards apex.

5.Pseudoparaphyses: These are distinct,vertical, paraphyses-like hyphae,that originate above the level of asci and grow downwards between the developing asci,finally becoming attached to the base of the cavity,thus forming curtains between asci.These are often broader,regularly septate,branched and anastomosing.Eg. *Elsinoe.*



Ascomycotina is sub divided into six classes based on presence or absence of ascocarp and shape of the ascocarp.

Class 1. Hemiascomycetes 2. Plectomycetes 3. Pyrenomycetes 4. Discomycetes 5. Loculoascomycetes. 6. Laboulbeniomycetes.

Important plant pathogens are in the classes : Hemiascomycetes,Plectomycetes,Pyrenomycetes and Loculoascomycetes

12. IMPORTANT CHARACTERISTICS OF CLASS HEMIASCOMYCETES

1.Mycelium is pseudomycelium or dikaryotic mycelium.

2.Ascocarp is absent i.e.,asci are naked.

3.Asci are not formed from ascogenous hyphae but formed directly from zygote or ascogenous cells.

4.Asci release ascospores by bursting or deliquescing of ascus.

5.Orders:

a.Protomycetales, Family:Protomycetaceae.Eg.Protomyces,Protomycopsis

b.Taphrinales, Family:Taphrinaceae Eg.Taphrina

IMPORTANT CHARACTERISTICS OF ORDER TAPHRINALES, FAMILY TAPHRINACEAE :

1. The order Taphrinales includes a single family Taphrinaceae and a single genus *Taphrina.*

2. Mycelium is septate containing typical thick walled binucleate cells called ascogenous cells.Hyphae may be intercellular, sub cuticular, or may grow with in walls of epidermis.

3. Asexual reproduction is through small oval or spherical uninucleate haploid blastospores that bud from ascospores either with in the ascus or after their release.

4. Ascocarps are not produced. Asci are naked. Sex organs are not formed. Asci are formed from special binucleate ascogenous cells. Asci are unitunicate and tip of the ascus bursts at the time of libetration of ascospores.

Eg. *Taphrina deformans* - peach leaf curl

T. maculans – leaf blotch of turmeric

13. IMPORTANT CHARACTERISTICS OF CLASS PLECTOMYCETES

1. Ascocarp is a non-ostiolate cleistothecium.

2. Asci are thin walled, globose to pyriform,unitunicate.

3. Asci are produced from ascogenous hyphae,evanescent, scattered at various levels in the cleistothecium and not forming a definite hymenium.

4. Ascospores are unicellular, released by disintegration of ascus wall.

IMPORTANT CHARACTERISTICS OF ORDER : ERYSIPHALES, FAMILY : ERYSIPHACEAE :

1. Erysiphales is the exceptional order as it produces cleistothecium instead of perithecium. The reason is that the asci are grouped in fascicles or form a basal layer (hymenium) at maturity and ascospores are released violently with force.Cleistothecia are formed on superficial mycelium with out formation of stroma.

2. Members cause a disease called powdery mildew because they produce enormous number of conidia on the surface of infected host plants which appear to the naked eye as a white powdery coating.

3. Mycelium is hyaline and mostly ectophytic

4. Members are obligate parasites of plants and nourishment through haustoria.

5. Asci are persistant, globose to pyriform and explodes at the time of release of ascospores.

6. Important plant pathogenic genera are 1. *Erysiphe 2. Leveillula 3. Phyllactinia 4. Uncinula 5. Sphaerotheca 6. Podosphaera 7. Microsphaera*

Somatic characteristics:

Mycelium is well developed, septate, uninucleate, profusely branched entirely superficial (ectophytic) except *Leveillula* (endophytic) and *Phyllactinia* (semi-endophytic),produce haustoria into epidermal cells to absorb nourishment.

Asexual reproduction :

Asexual reproduction is through conidia produced on conidiophores. Conidiophores are long, erect and hyaline.

Three types of conidial stages are recognised in powdery mildews.

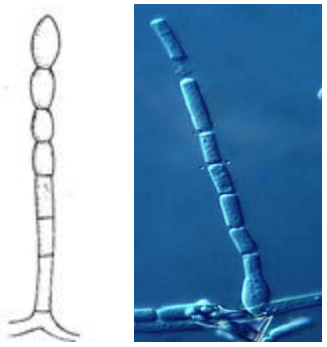
1. Oidium 2. Oidiopsis 3. Ovulariopsis

1. ***Oidium (Acrosporium)*** : Mycelium is ectophytic, hyaline. Conidia are developed from a flask shaped mother cell (spore mother cell) formed on a short conidiophore . Conidia are barrel shaped with flat ends and are produced in chains..The conidia are also referred to as meristem arthrospores as these are formed by fragmentation of hyphae. Eg. The perfect stages viz., *Erysiphe,Podosphaera, Uncinula, Sphaerotheca and Microsphaera* produce *Oidium* as conidial stage.

2. ***Oidiopsis***: Mycelium is endophytic.Conidiophores may be branched or unbranched, erect, septate, hyaline and emerge through stomata. Conidia are

produced singly and cylindrical in shape. Conidia are of two types. a. blunt tip b. pointed tip. Eg. *Leveillula* sp. produce *Oidiopsis* as conidial stage.

3. ***Ovulariopsis:*** Mycelium is partly ectophytic and partly endophytic.The conidiophores are hyaline, septate, unbranched, and bear a single conidium. Conidia are rhomboid in shape.In some species,the conidiiphores are spiral in shape. Eg. *Phyllactinia subspiralis. Phyllactinia sp* .produce ovulariopsis as conidial stage.



Oidium

Oidiopsis

Ovulariopsis

Powdery mildew conidia do not require free water for germination and are able to germinate at very low humidity levels.

Sexual reproduction:

Some species are homothallic and some are heterothallic. Antheridia and ascogonia are sex organs.Both gametangia are uninucleate .Fruiting body is cleistothecium which is produced on superficial mycelium as a result of gametangial contact. The cleistothecia are first white and finally black in color when mature. The wall is made up of pseudoparenchymatous tissue of several layers called peridium. Over wintering of powdery mildews takes place in clestothecial stage which are resistant to winter conditions. In perennials , the mycelium may over winter in the dormant buds of host. In warm weather , many species never form cleistothecia and perpetuate by means of conidia. The cleistothecia are provided with characteristic appendages which vary considerably in length and character.

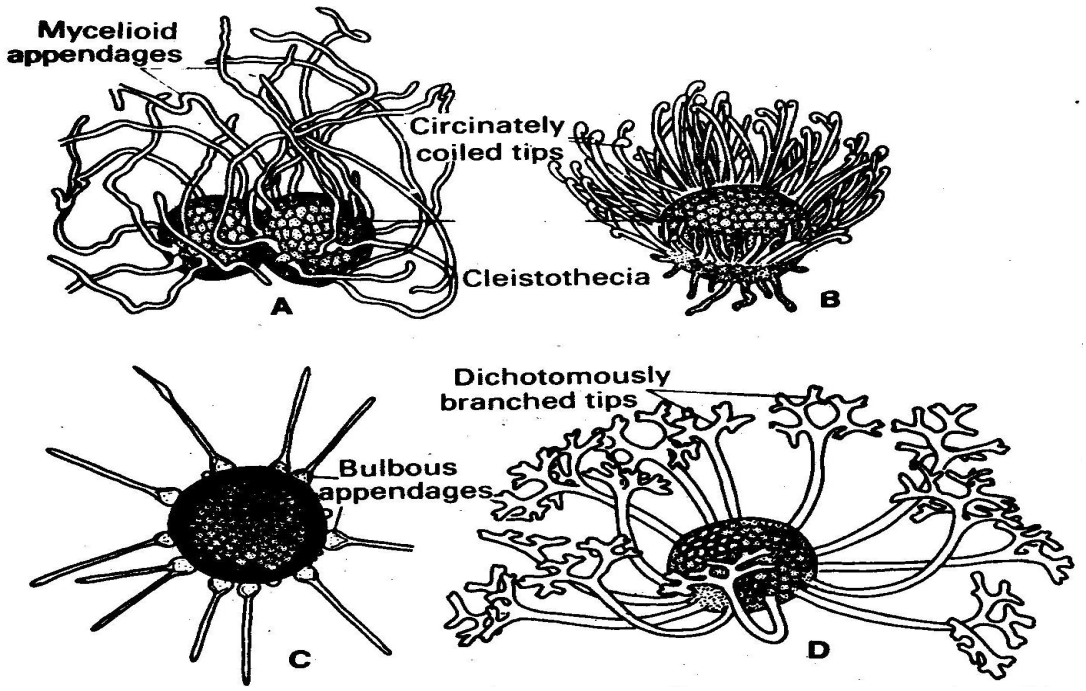
Types of cleistothecial appendages:

1. **Mycelioid appendages:** These are flexible, flaccid and resemble somatic hyphae. Eg. *Erysiphe, Sphaerotheca, Leveillula.*

2. **Circinoid / hooked / coiled appendages** : These are rigid with curled or coiled tips. Eg. *Uncinula*.

3. **Dichotomously branched tips:** These are rigid,flattened with dichotomously branched tips. Eg. *Podosphaera, Microsphaera.*

4. **Bulbous base with pointed tip:** These are rigid, spear like with bulbous base and pointed tip. Eg. *Phyllactinia.*



KEY FOR THE IDENTIFICATION OF POWDERY MILDEW GENERA:

1. Type of cleistothecial appendage

a. mycelioid

b. dichotomously branched

c. circinoid

d. bulbous base with pointed tip

2. Number of asci in cleistothecium

a.one

b.many

3. Type of conidial stage

a. Oidium

b. Oidiopsis

c. *Ovulariopsis*

4. Nature of mycelium

a. ectophytic

b. endophytic

c. semi- endophytic

MYCELIUM

1. Ectophytic

a. One ascus per cleistothecium

Oidium type conidial stage

Mycelioid appendages- Eg. *Sphaerotheca*

Dichotomously branched appendages - Eg. *Podosphaera*

b. Several asci per cleistothecium

Oidium type conidial stage

Mycelioid appendages -Eg. *Erysiphe*

Circinoid appendages -Eg. *Uncinula*

Dichotomously branched appendages -Eg. *Microsphaera*

2. Endophytic

Many asci per cleistothecium

Oidiopsis type conidial stage

Mycelioid appendages-Eg. *Leveillula*

3. Semi- endophytic

Many asci per cleistothecium

Ovulariopsis type conidial stage

Bulbous base with pointed tip -Eg. *Phyllactinia*

Important powdery mildew diseases:

CROP	PATHOGEN
1. Pea	*Erysiphe polygoni*
2. Cucurbits	*E. cichoracearum*
3. Grasses	*E. graminis*
4. Mulberry	*Phyllactinia corylea*
5. Chillies	*Leveillula taurica*
6. Apples	*Podosphaera leucotricha*
7. Roses	*Sphaerotheca pannosa*

8. Lilac	*Microsphaera alni*
9. Grapes	*Uncinula necator*

14. IMPORTANT CHARACTERISTICS OF CLASS: PYRENOMYCETES

1. Ascocarp is mostly a true perithecium in which asci are arranged in a definite layer called hymenium. Perithecium may be globose or flask shaped. Some members produce cleistothecium.
2. Asci are unitunicate, persistant, club shaped or cylindrical.

This class includes 2 important Orders viz., Hypocreales and Sphaeriales.

IMPORTANT CHARACTERISTICS OF ORDER HYPOCREALES :

1.In the centrum ,apical paraphyses called peri-physoids arise from perithecial apex below the periphyses and finally disintegrate as the asci grow among them.

2.Ascocarps are usually bright coloured , fleshy, rarely non-ostiolate.

3.Asci are clavate to cylindrical.

4.Ascospores are colourless, non-septate or multiseptate .

IMPORTANT CHARACTERISTICS OF FAMILY CLAVICIPITACEAE ;

1.Members produce perithecia within a well developed stroma composed of entirely fungal tissue.

2.Asci are long, narrow and cylindrical with a thick cap perforated by a long cylindrical pore through which ascospores escape.

3. Lateral walls of ascocarps are lined with periphysoids (lateral paraphyses that originate all along lateral walls of perithecium but do not occur among asci at the base of perithecium.).

4.The ascospores are thread like and break into fragments after they are released and each fragment function as individual spore capable of giving rise to mycelium.

5.Many members are parasitic on grasses infecting gynoecium which later converts it into sclerotial bodies (ergots) and thus causing a group of diseases known as ergots.

6.Asexual stage:The fungus parasitises the ovaries of plants and form sporodochia (asexual stage) bearing short conidiophores with minute, oval

conidia at their tips. These conidia are mixed with a sticky sweet nectar like secretion.This sugary slime is called honey dew and hence the asexual stage is commonly called as **honey dew stage/sphacelia stage**.

7.Sclerotial stage:Later mycelium hardens converts into purple black hard sclerotia.The sclerotium of *Claviceps* is known as ergot commercially. During the harvesting operation, many sclerotia are knocked off the spikelets and fall to the ground where they pass the winter.The ergots are highly poisonous as they contain powerful alkaloids such as ergonovin, ergometrine and ergotamine.When the animals or human beings consume ergot contaminated grains or flour, a serious disease termed **ergotism** occurs.

Another important disease in humans due to consumption of ergot contaminated grain flour of rye is **St. Anthony's fire.** Alkaloids have also got medicinal values. They are used to prevent haemorrhage (bleeding) during child birth and as artificial abortifacient. The drug prepared from ergot bodies is called **ergotin**.

Diseases:

Ergot of rye- *Claviceps purpurea* (I.S- *Sphacelia segetum*)

Ergot of bajra- *C. microcephala,C.fujiformis*

Sugary disease of sorghum- *Claviceps sp.* (I.S: *Sphacelia sorghi)*

Parasitic on insects - *Cordyceps sp.*

15.IMPORTANT CHARACTERISTICS OF CLASS LOCULOASCOMYCETES

1. Ascocarp is ascostromata or pseudothecium.
2. Presence or absence of sterile structures pseudoparaphyses in ascocarp.
3. Asci are bitunicate and are borne in locules in stromatic tissue.

Order: 1. Pleosporales

Family: Venturiaceae

Eg. *Venturia inaequalis(I.S: Spilocaea pomi)*

Family: Pleosporaceae

Eg. *Cochliobolus miyabeanus(I.S:Bipolaris oryzae)*

Order 2. Myriangiales

Family: Myriangiaceae

Eg. *Elsinoe ampelina (I.S:Sphaceloma ampelinum)*

Order 3. Dothidiales

Family: Dothidiaceae

Eg.*Mycosphaerella arachidis*

(I.S:Cercospora arachidicola)

Mycosphaerella berkeleyi

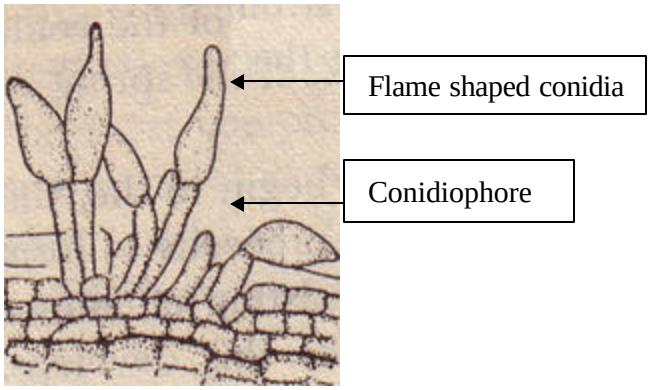
(I.S:Cercosporidium personatum)

IMPORTANT CHARACTERISTICS OF ORDER: 1. PLEOSPORALES, FAMILY: VENTURIACEAE

1. Fruiting body is called pseudothecium produced sub epidermally or sub cuticularly.
2. Presence of pseudoparaphyses in fruiting body.
3. Conidiophores are short producing flame shaped conidium.
4. Conidiophore and conidia resemble a short burning candle.
5. Ascospores are 2 celled, ellipsoid, unequal in size, hence the name of the species "inequalis".

Eg. Apple scab- *Venturia inaequalis (I.S:Spilocaea pomi)*

Pear scab- *V. pyrina*



IMPORTANT CHARACTERISTICS OF FAMILY : PLEOSPORACEAE

1. Ascocarp is pseudothecium.
2. Ascospores are filiform and many celled.
3. Conidia are dark, cylindrical with many transeverse septa (pseudosepta)

Eg. Brown spot of rice- *Cochliobolus miyabeanus* (*I.S: Bipolaris oryzae)*

Leaf spot of maize- *C. heterostrophus*

16. IMPORTANT CHARACTERISTICS OF ORDER:2. MYRIANGIALES

FAMILY: MYRIANGIACEAE

1. Ascocarp is ascostromata with uniascal locule.
2. Locules are distributed at various levels of ascostromata.
3. Asci are globose, thick walled with 8 ascospores.
4. Ascospores are 4 celled.

Eg. Citrus scab- *Elsinoe fawcetti,* Grape anthracnose- *E. ampelina*
Mango scab- *E. mangiferae*

IMPORTANT CHARACTERISTICS OF ORDER :3, DOTHIDIALES,

FAMILY : DOTHIDIACEAE

1. Ascocarp is pseudothecium, spherical in shape, immersed in host tissue, ostiolate with periphyses, polyascal locules, pseudoparaphyses absent.
2. Asci are clavate with 8 ascospores.
3. Ascospores are 2 celled, hyaline.
4. Sexual reproduction is by spermatization in some of the species producing spermatia in spermagonium.

Eg. Tikka disease

a)Early leaf spot of groundnut- *Mycosphaerella arachidis*
(syn: *M. arachidicola)* (I.S: *Cercospora arachidicola)*

b)Late leaf spot of groundnut- *Mycosphaerella berkeleyi*
(I.S:Phaeoisariopsis *personata)* (syn: *Cercospora personata)*

Sigatoka leaf spot of Banana:Mycospherella musicola
(I.S:cercospora musicola)

IMPERFECT STAGES FOR THE GENERA OF CLASS LOCULOASCOMYCETES:

PERFECT STAGE	***IMPERFECT STAGE***
1. *Venturia inaequalis*	*Spilocaea pomi*
2.Cochliobolus miyabeanus	*Bipolaris oryzae*
3.Elsinoe ampelina	*Sphaceloma ampelinum*
4.Mycosphaerella arachidicola	*Cercospora arachidicola*
5.Mycosphaerella berkeleyi	*Phaeoisariopsis personatum*
6.Mycospherella musicola	*Cercospora musicola*

17.SUB- DIVISION: BASIDIOMYCOTINA

1.Members of this sub-division are highly advanced fungi.

2.The name Basidiomycotina is given because the fungi produce sexual spores on a special club shaped fruiting body called basidium.

3.A definite number of sexual spores called basidiospores (usually four in number) are produced on each basidium.

4.Fungi belonging to this sub division are referred as club fungi.

5.The group includes mushrooms,toadstools,shelf fungi,jelly fungi, puff balls, coral fungi,bracket fungi, birds nest fungi,stink horns, rusts and smuts.

General characteristics:

1. Produce sexual spores (basidiospores) on the out side of a specialized spore producing structure called basidium.
2. A typical basidium is a club shaped structure ,bearing specially 4 basidiospores on pointed projections called sterigmata.
3. Basidiospores are haploid, uninucleate and are the result of plasmogamy, karyogamy and meiosis.
4. Dikaryotic phase dominates the life cycle.
5. Presence of clamp connections on the mycelium.
6. Presence of dolipore septum, except in rusts and smuts.
7. Absence of motile spores.

Somatic structures:

The mycelium consists of well developed septate mycelium.The mycelium passes through three distinct stages before the completion of life cycle. They are primary, secondary and tertiary mycelium.

1.Primary mycelium: (homokaryon or monokaryotic mycelium) .It consists of hyphae with uninucleate cells. It usually develops from the germination of a basidiospore.It may be multinucleate at first when the nucleus of basidiospore divides many times as the germ tube emerges and grow. This multinucleate stage is short lived because septa are formed dividing the mycelium into uninucleate cells.

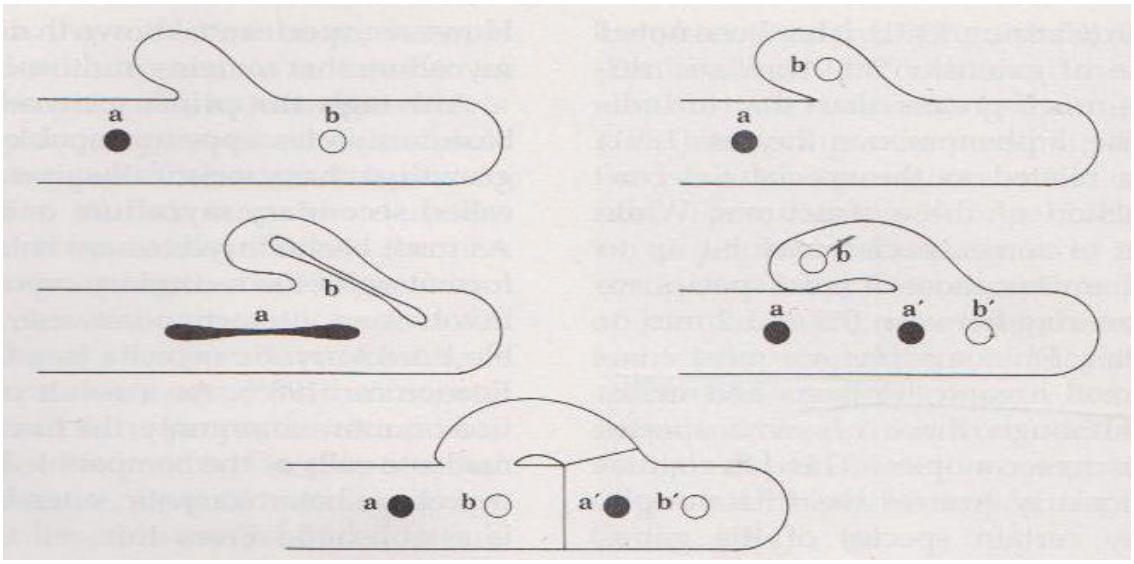
2.Secondary mycelium: (dikaryon or dikaryotic mycelium).This originates from primary mycelium and its cells are dikaryotic (binucleate, n+ n nucleus) formed by

somatogamy between compatible cells of monokaryotic mycelium or fusion of 2 basidiospores or spermatization.It exists during major part of the life cycle.Thus, this stage is an independent and extensive phase unlike the short dikaryotic phase of Ascomycotina.This is associated with special structures called clamp connections through which dikaryotization takes place.(dikaryotization is a process by which monokaryotic primary mycelium is converted to dikaryotic secondary mycelium).

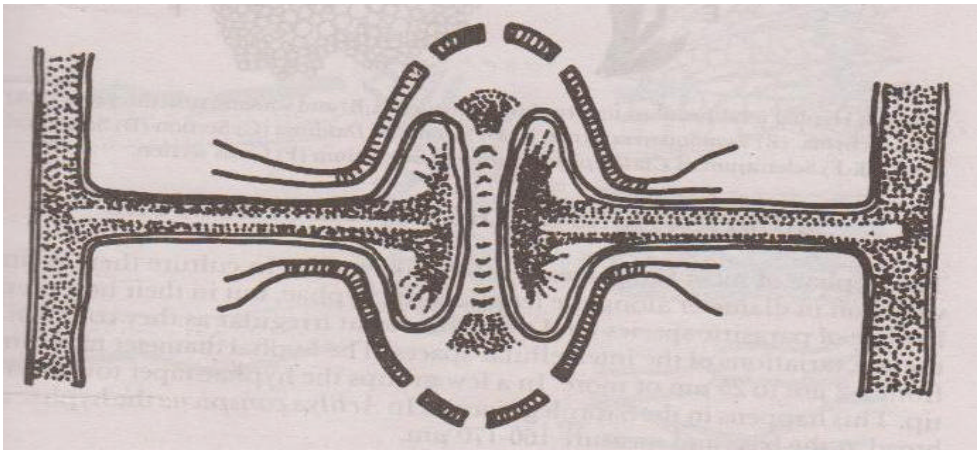
3.Tertiary mycelium: This is the binucleate mycelium which is organized into specialised tissues which form into fruiting bodies called sporophores (basidiocarps) in the members of higher Basidiomycotina .

Clamp connections: It is a hook like structure formed laterally in between the dividing nuclei in a dikaryotic hypha. It acts as a by-pass for the nuclei , as they can not pass through septal pore ie., dolipore septum. It is meant for multiplication of dikaryotic cells.

Mode of development of clamp connection: When a binucleate cell is ready to divide, a small lateral branch called clamp connection arises from the cell between the 2 nuclei (a and b) and begins to form a curved hook.Then the 2 nuclei divide simultaneously. One division orients obliquely so that one daughter nucleus "b" forms in the clamp connection and the other daughter nucleus "b^1" forms in the dividing cell. The second division orients itself along the length of the dividing cell so that one daughter nucleus "a" forms near one end of the cell and the other "a^1" **approaches** the nucleus "b^1" of the first division near the other end of the cell. In the mean time, the clamp bents over and its free end fuses with the cell so that clamp forms a bridge through which one of the daughter nucleus " b" passes to the other end of the cell and approaches daughter nucleus " a ". A septum is formed to close the clamp at the point of origin and another septum vertically under the bridge to divide the parent cell into two daughter cells with " a" and " b " in one daughter cell and nuclei " a^1 " and " b^1 " in the other cell.The clamp remains permanently attached to hyphae. Its presence indicates that the hypha is dikaryotic.



Dolipore septum: Both primary and secondary mycelium consists of dolipore septum. The septum around the central pore swells at the center forming a barrel shaped structure with open ends,thus forming a septal pore.The septal pore is surrounded by a cup like or dome shaped membrane called parenthosome or septal pore cap or nuclear pore cap. It is made up of a double membrane and its function is to shut the pore. The dolipore septum will not allow the movement of nuclei in hyphae but
maintains continuity of cytoplasm.

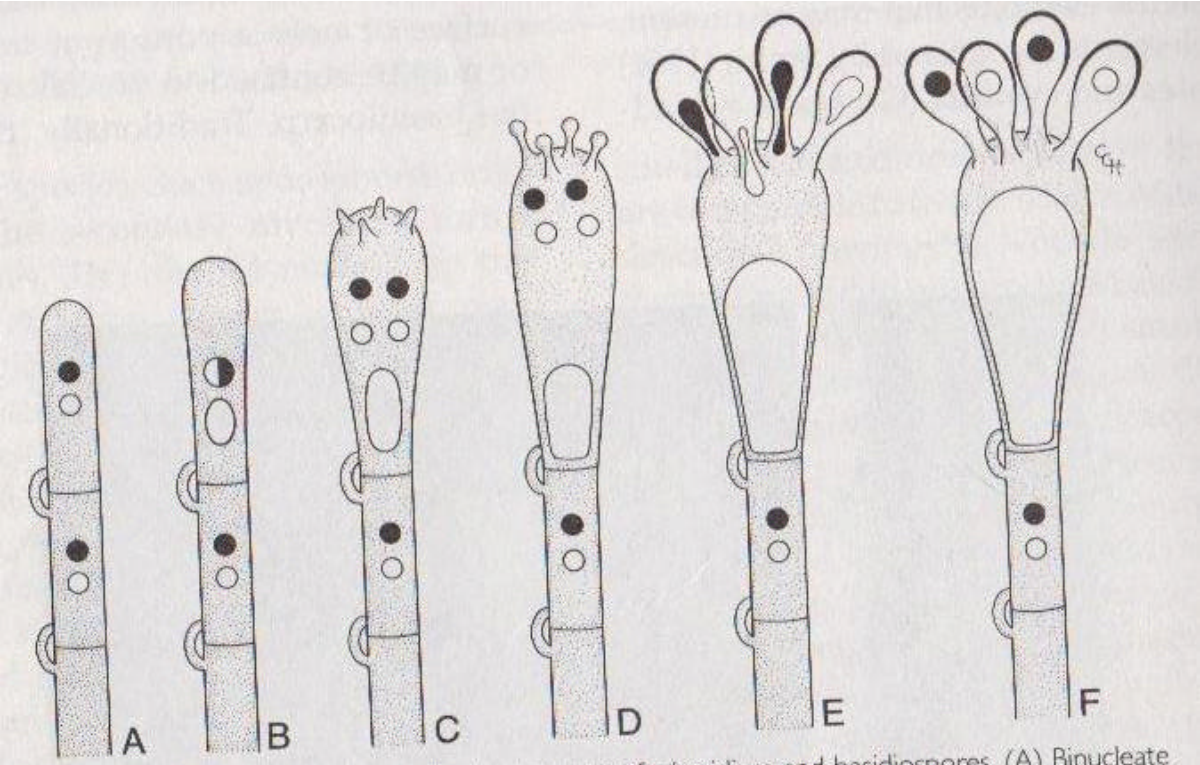


Asexual reproduction: Asexual reproduction takes place by means of budding (conidia), fragmentation of hyphae (arthrospores) , uredospores. Conidial production is common in smuts while rusts produce uredospores
(summer spores) that are conidial in origin and function.

Sexual reproduction: Sexual reproduction results in the production of basidium bearing haploid basidiospores. Basidiospores are formed as a result of karyogamy and meiosis taking place in basidium. In most of the members, sex organs (gametangia) are not produced and the somatic hyphae or detached somatic cells (arthrospores) undergo sexual process by somatogamy. In *Puccinia* sexual process is accomplished by spermatization through specialized organs called spermatia acting as male gametes and receptive hyphae as female organs. Thus, sexual cycle involves in typical cases, a monokaryotic phase and establishment of dikaryotic phase by somatogamy or spermatization of primary mycelium and then karyogamy and meiosis in the basidium and return to monokaryotic phase by means of basidiospores. Thus, in the life cycle there is an alternation of monokaryotic and dikaryotic phases.

Basidium: Basidium is a club shaped, sexual, fruiting body bearing on its surface a definite number of (usually 4) basidiospores which are formed as a result of karyogamy and meiosis.

Development of basidium: A simple, club shaped basidium originates as a terminal cell of a binucleate hyphae and is separated from the rest of the hyphae by a septum over which a clamp connection is generally seen. At first, basidium is narrow and elongated and later it enlarges and becomes broader. Mean while, the 2 nuclei with in the young basidium, fuse (karyogamy) and the zygote nucleus soon undergoes meiosis giving rise to 4 haploid nuclei. In the meantime, four small outgrowths termed as sterigmata push out at the top of the basidium and their tips enlarge eventually forming the basidiospore initials. During this time, a vacuole forms at the base of the basidium and as it increases in size, it pushes the contents of basidium out into basidiospore initials which finally become basidiospores.



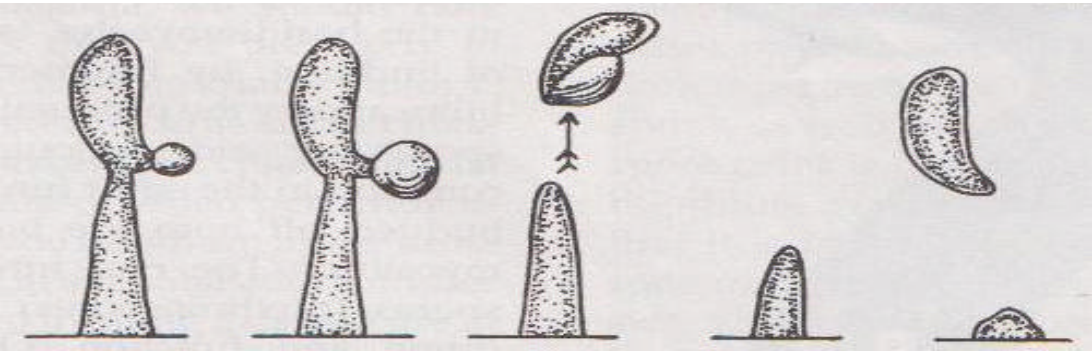
Successive stages in development of a basidium and basidiospores. (A) Binucleate hyphal tip. (B) Uninucleate, diploid basidium following karyogamy. (C) Postmeiotic basidium with four haploid nuclei. Sterigmata have begun to develop. (D) Basidiospore initials on sterigmata and nuclei preparing to migrate into the spore initials. (E) Migration of nuclei into basidiospore initials. (F) Highly vacuolate, maturing basidium bearing four young uninucleate basidiospores.

Parts of basidium: Basidium is divided into 3 patrs. Probasidium (portion where nuclear fusion takes place),metabasidium / promycelium (portion where meiosis occurs) and sterigmata (any portion between metabasidium and basidiospore).

In smuts and rusts, fusion of 2 nuclei takes place in a specially formed thick walled spores called chlamydospores and teleospores respectively. During the germination of chlamydospore / teleospore, fusion of 2 nuclei takes place in the spore, followed by meiosis. A germ tube called promycelium is formed which becomes transversely septate into 4 cells, each cell containing a haploid nucleus. The basidiospores are formed on the sterigmata on promycelium.

Basidiopspores: A basidiospore is typically a unicellular, uninucleate (exceptional 2 nuclei) haploid structure .The basidiospores are formed exogenously on the basidium in contrary to the endogenous formation of ascospores. The basidiospores may be globose, oval, elongate or sausage shaped and may be hyaline or coloured.

Dispersal of basidiospores: In majority cases, the spores are released violently and such spores are called ballistospores.Many possible mechanisms of spore discharge have been suggested. Buller was one of the first to examine critically the spore discharge.According to him, Basidiospores rest on the tip of sterigmata in an oblique fashion and a bubble or drop (called Bullers drop consist of liquid which forms at the hilar appendix ie.,a minute projection of the spore near the point of attachment to the sterigmata) is responsible for basidiospore discharge . This drop keeps on increasing in size and its expansion results in explosive discharge of spore to a distance of about 0.1mm. The spores are discharged in succession at intervals of several seconds to minutes.



Basidiocarp (Fungus flowers): Basidiocarp is a fruiting body that bears basidia which may be crust like, gelatinous, papery, spongy, corky, woody in texture. They vary in size from microscopic to a meter or more in diameter. Most Basidiomycotina bear their basidia in basidiocarps except in rusts and smuts. Basodiocarp producing fungi are mushrooms, shelf fungi/ bracket fungi, coral fungi, puff balls,bracket fungi,birds nest fungi,earth stars etc. Basidia are formed typically in definite layers called hymenium. The hymenium is a layer composed of basidia and any other sterile structures like cystidium (larger and protrude beyond the other structures and of taxonomic importance) and basidiole (resemble basidium but with out basidiospores and provide support to fertile basidium).

Compatibility: The members are either homo or heterothallic (majority).

IMPORTANT CHARACTERISTICS OF CLASS TELIOMYCETES:

1. Include rusts and smuts.
2. Basidiocarp is lacking and replaced by thick walled teleospores or chlamydospores in sori with in the host tissue.
3. Basidia arise from thick walled resting spores i.e., teleospores or chlamydospores.
4. Members are obligate parasites or facultative saprophytes.

In class Teliomycetes there are two orders.1.Uredinales 2.Ustilaginales

IMPORTANT CHARACTERISTICS OF ORDER UREDINALES:

1. The popular name for the Uredinales is the rust fungi, which relates to the reddish brown colour of some of the spores. All are obligate parasites of crop plants.
2. The mycelium is primary in the early stage and in the later stages secondary. The mycelium is inter cellular and produce haustoria that penetrate the host cells and obtain nourishment. There is no tertiary mycelium and hence there is no basidiocarp.

3. Clamp connections are rare or absent. Dikaryotisation takes place either through somatogamy or spermatisation.

4. Teleospores originate from the apical cells of dikaryotic hyphae. They may be uni or multi cellular. The structure of teleospores forms the basis for identification of the rust genera. The teleospore acts as an encysted basidium in which karyogamy occurs. It germinates by producing a promycelium (metabasidium) in which meiosis takes place.

5. The rusts have **polymorphic life cycle**. Production of many spore forms in the life cycle is called polymorphism. Generally 5 types of spores are seen during the life cycle viz., spermatia (uninucleate) in spermagonium, aeciospores(binucleate) in aecium,uredospores(binucleate) in uredium , teleospores(binucleate)in telium and basidiospores (uninucleate) on promycelium or metabasidium.The spermagonium represents gametic stage (male gamete- spermatium, female sex organ- receptive hypha), aecia represent the stage in which dikaryotisation occurs,uredia represent conidial or repeating asexual stage, telia represent sexual stage and act as encysted basidium in which karyogamy occurs and subsequently giving rise to basidiospores from promycelium or metabasidium.

6. **Autoecious rust:** If all the spore stages are produced on the same host then the fungus is called autoecious and the phenomenon is called **autoecism.**Eg.*Melampsora lini*- linseed rust, *Uromyces appendiculatus* - bean rust.

7. **Heteroecious rust:** If spore stages are formed on two unrelated hosts ie., pycnia and aecia on one host and the uredia and telia on the other host, such rusts are called heteroecious rusts and phenomenon is called **heteroecism.** Eg. *Puccinia graminis f. sp. tritici*- black stem rust of wheat. **Primary host:** The host in which heterocious rust produce the telial stage is called primary host (Eg. wheat). **Secondary or alternate host** The host in which telial stage is not produced is called alternate or secondary host (Eg. barberry) .

8. Based on life cycle pattern, rusts are divided into macrocyclic, demicyclic and microcyclic rusts.

Macrocyclic rust (**long cycled rust):** Rusts in which all 5 spore forms are produced or produce at least one type of binucleate spore in addition to teleospores are called macrocyclic rusts. It may be autoecious macrocyclic rust (Eg.*Puccinia helianthi*- sun flower rust) or heteroecious, macrocyclic rust *(Eg.Puccinia graminis f.sp. tritici* - black stem rust of wheat).

Demicyclic rust: The rust in which uredial stage is absent. eg. *Gymnosporangium juniperi – virginianae*- cedar apple rust.

Microcyclic rust (short cycled rust): Rusts which produce no binucleate spore other than teleosporei.e., teleospore is the binucleate spore produced and both aecia and uredia are lacking. Eg.*Puccinia malvacearum*- hollyhock rust.

IMPORTANT CHARACTERISTICS OF FAMILY PUCCINIACEAE:

1.Teleutospores are free or variously united, but never in the form of layers or crusts. 2.Teleutospores are stalked. Eg. *Puccinia, Uromyces, Hemileia*

Genus Puccinia:

Obligate parasites.Teleutospores are two celled and stalked.They lie free in the sorus.

Disease: ***Puccinia graminis f.sp. tritici***- black stem rust of wheat

Genus Uromyces:

Teleutospores are single celled with a thick apex (papillum) and stalked. The stalks are fragile and short.

Eg. *U. appendiculatus* - bean rust

Genus Hemileia:

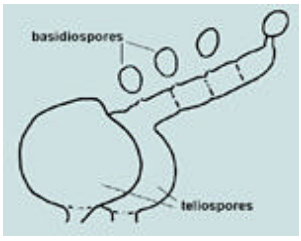
Uredospores are reniform, bifacially ovate resembling orange segments, concave side smooth, convex side echinulate.

Teleutospores are turnip shaped. 1 celled, stalked, smooth walled and produced on erumpent,club shaped stalks which arise through stomata.

Eg. H. vastatrix - coffee rust

Puccinia

Uromyces



Hemileia

18. LIFE CYCLE OF *PUCCINIA GRAMINIS F. SP. TRITICI*

The pathogen is an obligate parasite and causes black stem rust of wheat. It is a heterocious rust that requires 2 hosts for completion of its life cycle. The primary host (wheat) and the secondary host (barberry). .On barberry it produces pycnia and aecia while uredial telial stages are produced on wheat.

It is a macrocyclic rust producing all the five types of spores. The different kind of spores and their spore stages are designated as follows.

Stage	Spore	Nucleus status
O	spermagonia with spermatia (pycnia with pycniospores)	uninucleate
I	aecia with aeciospores	binucleate
II	uredia with uredospores	binucleate
III	telia with teleospores	binucleate
IV	basidia with basidiospores	uninucleate

It produces the first 2 stages in barbery and other 3 stages on wheat or other graminaceous hosts.

Significance of each stage :

Stage " O ": The spermatia produced in spermagonia were till recently thought to be functionless asexual spores. Mycologists have not found them to germinate to produce mycelium as in case of otHer asexual spores. Hence, they thought that they are vestigial bodies. At the time when mycologists do not know the function of pycnia and pycniospores the stage was designated as " O " stage. But in 1927, Cragie found that spermatia are male gametes and are essential for spermatisation of receptive hyphae (female organ) and consequent formation of aeciospores. This stage " O" represents the sexual stage of rust fungi but the nomenclature stage " O " retained even today to to avoid confusion.

Stage I: Aeciospores are the first binucleate spores formed in the life cycle.

Stage II: Uredospores are also called as repeating asexual spores as they function as conidia for the propagation of the rust fungus.

Stage III: Teleutospores represents the perfect stage because karyogamy and meiosis ocuur in them.

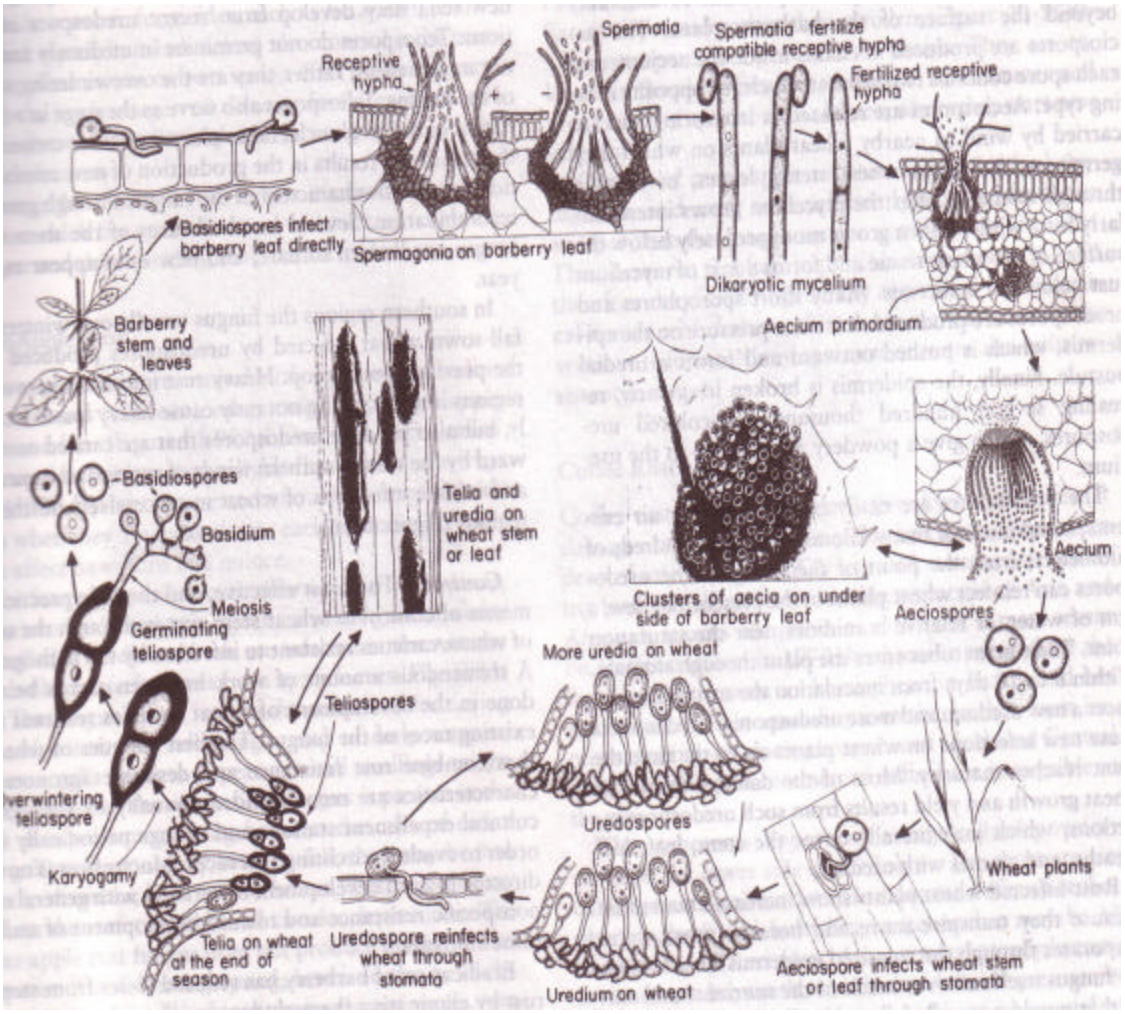
Stage IV: Basidiospores represent the sexual spores.

Stages " O" and " I" occur on barbery while stages " II" and " III " occur on wheat.

Basidiospores can infect only barbery plant where as aeciospores can infect only wheat plant.

Stage " O": **Spermagonia with spermatia:**

The spermagonia or pycnia are the structures which bear the sex organs of the pathogen. It contains spermatia which are the male sex organs and the receptive hyphae which are the female sex organs. These spermagonia are formed near the upper epidermis in about 4 days after infection of the host by a basidiospore. In nature it generally happens that several basidiospores at random will reach and infect the same barbery leaf so that both + and – mycelium develop side by side and intermingle in the barbery tissue. Each spermagonium contains numerous spermatia. These are exuded (ooze out) in small droplets of nectar present in the spermagonium. Each spermatium carries + or – nucleus depending on the strain of mycelium which produced the spermagonium. All spermatia from a single spermagonium carry the same factor or genetic make up as that of receptive hyphae. These arise from upper part of spermagonia and protrude through the ostioles. Spermatisation i.e., fusion between receptive hyphae and spermatia of opposite sex takesplace through agency of insects which are attracted by the honey fluid. The spermatial contents pass into the receptive hyphae . Meanwhile the mycelium penetrates the entire leaf and the hyphae near the lower epidermis develop number of aecial primordial. It is presumed that spermatial nuclei which pass from the spermatia into the receptive hyphae reach the cells of the aecial promordia rendering them binucleate. It has been demonstrated that aecial primordial fail to develop into aecia until and unless spermatisation takes place.

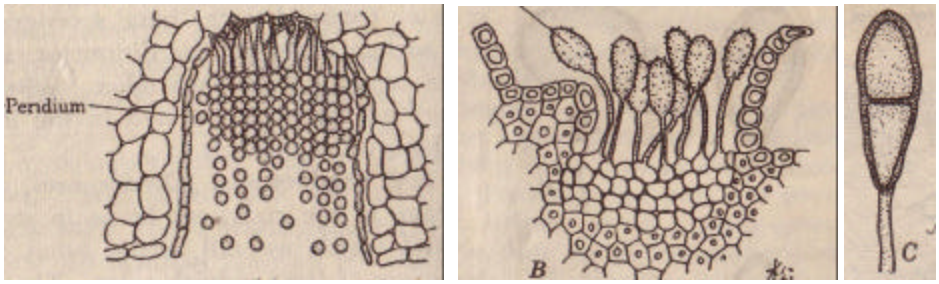


Life cycle of ***Puccinia graminis f. sp. tritici***

Stage"I" : Aecia and aeciospores are formed in the lower epidermis soon after dikaryotisation. These are the first binucleate spores produced in the life history of the fungus. An aecium is a group of binucleate hyphal cells (aeciospore mother cell) which give rise to aeciospores in chains. The aeciospores finally disseminated by the wind and under favourable conditions germinate on graminaceous host . These can not infect barbery.

Stage " II": Soon after infection by aeciospores on graminaceous host , binucleate mycelium begins to form masses of cells. These are called uredia from which binucleate uredospores are borne on long stalks. The uredospores are one celled, oval, yellowish and spiny. They germinate readily in water and produce one or more germ tubes. The uredospores are those spores which perpetuate the fungus throughout the growing season and they are capable of reinfecting the

graminaceous host on which they produce. Hence, they are also known as repeating asexual spores. They spread from plant to plant and from field to field and the disease soon becomes an epiphytotic. The uredospores upon germination produce binucleate mycelium which grows between the cells of the host and in a few days produce new uredia and uredospores.



Aecium **Uredium** **Teliospore**

Stage " III" : Late in summer, at the time of ripening of grain another kind of spores known as teleospores or teleutospores are developed in the same mycelium when the uredia begin to cease. The pustules which produce teleospores are known as telia and constitute the black stage of rust. The teleospores are ellipsoidal, oblong or obclavate, typically two celled, and thick walled with slight constriction at the septum. The young teleospore is binucleate . Karyogamy eventually takes place and render the teleosspores diploid and uninucleate . The teleospores are not capable of germinating immediately and should have resting period of several months and thus remain dormant until the following spring.

Stage " IV" : Early in the spring each cell of teleospore germinate and produce a basidium (promycelium). The diploid nucleus in teleospore migrates in to the promycelium and undergoes meiosis and four haploid nuclei are formed. Then septa are formed, separating the nuclei from one another into four cells. Each cell of promycelium produces a sterigmata on which basidiospore is formed. The nuclei now migrate into the basidispore. Two of the basidiospores are of one strain (+) and two are of other strain (–) . Soon after their formation ,the basidiospores are ejected and are carried away by wind. They can not infect graminaceius host, but can infect barbery and produce a well developed monokaryotic mycelium. Thus, the life cycle gets repeated on these two hosts viz., wheat and barbery.

IMPORTANT CHARACTERISTICS OF MELAMPSORACEAE :

1.Teleutospores are single celled and sessile (no stalk).

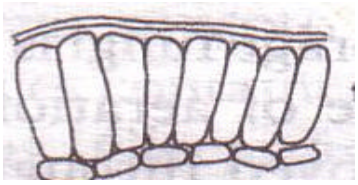
2.Teleutospores are laterally united to form layers, crusts or columns and are sessile.

3.They are found sub epidermally.

Genus Melampsora:

Teleutospores are single celled, sessile and laterally united to form layers and sub- epidermal.

Eg. *Melampsora ricini*- castor rust.



Melampsora teliospores

19.IMPORTANT CHARACTERISTICS OF ORDER USTILAGINALES:

1. The fungi included in this order are popularly called as smut fungi and the diseases they cause are called smut diseases. The smuts are so called because they form , black dusty spore masses(chlamydospores/ teleutospores/ smut spores) which resemble soot formed in the sori on the leaves, stem and flowers of host plants.
2. This order also includes a group of fungi referred to as Basidiomycetes yeasts.
3. All smut fungi are facultative saprophytes.
4. The mycelium is inter cellular, except in *Ustilago maydis* (intra cellular) and form haustoria. The primary mycelium originates from germination of basidiospore or conidia later it becomes dikaryotic. No tertiary mycelium. Mycelium generally does not develop profusely in artificial media. Yeast like cells which reproduce by budding are produced. Clamp connections are present while dolipore septum absent.
5. Chlamydospores are formed from intercalary cells.
6. Basidiospores are not produced on sterigmata and are not produced in definite numbers and are not discharged violently.

7. Asexual reproduction is by means of budding of sporidia producing secondary sporidia(also called as conidia).

8. No sex organs are produced . Plasmogamy takes place by fusion of any two basidiospores or two conidia. Somatic hyphae may also fuse resulting in dikaryotic condition.

9. The basidium(promycelium) may be septate or aseptate and may bear 4 or many sporidia.

10. Formation of teleutospore: Teleutospores are the characteristic structures of the order. These are formed in masses in sori developing in various places like flowers, leaves stem etc .At the time of formation of teleutospores , the dikaryotic mycelium develop profusely in certain portions of the host, lays down many septa and forms masses of hyphae composed of short cells. The protoplast of each hyphal cell round up and hyphal wall gelatinize. Each protoplat then secretes around itself a thick wall that eventually converts the protoplast into a round teleutospore. Since, these spores are formed in the manner of chlamydospore formation, theses are also called as chlamydospores. Teleutosores are of considerable importance in taxonomy of Ustilaginales. Surface ornamentation is the most important character.. They may be reticulate, spiny, tuberculate, or smooth. The spores are typically globose,sessile, one celled and variously coloured like brown , black or yellow. In some species, the spores are free from one another and in some they held together to form spore balls. The spore balls have fertile and sterile cells with fertile cells capable of germination.

11. Cause a group of diseases called as smuts or bunts.

The Order Ustilaginales is divided into 3 families based on method of germination of teleutospore and behaviour of basidiospores.

IMPORTANT CHARACTERISTICS OF USTILAGINACEAE:

1.Known as smut fungi

2.Promycelium is septate

3.Basidiospores are produced laterally from each cell of the promycelum

DISTINGUISHING CHARACTERISTICS OF GENERA (OR) KEY FOR IDENTIFICATION OF GENERA:

Ustilago: 1.Teleospores singles
2.Sori dusty at maturity
3.Sori covered peridium (membrane) of host origin

Spacelotheca: 1.Teleospores singles
2.Sori dusty at maturity
3.Sori covered by membrane (peridium) made up of fungal cells
4.Central columella present

Tolyposporium: 1.Spores in balls
2.Spore balls permanent, spores adhering by thickenings of exospore .

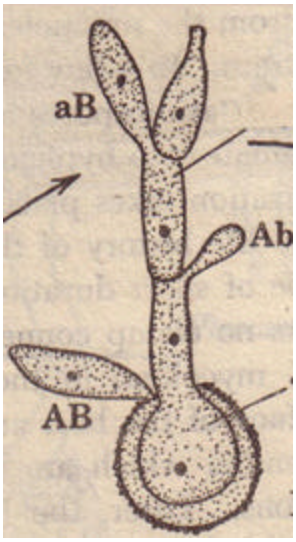
DISEASES CAUSED BY THE GENERA:

U. nuda tritici- loose smut of wheat
Sphacelotheca sorghi- short or grain or kernal smut of jowar
S. cruenta- loose smut of jowar
S. reliana- head smut of jowar
Tolyposporium ehrenbergii- long smut of jowar
T. penicillariae- smut of bajra

DIFFERENCE BETWEEN RUSTS AND SMUTS

Character	**Rusts**	**smuts**
1. Systematic position	Order: Uredinales	Ustilaginales
2. Plant parts affected	foliar parts (leaves, stem, petiole)	floral parts(flowers)
3. Symptoms	reddish brown coloured pustules	ovaries turn into black sooty masses
4. Parasitism	obligate parasites	facultative saprophytes
5. Polymorphism	polymorphic	not polymorphic

6. Teleutospores	terminal , 1 or 2 celled, stalked or sessile	intercalary, 1 celled, sessile
7. Basidiospores	produced o n sterigmata, violently discharged, 4 in number	sessile,not violent 4 to many(indefinite in number)
8. Sex organs	spermatia (male) receptive hyphae(female)	no sex organs
9. Dikaryotisation	spermatisation	fusion of 2 basidia or Basidiospores or conidia or promycelium



Germinating teliospores of smut fungi

20. IMPORTANT CHARACTERISTICS OF FAMILY TILLETIACEAE:

1.Known as bunts

2.Promycelum is non- septate

3.Basidiospores arise terminally

Germinating teliospores of bunt fungi

DISTINGUISHED CHARACTERISTICS (OR) KEY FOR IDENTIFICATION OF GENERA:

Tilletia:

1.Teleospores singles

2.Spores dusty and escaping at maturity

3.Sporidia are fused to form H shaped structures

Neovossia:

1.Teleospores singles

2.Spores dusty and escaping at maturity

3.Sporidia do not fuse, no H shaped structures

Urocystis:

1.Teleospores in balls

2.Sori dusty, spore balls surrounded by an adhering layer of hyaline sterile cells.

3. spore balls escape from sorus

DISEASES CAUSED BY THE GENERA:

Tilletia caries and T. foetida- bunt of wheat

Neovossia horrida- bunt of paddy

N. indica- Karnal bunt of wheat

Urocystis cepulae- onion smut

U. tritici- flag smut of wheat

DIFFERENCES BETWEEN SMUTS AND BUNTS :

S.No.	Smuts	Bunts
1	Belongs to family Ustilaginaceae	Belongs to family Tilliteaceae
2	Promycelium is Septate	Promycelium is non-Septate and hollow tube like
3	Basidiospores are formed laterally from each cell of the promycelium	Basidiospores are formed at the tip of the promycelium
4	Basidiospores are usually four	Basidiospores are more than four usually eight
5	H shaped structures are not formed	H shaped structures are present in which plasmogamy occurs.
6	Meiosis occurs in promycelium or teliospores	Meiosis always occurs in teliospores before germination
7	No fishy odour is observed	Characteristic stinking fishy odour is observed
8	Genera included are *Ustilago, Sphaecelotheca, Tolyposporium*	Genera included are *Tilletia, Neovossia, Urocystis*

21.IMPORTANT CHARACTERISTICS OF HYMENOMYCETES:

1.These fungi are popularly called as mushrooms.

2.It includes bracket or pore fungi, toadstools, jelly fungi, honey mushrooms, etc.

3.Basidia are formed on a hymenium of a well developed fruiting body, basidiocarp.

4.Basidiocarps are gymnocarpous or hemiangiocarpous.

5. Basidia are not formed from teleospores.

6.The hymenium is exposed in the fruiting body from the beginning and thus basidiospores are exposed before they mature.

7.Basidiospores are called ballistospores (the spores which are perched obliquely and discharge forcibly and violently are called ballistospores).

8.Members are saprophytes or facultative parasites.

IMPORTANT CHARACTERISTICS OF ORDER APHYLLOPHORALES:

1. All the members produce single celled , club shaped basidia in well defined hymenium.Basidiocarp is tough and non fleshy, may be cottony, leathery, corky or woody in texture.

2. The development of basidiocarp is gymnocapous i.,e., the hymenium is exposed while the spores are still mature.Thus, hymenium is exposed through out development.

3. Hymenophore(the layer that supports hymenium) may be smooth, flattened or resupinate, teeth like, with pores etc.

4. This order consists of both terrestrial and wood inhabiting forms. Some are serious pathogens of forest trees causing root rot and heart rot. Dead trees and lumber are commonly attacked by certain members.

IMPORTANT CHARACTERISTICS OF FAMILY GANODERMATACEAE;

1.Members are commonly called as bracket fungi or shelf fungi and members are lignicolous forms.

2.The fruiting body of the fungus is called bracket which is formed laterally at the base of affected plant as a leathery stalked fan shaped or bracket shaped or with out stalk,made up of trimitic hyphal system,hymenophore poroid. The bracket is tough,leathery or woody in texture and size vary from 1-20 inches in diameter.The stalk is cylindrical and brown to black in colour.

3.The upper surface of bracket is reddish brown in colour and coated with a hard shiny substance resembling sealing wax, while the lower side is white or yellowish in colour. When examined with a lens, minute holes or pits are seen all over the under surface. These are the openings of numerous hymenial tubes or pores which are vertically oriented inside the fruiting body.Each basidium gives rise to 4 sterigmata, each of which bears a basidispore at tis tip.

4.Basidiospores are coloured,two layered and cystidia are absent in hymenium.Bracket shaped basidiocarp,broadly and horizontally attached to the tree trunks by means of a short stalk or stipe.*Ganoderma* differs from other bracket fungi in having much longer span of spore release,extending upto 5 months. **Diseases caused by *Ganoderma*** :

Ganoderma lucidum - root rot and wilt of coconut & other palm trees and citrus.

Ganoderma

22.SUB- DIVISION: DEUTEROMYCOTINA

These are a group of fungi which reproduce only by means of asexual spores or fragmentation of hyphae or modified mycelium. The asexually produced spores are generally called as conidia. A conidium is a non-motile asexual spore formed at the tip or side of sporogenous cell. For several genera of this group sexual reproduction/ sexual stages/ perfect stages/ teleomorphic stages are not known or have not been discovered or not found or rarely formed or have been dropped from the life cycles in the evolution of these organisms.

These fungi are commanly called as **imperfect fungi** and technically called as **fungi imperfecti** as they have only imperfect stages or conidial stages.Whenever the perfect stage of an imperfect fungus is detected in nature or laboratory cultures, it is shifted to proper place on the basis of fruiting body.In most cases the perfect stages have been found to belong to sub-division Basidiomycotina.

Mycelium is well developed, septate with branched hyphae and multinucleate cells.

Since , present classification is based on characters of sexual stage, these fungi are not fit for natural classification.

For most of these genera perfect states are not known or rare in nature, they are temporarily grouped as members of form class, form order, form family , form genus and form species.

CLASSIFICATION OF DEUTEROMYCOTINA :

The classification is completely artificial. It is based on their conidial peculiarities and neither bears connection to their sexual stage nor to their origin or evolution. It can not therefore be called as a natural classification.

The main characteristics (criteria) on which classification of fungi imperfect fungi is based are

1. presence or absence of asexual spores(conidia)
2. type of asexual fruiting body

3. manner of production of asexual spores
4. morphology (shape, size, color and septation) of asexual spores.

SACCARDOAN (1906) SPORE GROUP SYSTEM :

Traditionally, the form sub classes, Coelomycetidae and Hyphomycetidae have been divided in to sections. The section is not an official category in the classification system. The various families under each section were divided further by Saccardo into seven sections based on conidial characters viz., shape, color, septation. Saccardo (1906) later, modified the section names with the prefixes hyalo or phaeo depending upon whether the conidia were hyaline or pigmented. This approach is referred to as the Saccardoan Spore Group System since it was Saccardo (1899) who initially proposed the system.

Saccardo described the spores in Deuteromycotina based on shape, septation and colour.

I. Amerosporae: conidia non septate (single celled) , spherical, ovoid to elongated, or short cylidric.

a)Hyalosporae(Hyalo =colourless): conidia hyaline Eg: *Phoma*

b)Phaeosporae(phaeo=coloured): conidia coloured Eg: *Sphaeropsis*

II. Didymosporae : conidia ovoid to oblong, one septate (two celled)

a)Hyalodidymae: conidia hyaline Eg: *Fusarium* micro conidia

b)Phaeodidymae: conidia coloured Eg*: Botryodiplodia*

III. Phragmosporae : conidia oblong, two to many septate (3 or more celled) , only transverse septa present.

a)Hyalophragmae: conidia hyaline Eg: *Pyricularia*

b)Phaeophragmae: conidia coloured Eg: *Drechslera*

IV. Dictyosporae : conidia ovoid to oblong, both longitudinal and transverse septa present (muriform) .

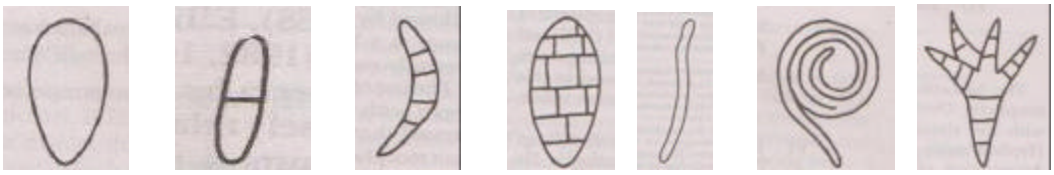
a) Hyalodictyae: conidia hyaline Eg: *Epicoccum*

b)Phaeodictyae: conidia coloured Eg: *Alternaria*

V. Scolecosporae: conidia thread like to worm like, filiform, septate or aseptate (one to several celled) Eg: *Cercospora*

VI. Helicosporae(Allantosporae) : conidia spirally cylindrical, curved (allantoid), septate or aseptate. Eg:*Helicomyces*

VII. Staurosporae : conidia stellate (star shaped) , radially lobed, septate or aseptate (one to several celled). Eg: *Actinospora*



Amerosporae Didymosporae Phragmosporae Dictyosporae Scolecosporae Helicosporae Staurosporae

Color of conidia

1. **Hyalosporae** : cell wall of conidia hyaline
2. **Phaeosporae** : cell wall of conidia coloured/ pigmented.

AINSWORTH (1973) CLASSIFICATION:

According to Ainsworth (1973), 2 form classes are there in Deuteromycotina.

1. Coelomycetes
2. Hyphomycetes

IMPORTANT CHARACTERISTICS OF CLASS COELOMYCETES:

The conidia are borne on conidiogenous cells with or with out distinct conidiophores, enclosed in fungal fructifications (asexual fruiting bodies) such as pycnidium or acervulus.

Coelomycetes is divided into 2 form- orders 1.Sphaeropsidales 2. Melanconiales

IMPORTANT CHARACTERISTICS OF ORDER SPHAEROPSIDALES:

The fruiting bodies are called **pycnidia**. A pycnidium is a globose or flask shaped asexual fruiting body that is lined inside with conidiophores. It may be completely closed or may have an opening called ostiole. It may be papillate or beaked or long necked at apex , leading to an opening. They vary greatly in their shape, size, color and consistency of pseudoparenchymatous wall.

Sphaeropsidales are further divided in to 4 form families 1 Sphaeropsidaceae 2. Excipulaceae 3. Nectrioidaceae (Zythiaceae) 4. Leptostromataceae

Family : 1. Sphaeropsidaceae

Pycnidia are flask shaped or globose, thin or thick walled, dark coloured, ostiolate, hard texture. Eg. *Phoma, Phomopsis, Macrophomina, Phyllosticta, Septoria, Diplodia* , *Botryodiplodia.*

DISTINGUISHED CHARACTERS OF THE GENERA:

Phoma:

Pycnidia - small, dark coloured, immersed or semi immersed in the host tissue. Globose or flask shaped, thin walled, and ostiolate. Wall consisting of dark pseudoparenchymatous cells. Conidiophores / conidiogenous cells are short, hyaline lining the inner pycnidial wall producing conidia in succession.

Conidia -hyaline, aseptate, guttulate(oil globules) , pyriform to globose and ooze out in long thread like cirrhus through the ostiole.

Eg. *Phoma lingam* – black leg of crucifers

P. vexans – blight and fruit rot of brinjal

Phomopsis:

Pycnidia- brown to black, globose, papillate ostiole, with one or more locules.

Conidiophores / conidiogenous cells- simple or branched.

Conidia of 2 types. (a)alpha conidia- hyaline , ovoid, 1 celled, (b) beta conidia – hyaline, filiform, straight or curved, , 1 celled.

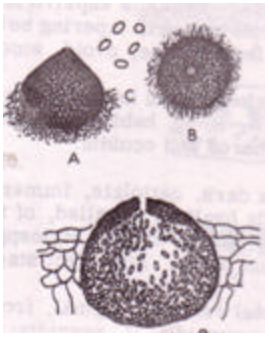
Eg. *Phomopsis vexans* - fruit rot and blight of brinjal.

Phyllosticta :

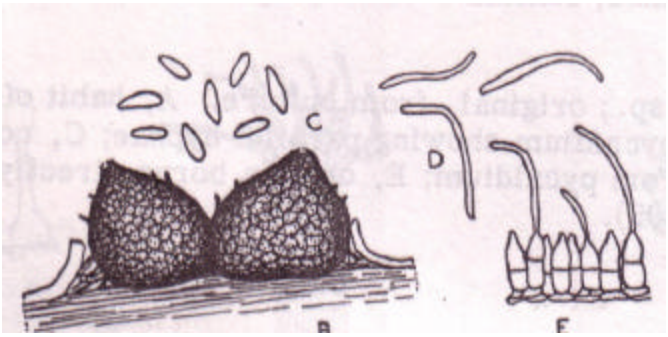
Pycnidia dark, ostiolate, globose, immersed in host tissue, erumpent or with a short beak. Conidiophores are short and obsolete.Conidia are small, one celled, hyaline,ovoid to elongate.

Phyllosticta and Phoma are differentiated on the basis of plant organs attacked. Phyllosticta principally occurs on leaves causing leaf spots and shot holes While, Phoma occurs mainly on stem, twigs and fleshy roots.

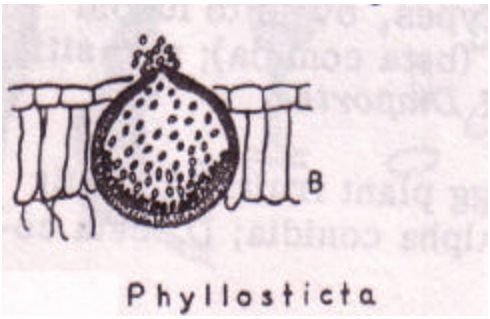
Eg: *P. gingeberis* – leaf spot of ginger

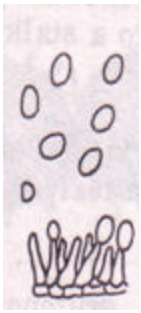


Phoma



Phomopsis





Macrophomina:

Pycnidia- globose, dark brown, papillate ostiole.

Conidiogenous cells- barrel shaped, hyaline.

Conidia – hyaline , aseptate, cylindrical to fusiform

Sclerotia- more common in cultures, black, smooth, hard.

Eg. *Macrophomina phaseolina* – charcoal rot, canker, damping off, of jowar, maize, ground nut.

Septoria:

Pycnidia – immersed in host tissue, globose, brown, thick walled, papillate and ostiolate. Wall consists of pale brown cells.

Conidiophore / conidiogenous cells – hyaline, broad and round at base and narrow above or barrel shaped.

Conidia – hyaline, many septate, filiform.

Eg. *Septoria nodorum*- glume blotch of wheat

S. lycopersici- leaf spot of tomato

Diplodia :

Pycnidium - black, globose, papillate, ostiolate,

Conidiophore/ conidiogenous cells - slender, hyaline, cylindrical

Conidia – brown, 2 celled, ovoid , apex obtuse (round) and base truncate (shorten) .

Eg. *Diplodia natalensis - Diplodia gummosis of citrus*

Botryodiplodia:

Pycnidium – carbonaceous, dark brown or black, no ostiole,

Conidiophores- simple and short.

Conidia – dark brown, 2 celled, ovoid.

Eg. *Botryodiplodia theobromae* – Flat limb of sapota

Septoria ***Diplodia*** ***Botryodiplodia***

23.IMPORTANT CHARACTERISTICS OF FAMILY EXCIPULACEAE

Pycnidia are cup shaped.

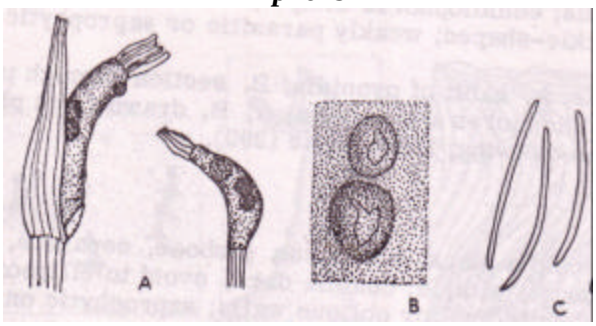
Ephelis:

Pycnidium – cup shaped,

Conidia – hyaline, 1 celled, acicular (needle shaped).

Eg. *Ephelis oryzae*- udbatta disease of rice .

Ephelis



(A= Stroma and pycnidia, B= Pycnidia (cup shaped), C= Conidia)

FAMILY 3. NECTRIOIDACEAE (ZYTHIACEAE):

Pycnidia resemble perithecia of Nectria and hence the Family name Nectrioidaceae .

Zythia:

Pycnidia - flask shaped, coloured, soft textured (fleshy) , ostiolate.

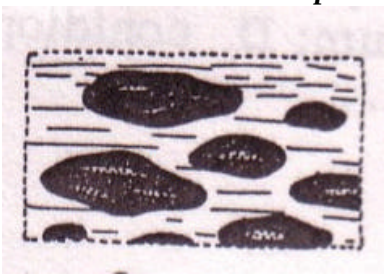
Conidia – hyaline, aseptate, oblong, rounded at each end.

Eg. *Zythia fragariae* - leaf blotch and stem end rot of straw berry

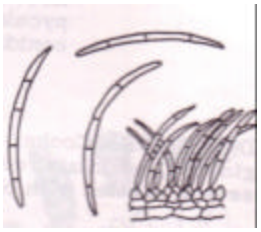
Family 4. Leptostromataceae :

Pycnidia are shield shaped or elongated or flattened.

Leptostroma



Shield shaped pycnidia



Conidiophores and conidia

Leptothyrium:

Pycnidium – shield shaped, dark, dimidiate (one half smaller than other).

Conidiophores- simple.

Conidia – hyaline, 1 celled, falcate (curved like sickle) .

Eg. *Leptothyrium pomi*- fly speck of apple

IMPORTANT CHARACTERISTIS OF ORDER MELANCONIALES,

FAMILY MELANCONIACEAE:

All the members of this order are grouped into a single family Melanconiaceae.

The fungi producing asexual fruiting bodies are called Acevulus. Acervulus is a mycelial mat not having wall of its own and produces a cavity with in which closely packed short conidiophores forming a bed like mass are produced.

DISTINGUISHED CHARACTERISTICS OF THE GENERA:

Colletotrichum:

Cushion shaped acervulus is seen below epidermis or cuticle with dark setae.

Setae – septate, stout at base and pointed at tip, dark brown, long, present in the periphery or in between the conidiophores.

Conidiophores – simple, elongate, septate, hyaline to brown,

Conidia- sickle shaped, , guttulate (oil globule), hyaline, single celled.

Eg. *Colletotrichum capsici*- fruit rot and die back of chillies

C. lindemuthianum - anthracnose of bean

C .falcatum- red rot of sugarcane

Gloeosporium:

This genus is differentiated from Colletotrichum based on absence of setae in acervulus.

Eg. *Gloeosporium ampelophagum* - anthracnose or bird's eye disease of grapes.

G. musarum – anthracnose of banana

Pestalotiopsis:

Acervuli are formed below the epidermis.

Conidiophores**-** hyaline, branched, septate, cylindrical.

Conidia - fusiform , 5 celled , basal cell hyaline with a single appendage, apical cell hyaline with 2 or more apical , simple or branched appendages , middle cells dark brown and thick walled.

Eg. *Pestalotiopsis palmarum* – grey blight of coconut and palmyra

P. mangiferae - leaf spot of mango

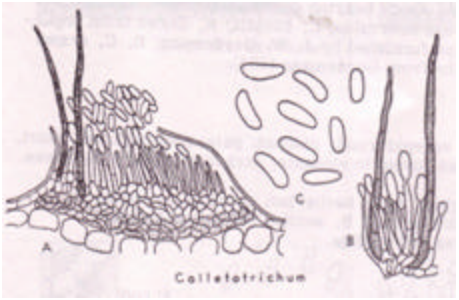
Pestalotia:

Acervulus**-** sub epidermal.

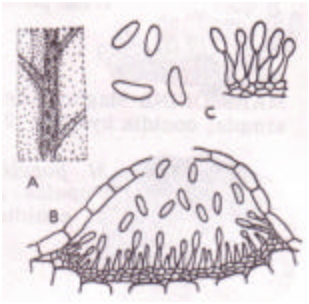
Conidiophores- short, simple or branched,

Conidia- similar to conidia of Petalotiopsis except 6 celled conidia.

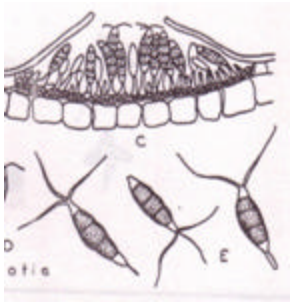
Eg. *Pestalotia psidi*- grey blight, scab and fruit spot of guava.



Colletotrichum



Gloeosporium



Pestalotia

24.IMPORTANT CHARACTERISTICS OF CLASS HYPHOMYCETES

Conidia and conidiophores are borne directly on hyphae. Conidiophores bearing conidia may be separate or in aggregates arising from the mycelium. There are certain fungi which lack conidial formation and forming mycelial structures such as scretotial bodies. The members are identified based on morphology of conidia.

Hyphomycetes is divided into 4 form orders.

1. Hyphomycetales/ Moniliales/ Hyphales
2. Tubercularíales
3. Stilbellales
4. Agonomycetales.

IMPORTANT CHARACTERISTICS OF ORDER MONILIALES:

Conidia are produced on unorganized, .hyaline conidiophores or directly from hyaline hyphae. This order is divided into 2 families

1. Moniliaceae 2. Dematiaceae.

FAMILY MONILIACEAE ;

Produce free conidiophores or conidiogenous cells from somatic hyphae. Mycelium, conidiophores and conidia are hyaline or light coloured but not brown or black.

DISTINGUISHING CHARACTERISTICS OF THE GENERA:

***Aspergillus* :**

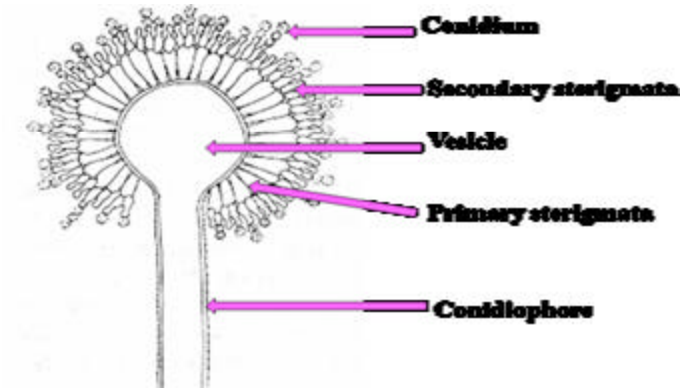
Well known saprophyte, grown on all types of substrate and also a weak parasite. commonly called as " weed of the laboratory"

Mycelium- septate, branched, with multinucleate cells .

Conidiophore-The hyphal cell that gives rise to conidiophore is called foot cell. Conidiophores arise singly on somatic hyphae, long, erect, non septate and bears at its tip a spherical structure called vesicle, which bears two layers of bottle shaped structures called sterigmata or phialides on which conidia are produced in chains.The sterigmata of first layer (lower most) are called primary sterigmata and the second layer (upper most) are called secondary sterigmata.

Conidia: globose, one celled, multinucleate, thick , rough walled and black.

Eg**.** *Aspergillus niger*- collar rot of groundnut



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Aspergillus

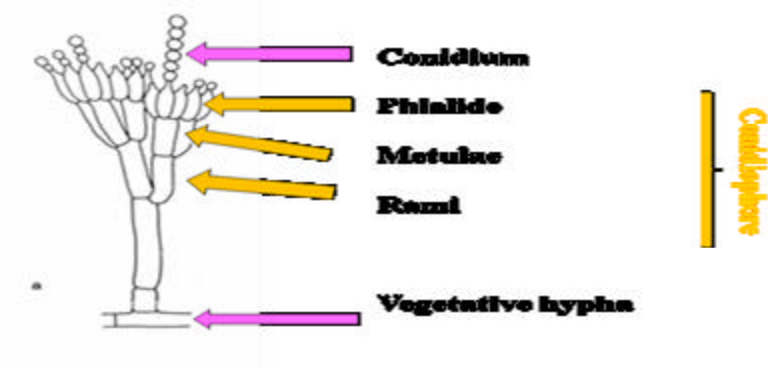
***Penicillium* :**

The conidial apparatus technically is called **"**penicillus" because it resembles a small brush or broom, hence the name penicillium

Mycelium***:*** highly branched, septate.

Conidiophore: arise from any cell of hyphae (not from foot cell), branch once or twice about 2/3 of the way to the tip in a characteristic symmetric or asymmetric broom like fashion. The first generation branches are called primary branches or rammi, on which whorls of second generation branches called metulae are produced. Each metula ultimately bears bottled shaped phialides which bears conidia in chains in basipetal succession. Conidia: globose, hyaline.

Eg. *Penicillium notattum*- citrus blue mold.



Penicillium

Pyricularia:

Mycelium – branched, septate, hyaline or lightly coloured.

Conidiophores- emerge through stomata or through epidermal cells and cuticle, simple, erect, septate, hyaline or light coloured with a few or several denticulate spore bearing pegs at the tips.

Conidia- hyaline, pyriform, broader at base and tapering towards apex , usually 3 celled.

Eg. *Pyricularia oryzae* - paddy blast.

Trichoderma:

The members are saprophytes, found in soil and several species are found to be antagonistic by producing non-volatile antibiotics against a range of plant pathogens. These are easily recognized by rapidly growing white, yellow or green colonies.

Conidiophores: hyaline, erect,solitary or aggregated into tufts, much branched with phialides in singles or in groups(non-verticillate).

Conidia- hyaline,grey, one celled,ovoid borne in small terminal clusters as balls on phialides. Eg: *Trichoderma viridi, T.harzianum* – biocontrol fungi.

Botrytis:

Conidiophores- branched, septate, long, slender, hyaline . Apical cell of conidiophore with swollen tips bearing clusters of conidia on short sterigmata.

Conidia – hyaline, 1 celled, ovoid.

Entire structure resemble like grape bunch.

Eg. *Botrytis cinerea* - grey mold of gram, bean, apple and grape.

***Verticillium* :**

Conidiophores**-** slender, septate ,branched, some of the branches bearing verticillate (in whorls) phialides that give rise to conidia.

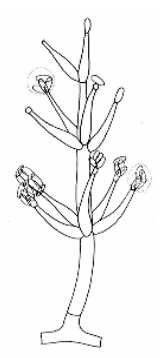
Conidia- ovoid to ellipsoid, 1 celled, borne singly or in moist clusters(mucus) apically.

Eg. *Verticillium albo - atrum* - wilt of cotton and tomato.

V. dahliae- wilt of tobacco and brinjal.

Pyricularia

Botrytis



Verticillium

25.IMPORTANT CHARACTERISTICS OF FAMILY DEMATIACEAE

The hyphae, conidiophores and usually the conidia are brown or black, but some times the hyphae alone or the conidia only are dark.

DISTINGUISHING CHARACTERISTICS OF THE GENERA:

***Alternaria* :**

Mycelium – branched, septate, dark brown.

Conidiophores – simple, straight or curved , 1-3 septate , dark coloured.

Conidia – dictyospore , brown, obclavate with a beak, 3-8 tranversely septate and 1-2 longitudinally or obliquely septate, conidia are produced acropetally in chains (catenulate) through the pores formed at the apex of the beak of conidia.

Eg. *Alternaria solani*- early blight on tomato and potato

A.brassicae- leaf spot of crucifers

***Drechslera*:**

Mycelium**-** branched, septate, brown.

Conidiophores**-** emerge through stomata, erect, septate, simple or branched, dark brown, geniculate (knee joints), indefinite in growth (continue growth sympodially even after production of conidia)

Conidia- dark brown, cylindrical, straight , several celled, many pseudoseptate, germinate from any or all cells .

Eg. *D. turcica*- leaf blight of sorghum

D. nodulosum- seedling blight and foot rot of ragi

Helminthosporium :

Mycelium – dark.

Conidiophore**-** single or clustered, tall, brown, simple.

Conidia- develop laterally through pores beneath septa, often appear in whorls, obclavate, brown, many pseudoseptate with prominent basal scar.

Eg. *Helminthosporium maydis*- southern corn leaf blight

H. victoriae- victoria blight of oat.

***Bipolaris* :**

Differentiated from Drechslera based on method of germination of conidia and shape

Conidia- germinate characteristically from two polar (end) cells only, fusoid and slightly curved.

Eg. *Bipolaris oryzae* – brown spot of rice ;P.S:Cochliobolus miyabeanus

(old: *Drechslera oryzae)*

***Cercospora* ;**

Mycelium **:** immersed in host tissue, branched, septate , pale brown

Conidiophore: emerge in clusters through stomata, brown, septate, simple or rarely branched with knee joints (sympodially extending) marking the scars of fallen spores

Conidia: terminal, arise singly from conidiophore, hyaline, filiform, severa celled (4 -12 septate), a scar at the base.

Eg. . *Cercospora arachidicola*- tikka disease (early leaf spot)on groundnut

P.S:Mycosphaerella arachidicola

***Phaeosariopsis (Cercosporidium*) :**

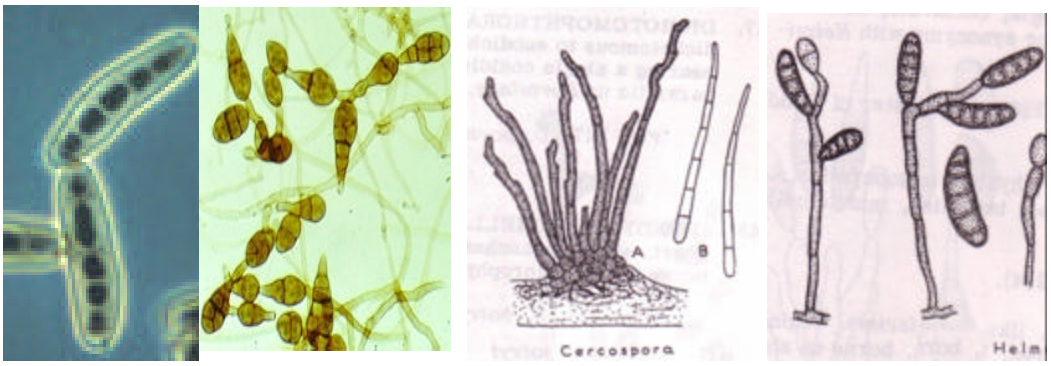
Mycelium **:** septate, intercellular with branched haustoria, pale brown, immersed entirely in leaf tissue.

Conidiophores : emerging through ruptured epidermis in clusters, pale to olivaceous brown, smooth, geniculate, septate , simple with prominenet conidial scars.

Conidia: light coloured, cylindrical, usually straight or slightly curved, rounded at ends, base shortly tapered with a conspicuous hilum, mostly 3-4 septate.

Eg*. Phaeoisariopsis personata (Cercosporidium personatum)* tikka disease (late leaf spot) on groundnut

P.S:Mycosphaerella berkeleyii



Helminthosporium ***Alternaria*** ***Cercospora*** ***Drechslera***

26. IMPORTANT CHARACTERISTICS OF ORDER TUBERCULARIALES

FAMILY TUBERCULARIACEAE:

Include the fungi which produce sporodochium. Sporodochium is a cushion shaped structure consisting of cluster of conidiophores with conidia woven together on a mass of hyphae .

DISTINGUISHING CHARACTERISTICS OF THE GENERA:

Fusarium:

Mycelium -superficial, cottony in culture, septate, hyaline, grouped into sporodochia

Conidiophore- slender,short,hyaline,simple, stout or branched irregularly bearing a whorl of spore producing structures called phialides bearing conidia.

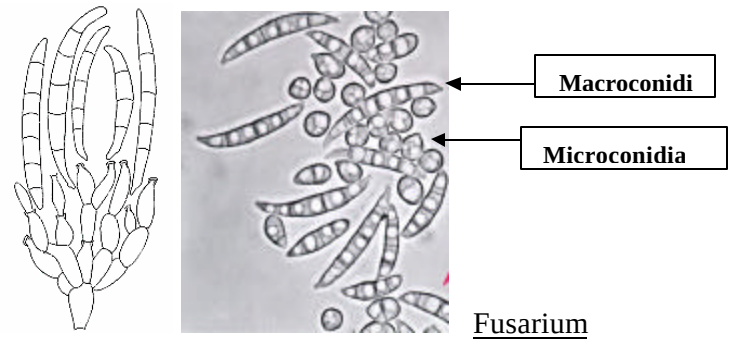
Two types of conidia - macroconidia (several celled, slightly curved or bent, pointed at the both the ends, sickle shaped with a foot cell, hyaline), microconidia(1 or 2 celled, ovoid, single or in chains, hyaline) and also chlamydospores.

Chlamydospores : hyaline, thick walled, terminal or inter calary, produced singly or in chains by the mycelial hyphae or macroconidia. formed by modification of previous cell.

Eg. *Fusarium oxysporum f. sp. ciceri*- wilt of gram

*Fusarium oxysporum f.*sp. *vasinfectum* – wilt of cotton

Fusarium oxysporum . sp . *udum*- wilt on redgram



Fusarium

Myrothecium:

Sporodochia - cusion like, marginal hyaline setae.

Conidiophores- sub hyaline to coloured, repeatedly branched, bearing conidia on phialides

Conidia- 1 celled, sub hyaline to dark, ovoid, gathering in slimy mass.

Eg. *Myrothecium roridum*- shot hole on leaves of tomato, bhendi.

IMPORTANT CHARACTERISTICS ORDER STILBELLALES,
FAMILY STILBELLACEAE:

Include fungi which produce synnemata. Synnemata (sing. synnama) is a structure in which conidiophores are united together through out their length and free at their tip producing slimy head of conidia at their tip or all around the aggregated conidiophores. The whole structure resemble a long feather duster or brush.

Graphium:

Synnemata- tall, dark, bearing a rounded , terminal mass of conidia embedded in mucus

Conidiophores- simple, hyaline , produced in abundance , bearing oblong conidia

Eg. *Graphium ulmi*- dutch elm disease

IMPORTANT CHARACTERISTICS ORDER AGONOMYCETALES,
FAMILY AGONOMYCETACEAE:

Includes the fungi which do not produce conidia, form sclerotial bodies i.e., modification of mycelium , reproduction is by random fragmentation of hyphae.

DISTINGUISHING CHARACTERISTICS OF THE GENERA:

Sclerotium:

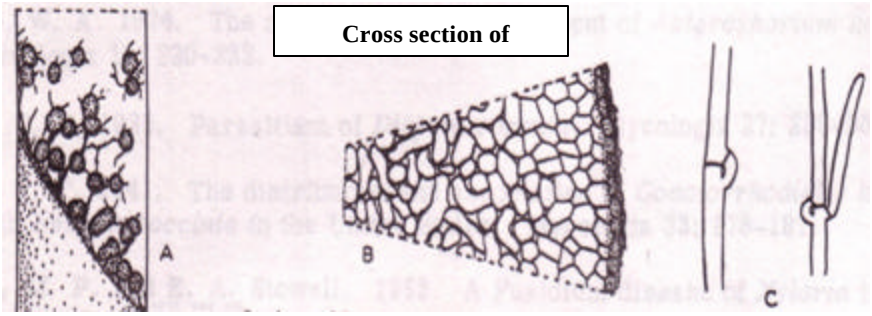
Spores lacking

Mycelium-white or light coloured.

Sclerotia hard, dark brown, globose , compact, bigger than sclerotial bodies of Rhizoctonia, (more than 1 mm diameter in size), consisting of colourless to light coloured , thin walled rectangular cells inside and brown to black , thick walled cells at the periphery.

Eg. *Sclerotium rolfsii***-** root rot of groundnut

*Sclerotium oryzae***-** stem rot of paddy



Sclerotium

***Rhizoctonia* :**

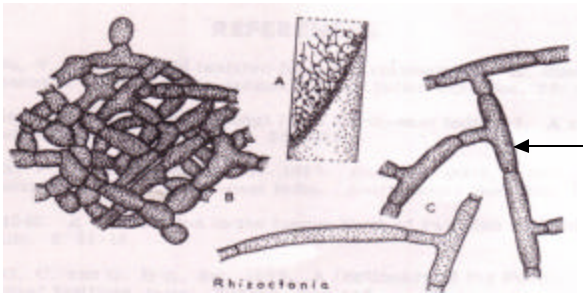
No spores.

Mycelium: brown, stout, septate branches arise at acute angles, hyphal cells barrel shaped and long.

Sclerotia: black, variable in form (globose, oval or irregular), loosely formed and connected by mycelial threads,hard, frequently small (less than 1 mm diameter), no differentiation of sclerotial tissue.

Eg**.***Rhizoctonia bataticola*- charcoal rot of soybean and sheath blight of paddy

R. solani- black scurf of potato



Rhizoctonia

27.PROKARYOTES –CLASSIFICATION (According to Bergey's Manual of Systematic Bacteriology

Classification of Phytopathogenic Prokaryotes,according to Bergey's manuak of systematic Bacteriology,1984

KINGDOM: Prokaryotae
DIVISION I:Gracilicutes,Gram negative
CLASS:Proteobacteria,mostly single celled
FAMILY:Enterobacteriaceae
Eg.Erwinia
FAMILY;Pseudomonadacxeae
Eg:Pseudomonas,Xanthomonas,Rhizobacter
FAMILY;Rhizobiaceae
Eg.Agrobacterium
FAMILY;UNKNOWN
Eg.Xylella

DIVISION II:Firmicutes,Geam positive
CLASS 1:Firmibacteria,mostly single celled
FAMILY:Bacillaceae
Eg.Bacillus
CLASS 2;Thallobacteria,branching bacteria
FAMILY;Corynebacteriaceae
Eg.Streptomyces,Clavibacter,Curtobacterium

DIVISION III;Tenericutes,no cell wall,only cell membrane
CLASS;Mollicutes
FAMILY:Spiroplasmataceae
Eg.Spiroplasma
FAMILY;STILL UNKNOWN
Known as Phytoplasmas

DIVISION IV:Mendesicutes
Eg.Primitive phylogenic Archaeobacteria

28.BACTERIA

Definition: Bacteria are extremely minute,rigid,essentially unicellular organisms (actinomycetes are filamentous),devoid of chlorophyll ,most commonly reproduce by transverse binary fission and the resulting cells are identical in size and morphology.

IMPORTANT CHARACTERISTICS OF PHYTOPATHOGENIC BACTERIA:

1. Straight to curved rods with rigid cell walls (except filamentous bacteria). Some bacteria assume irregular shapes like V, Y, L etc., in different stages of their growth. Ex: V form of *Corynebacterium* (*Clavibacter*) and L-forms of *Agrobacterium* and *Erwinia*.

2. Carbohydrate decomposition is mostly aerobic or oxidative (except *Erwinia*, which is a facultative anaerobe)

3. Mostly gram negative, rarely gram positive (Gr +ve genera: *Streptomyces, Corynebacterium, Clavibacter, Curtobacterium*)

4. PPB can be cultured on artificial media. However, pathogenic bacteria grow slowly compared to saprophytes

5. Majority are flagellate

6. PPB can be identified based on flagellation, carbohydrate metabolism and pigment production

7. These are passive invaders, i.e., enter plants through wounds or natural openings

8. Survive, in/on the seed and in plant debris and spread by means of water, rain, insects, and agricultural implements

9. All are susceptible to phages

10.All are non-spore formers except *Bacillus*.

11. None of them cause human and animal diseases

12. Cell wall rigid

13. Aerobes/ facultative anaerobes

14. Slow growth compared to other saprophytic bacteria

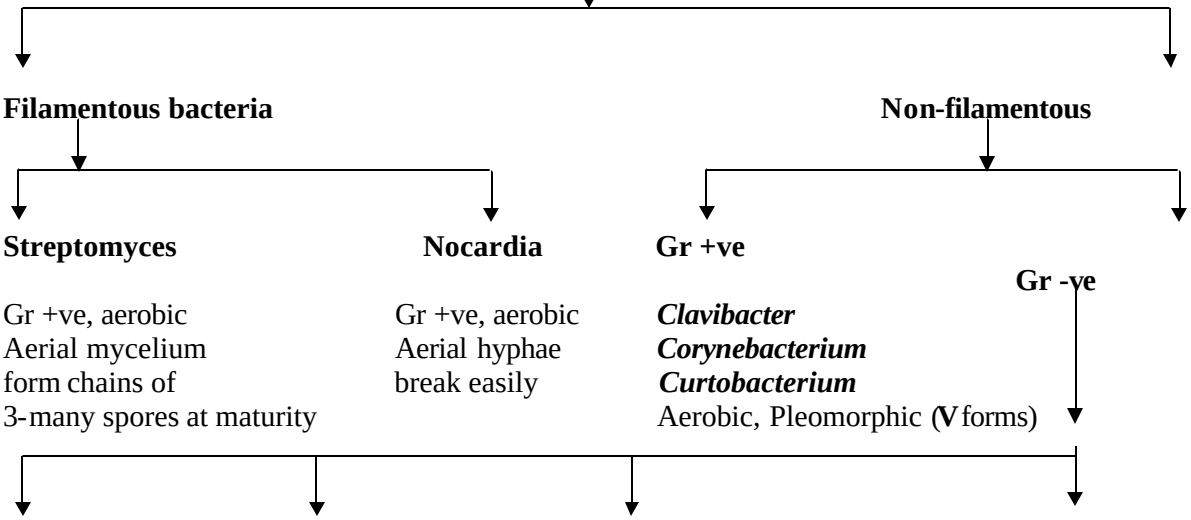
15. Incubation period: 36- 48 hrs. 25 ^{o} c

16. Majority are flagellate and hence motile

17. Identification of gram – ve bac

* Morphological differences-flagellation
*Cultural characteristics
*Physiological characteristics
Biochemical characteristics
*Pathogenicity –Host range

Key for identification of Plant Pathogenic Bacteria



KEY FOR THE IDENTIFICATION OF PHYTOPATHOGENIC BACTERIA

A. Filamentous

Nocardia (gram + ve, conidia not chains)
Streptomyces (gram + ve, conidia in chains)

B. Non filamentous
gram + ve
Corynebacterium ⇒ pleomorphic cells, non- motile
1 - 3 polar flagella , gram –ve, many flagellate
Erwinia⇒ many peritrichous flagella ,
fac. Anaerobe, sparsely flagelate
Pseudomonas⇒ mono/ lophotrichous flagella,
fluoroscent pseudomonads with soluble pigmets,

Non fluorescent pseudomonads

Xanthomonas ⇒ single polar flagellum,
colonies yellow,
produce insolubl pigments

Agrobacterium ⇒ sub polar/ sparsely
peritrichous flagellate
colonies white,
cause galls –hypertrophy

IMPORTANT CHARACTERISTICS OF PHYTOPATHOGENIC BACTERIA

1. *PSEUDOMONAS (RALSTONIA)*

⇒ cells single, gram – ve , aerobic , straight to curved rods
⇒ flagella- polar (mono / lophotrichous
⇒ chemoorganotrophs
⇒fluorescent pseudomonads with water soluble pigments (yellow - green)
non fluorescent psudomonads

2. XANTHOMONAS

⇒ cells single, gram – ve, aerobic, straight rods
⇒ single polar flagella
⇒ chemoorganotrophs
⇒ yellowish, non water soluble pigments
⇒ all species are plant pathogens

3. AGROBACTERIUM

⇒ gram – ve, aerobic, rods
⇒ flagella- 1 (lateral) / peritrichous (sparsely- 4)
⇒ colonies white (non pigmented), smooth
⇒ habitat: rhizosphere and soil
⇒ all produce galls , except *a. Radiobacter*
⇒ produce abundant polysaccharide slime

4. ERWINIA

⇒ cells single, gram – ve, straight rods
⇒ flagella (peritrichous- many)
⇒ non capsulateed
⇒ chemoorganotrophs
⇒ fac. Anaerobes
⇒ non acid fast

5. CLAVIBACTER (CORYNEBACTERIUM)

⇒ gram + ve, aerobic, straight or curved rods or pleomorphic (club shaped , v / y , palisade(picket fence)
⇒non flagellate/ few 1 - 3 polar flagella
⇒ chemoorganotrophs

6.STREPTOMYCES

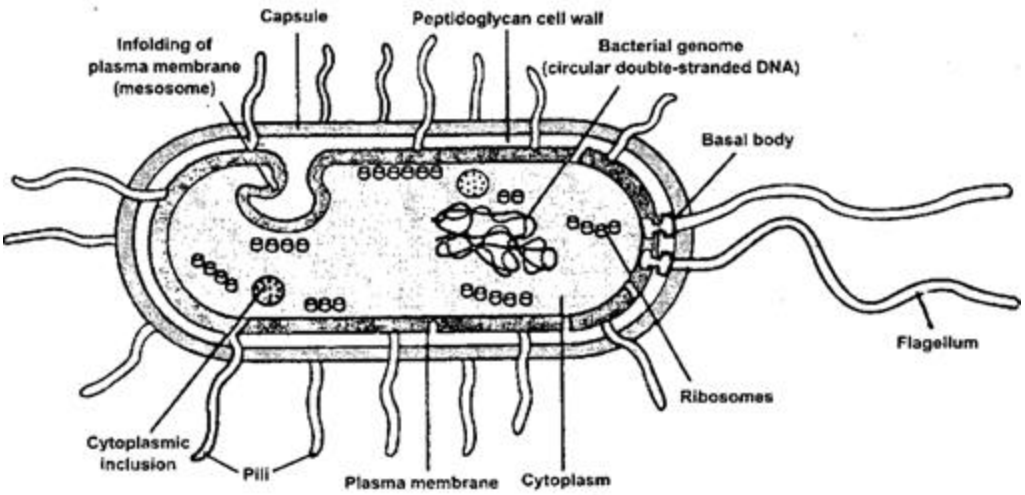
⇒ filamentous, gram + ve, spherical , aerobic
⇒ chemoorganotrophs
⇒ conidia in chains

7.ERWINIA

- rods
-cause necrosis or wilt diseases
-cells single ,gram –ve
-Peritrichous flagellate
-non-capsulated
-Facultative anaerobes
Non-acid fast

8.PECTOBACTERIUM

-separated from Erwinia ,cause soft rot
-Gram negative
-facultative anaerobe
-rods
-strongly pectolytic
-peritrichous flagellate



IMPORTANT PHYTOPATHOGENIC BACTERIAL DISEASES

Disease	Bacteria
1. Wilt of solanaceous crops (tomato)	*Raltsonia (pseudomonas) solanacearum* (non fluorescent pseudomonads)
2. Wild fire of tobacco	*P. syringae pv. tabaci* (fluorescent psudomonads)
3. Bacterial Blight of paddy	*Xanthomonas campestris pv. oryzae*
4. Citrus canker	*X. axonopodis pv. Citri*
5. Black arm / angular leaf spot of cotton	*X. campestris pv. malvacearum*
6. Black rot of crucifers	*X. campestris pv . campestris*
7. Crown gall of apple	*Agrobacterium tumefaciens*
8. Soft rot of vegetables	*Erwinia carotovora*
9. Fire blight of apple	*E. amylovora*
10. Tundu disease of wheat	*Corynebacterium tritici*
11. Common scab of potato	*streptomyces scabies*

30.FASTIDIOUS VASCULAR BACTERIA (RICKETTSIA LIKE ORGANISMS)

Def : similar to bacteria in all respects but can not be grown on conventional bacteriological media but requiring complex / special nutrient medium for its multiplication

- Howard Taylor Ricketts (1916) – first discovered rickettsia
- 1972- first observation in phloem of clover and periwinkle causing clover club leaf disease
- 1973- observed in xylem causing pierce' s disease of grapes

IMPORTANT CHARACTERISTICS:

- Cell wall is thin (20-30 nm thickness)and undulating
- Rods / pleomorphic in shape
- Sizevary from 1-4 μ m l , 0.2- 0.5 μ m dia.
- No flagella hence, non motile

- All Are gram negative except sugarcane ratoon stunt which is

grampositive

- Non spore former
- Found in xylem and phloem vessels of plants
- Intra cellular parasites
- Transmission by leaf .hoppers, bugs , psyllids and mechanical
- Sensitive to tetracycline and penicillin and high temperatures
- Can be eliminated by immersing propagative material in hot water at 45-50 ^{o}c for 2 -3 hrs. Or keep in hot air at 50- 58 ^{o} c for 4 -8 hrs. (Eg. Sugarcane ratoon stunt and pierce's disease of grapes).

IMPORTANT CHARACTERISTICS OF

1. *Leifsonia xyli* - Sugarcane ratoon stunt

- xylem inhabitant, gram + ve
- transmission ⇒ no vector, mechanical (sap) or through implements
- growth ⇒ special / complex nutrient medium

2. Candidatus liberobacter asiaticus -Citrus greening

- phloem inhabitant, gram - ve , rigid rods,.
- transmission by *Diaphorina citri* (psyllid) or vegetative propagation

3.Xylella fastidiosa - Pierce's disease of grapes

- xylem inhabitant, gram - ve
- transmission by leaf hopper and grafting

31.PHYTOPLASMAS AND SPIROPLASMAS

PHYTOPLASMAS (PHYTOPLASMATOLOGY):

- Non helical molicutes, Pplo's, Plto's, mycoplasmas, wall less prokaryotes
- Mollicutes- molli(soft) , cute (skin)
- MLO's / phytoplasmas
- **def:** prokaryotic, pleomorphic , resemble mycoplasma , wall less, (trilamellar unit membrane) self replicating, pass through filters, sensitive to tetracyclines, transmission by leaf hoppers ,found in sieve elements.

IMPORTANT CHARACTERISTICS OF PHYTOPLASMAS:

- Size vary from 100 nanometers to 1 micrometer dia
- Wall less, covered by trilamellar unit membrane with lipoproteins
- Cells pleomorphic
- Aerobic to facultative anaerobes
- Found intracellularly in phloem vessels of plants
- Ribosomes of bacterial type
- Genome is made up of dscircular DNA ,
- Osmotically stable
- Self replicable by transverse binary fission
- Obligate parasites
- Non Flagellate, non spore former and gram – ve.
- Resistant to **penicillin** but sensitive to **tetracycline** & chloramphenicol
- No Reversion to bacteria in penicillin free media unlike l- forms which revert back to bacteria eg.. *A. tumefaciens*)
- Subjected to viral infection.
- Transmission by leaf hoppers and grafting
- Genetically more related to acholeplasms than mycoplasmas
- can be controlled by cross protection
- require **sterols** for growth
- can be controlled by thermotherapy by growing plants at 37- 40 ^{o} c. Eg.Mulberry dwarf

Symptoms :

- yellows (yellowing and stunting)
- little leaf, virescence(greening of flowers)
- phyllody(flowers turn into green leafy structures)
- witches broom (broom like growth or massed proliferation caused by the mass clustering of branches)
- bronzing of leaves

DISEASES CAUSED BY PHYTOPLASMAS AND VECTORS

Disease	Vector
1. Aster yellows	*Macrosteles fascifrons (leaf hopper*)
2. Sesamum phyllody	*Orosius albicinctus ,O.orientalis(leaf hopper)*
3. Mulberry dwarf	*Hishimonas sellatus (leaf hopper)*
4. Sandal spike	*Jassus indicus (leaf hopper)*
5. Little leaf brinjal	*Hishimonas phycitis (leaf hopper)*
6. Grassy shoot- sugarcane	*Aphis maydis (ahid)*
7. Potato witches broom	*Orosius albicinctus(leaf hopper)*

SPIROPLASMAS (HELICAL MOLLICUTES)

(SPIROPLASMATOLOGY)

* **Def***:* helical, wall less prokaryotes, phloem of diseased plants, helical in culture, a kind of mycoplasmas, but can be cultured

IMPORTANT CHARACTERISTICS:

- Helical in liquid media
- Size vary from 100- 240 nm dia
- Grown on culture medium in laboratory medium.
- Gram + ve
- Colonies apper like fried egg in culture medium
- Multiplication by transverse binary fission
- No flagella
- Resistant to penicillin but sensitive to tetracycline

IMPORTANT DISEASES AND TRANSMISSION:

Disease	Vector (leaf hopper)
1. Corn stunt	*Dalbulus elimatus*
2. Citrus stubborn	*Circulifer tenellus*

32.VIRUSES AND VIROIDS

♦ **Plant Viroligy** : study of plant viruses

♦ **Virus** : vira (poison fluid) sanskrit- visha (poison)

♦ **Def** :1 (Bawden , 1964) - sub microscopic, infectious entities,multiply intracellularly, potentially pathogenic

♦ **Def** : 2.(Mathews, 1981) – a set of one or more na molecules, encased in protein coat, organise own replication with in suitable host

Virus production depends on

¨ host protein synthesizing machinary

♦ pools of requiredmaterial from host

IMPORTANT CHARACTERISTICS OF PLANT VIRUSES:

¨ ultra microscopic

¨ pass through bacterial proof filters hence called filterable agents

♦ obligate Parasites, highly infectious and host specific

♦ do not have lipman system / enzyme system for energy generation .

- ♦ posses genetic information to command host to produce enzymes
- ♦ absolute parasitism – dependent on host protein synthesizing machinary
- ♦ multiplication in terms of genetic material(dna/ rna)
- ♦ no binary fission
- ♦ virions – technical name of virus / virus particle
  - ¨ virion consist ofnucleic acid protected by protein coat (capsid) i.e., chemically nucleoproteins
  - ¨ antigenic property with capsid
- ♦ mutate and produce strains
- ♦ genome : majority- RNA Eg. *Tobamovirus* (Tobacco mosaic virus)
  few - DNA Eg.1. *Caulimovirus* (cauliflower mosaic virus)
  2. *Gemini virus* (sub. Group maize streak virus)
- ♦ Multicomponent viruses

1. Bipartite virus
2. Triipartite virus
3. Multipartite virus

- ♦ Maintain definite shape

1. Rod (end open) a. . Rigid rod eg. Tmv
   b.. Flexible rod eg. Pv-x
2. Polyhedral virus (spherical / icosahedran)
   eg tobacco necrosis & cucumber mosaic virus
3. Bacilliform (end covered by protein sub units)
   eg alfalfa mosaic virus
4. Gemini virus -maize streak virus

- ♦ Biological enigma

CLASSIFICATION OF PLANT VIRUSES
KINGDOM: VIRUSES

RNA VIRUSES

a. Single stranded RNA viruses

1. Rod shaped particles

Eg. *Tobamovirus* (tobacco mosaic virus)
furovirus(potato mop top virus)

2. Filamentous particles

Eg. *Potexvirus*(potato virus- x)
potyvirus (potato virus - y)

3. Isometric particles

Eg. *Waikavirus(* rice tungro virus)
comovirus (cowpea mosaic virus)
tospovirus(tomato spotted wilt virus)

nepovirus (grape fan leaf virus)
potato leaf roll virus

DNA VIRUSES

A. Double stranded dna viruses
1. Isometric particles
Eg. *Caulimovirus* (cauliflower mosaic virus)

B. Single stranded dna particles
1. Geminate (twin) particles
Eg. *Geminivirus(* maize streak virus)
2. Single isometric particles
Eg. *Banana bunchy top virus*

According to **ICTV** (International Committee on Taxonomy of viruses) system of classification, basically viruses can be classified based on the nature of their genetic material, i.e., DNA or RNA. Presently in plant viruses, 27 groups has been identified. Among these, two groups (families), viz., Rhabdoviridae and Reoviridae, can infect plants as well as animals and arthropods.

1. Viruses with **ss RNA without envelope**
a. Isometric particles Ex: *Tobacco necrosis virus*
b. Rod shaped particles Ex: *Potato virus X, Bean common mosaic virus*
2. Viruses with **ss RNA genome with envelope** Ex: *Rhabdo virus* group and *Tomato spotted wilt virus*
3. Viruses with **ds RNA** genome Ex: **Reo virus** and **Phyto reo virus** (wound tumor virus)
4. Viruses with **ss DNA** genome Ex: **Gemini virus** group (*Maize streak virus, Banana bunchy top virus, Bean golden mosaic*)
5. Viruses with **ds DNA** genome Ex: *Cauliflower mosaic virus* (**Caulimo virus**)*, Rice tungro bacilliform virus*.

SYMPTOMS OF VIRAL DISEASES

A. EXTERNAL SYMPTOMS :

1. Mosaic: alternate green and yellow patches Eg. Tmv

2. Vein clearing : tissue close to vein yellow, remaining area green
Eg vein clearing of bhendi.

3. Vein banding : tissue along vein green, tissue between vein chlorotic.
Eg tobacco leaf curl.

4. Ring spot : circular chlorosis with green centre Eg papaya ring spot.

5. Necrosis: death of cells in stem Eg. Top rot of potato

6. Distortion / malformation : leaves, flowers twisted, become narrow, end in rat tail appearanc Eg.. Leaf curl of papaya

7. Enation : masses of hypertrophoid tissue on leaf surfacew.

Eg.. Leaf curl of tobacco

8. Masked symptoms : plants contain virus , but symptomless under unfavourable conditions. Symptoms reappear under favourable. Conditions.

masked virus : virus showing phenomenon of masking.
Eg. Cauliflower mosaic virus at $> 24^0$ c

9. Symptomless carrier : the infected plant showing no obvious symptoms

Latent virus : virus not inducing development of symptoms in its host over entire range of envl. Conditions. Eg. Tristeza virus on sweet orange

B. INTERNAL SYMPTOMS:

1. Cell inclusion bodies

a)X- bodies- amorphous amoeboid like

b)Flat crystalline plates

2. **Destruction of normal tissue** .

a)Stem pittings Eg. Tristeza virus

METHODS OF TRANSMISSION OF PLANT VIRUSES:

(a) Artificail transmission (**b**)Natural transmission

a) Artificial transmission

1.Mechanically through Sap: rubbing the sap from infected leaves to healthy leave Eg. Tobacco and tomato mosaic virus

2.Grafting : grafting of plants from infected to healthy.
Eg Citrus tristeza, Tobacco leaf curl

b) Natural transmission

1.Contact : physical/ aerial contact of leaves Eg. TMV,PV-X

2.Seed/ propagative material :

a. Internal seed borne viruses
Eg. Bean, cowpea, soybean mosaic virus

b. Vegtatively propagating material
Eg. Sugarcane mosaic virus – setts
PV-X -tubers

3.Phanerogamic parasites – virus transfer between unrelated hosts

Eg. Dodder
Cuscuta campestris – Tomato bushy stunt virus
C. c alifornica – TSWV

4.Soil : virus viable for 6 yers in soi eg. Wheat mosaic virus

5.Fungi

Eg. *Synchytrium endobioticum* – PV-X
Olpidium brassicae - Tobacco necrosis virus

6.Nematodes

Nepoviruses
Eg.*Xiphinema index*- Grape fan leaf virus
Longidorus attenuatus - Tomato black ring virus

Netuviruses
Eg. *Trichodorus cylindricus* - Tobacco rattle virus

7.Insect vectors : most potential vectors

vector – any living organism that transmits a parasite

* insects with sucking mouth parts more efficient than biting and chewing mouth parts.

* a single virus can be transmitted by several insects .Eg. Onion yellow dwarf virus by more than 50 species of aphids

♦ a single insect may transmitt several viral diseases
Eg: *Myzus persicae* (aphid) transmits more than 50 viruses

VIRUS- INSECT VECTORS

DISEASE/ VIRUS	**INSECT**
1. Rice tungro/ waikavirus	*Nephotettix apicalis* (leaf hopper)
2. Ragi mosaic virus/RMV	*Myzus persicae* (aphid)
3. Redgram sterility mosaic /RSMV	*Aceria cajani*(mite)
4. Tomato &tobacco leaf curl/ TLCV	*Bemisia tabaci* (white fly)
5. Yellow mosaic of pulses	*Bemisia tabaci*
6. Bunchy top of banana/ BTV	*Pentalonia nigronervosa (* aphid)
7. Bhendi yellow vein mosaic / BYVMV	*Bemisia tabaci*
8. Tomato spotted wilt virus/TSWV	*Thrips tabaci* (thrips)
9. Potato leaf roll /	*Myzus persicae*(aphid)

PLV

10. Cowpea mosaic/ CMV — *Ceratoma trifurcata (* beetle)

11. Wheat streak mosaic/ WSMV — *Aceria tuptipae* (mite)

TYPES OF VIRUSES

1. **Persistent virus/ circulative virus:**

Persistent virus :

A virus which retains for longer period (sometimes through out life) by vector and some times pass to the progeny of vector and transmitted by mouth parts

Circulative virus:

Viruses which enter the vector thro. Mouth parts , accumulate internally and pass thro. The tissue before getting introduced into the plants thro. Mouth parts of the vector.

Eg.Barley yellow dwarf & potatao leaf roll virus

2. **Non persistent virus/ stylet borne virus** :

Non persistent virus :

A virus which is not retained for not more than a few hours by vectors

Stylet borne virus:

virus is thought to be transmitted by stylets with out entering insect

Eg. Cucumber, bean ,Chilli mosaic virus: Rice tungro virus

3. **Semi persistent virus** :

A virus which is retained for a few days by vectors . Virus do not pass to the progeny

Eg.. Cauliflower mosaic virus

4. **Propagative viruses :**

if circulative viruses multiply in their vectors.

5. **Satellite virus :**

virus always associated with helper viruses and depend on for multiplication and infection. Eg CMV

VIROIDS

(MINI NAKED VIRUS)

Def : obligate .parasites, low molecular weight nucleic acids (ss r n a) with out protein coat, replicate themselves and cause diseases only in plants

Diener (1971) – firsttime discoveredvoroid causing potato spindle tuber about 20 plant diseases are known to be caused by viroids

IMPORTANT CHARACTERISTICS:

- Obligate parasites
- Smallest known infectious agent of plant diseases
- Lacks protein coat
- Genome – circular ss rna
- Transmission mechanically thro . Sap and by vegetative propagation
- No vector is known
- Replication mechanism – not known (r n a copying ?)
- None of the viroids cause animal or human disease
- Can survive out side host or dead plant debris for few min. To few hrs.
- Resistant to high temperatures

IMPORTANT DISEASES AND TRANSMISSION

DISEASE	VIROID	TRANSMISSION
1.Coconut cadang - cadang	CCCV	seed & pollen
2.Potato spindle tuber	PSTV	mechanical/ seed/ pollen
3.Citrus exocortis	CEV	Mechanical/ SAP
4.Chrysanthemum stunt	CSV	SAP

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ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY

B.Sc.(Ag)

C.NO.PATH 171
(Credits 2+1)

INTRODUCTION TO PLANT PATHOGENS

Lecture Notes

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2004

FAMILY :1 PUCCINIACEAE -

IMP CHA: TELEUTOSPORES FREE OR UNITED, NO LAYERS, STALKED.

EG. PUCCINIA, UROMYCES, HEMILEIA

PUCCINIA

UREDOSPORES: REPEATING ASEXUAL SPORES, SINGLE CELLED, BROWN, OVAL, THICK WALLED,SPINY, STALKED, BINUCLEATE.

TELEUTOSPORES: SEXUAL RESTING SPORES, 2CELLED, STALKED, DARK BROWN, THICK WALLED, SPINDLE SHAPED, SMOOTH, ROUND OR POINTED AT APEX, CONSTRICTION AT SEPTUM, BINUCLEATE.

EG. BLACK STEM RUST OF WHEAT - P. GRAMINIS F.SP. TRITICI

UROMYCES

UREDOSPORES: SINGLE CELLED, OVAL, YELLOWISH BROWN, STALKED, ECHINULATE.

TELEUTOSPORES: SINGLE CELLED, PAPILLA AT APEX, OVATE, DARK BROWN, PEDICILLATE, SMOOTH WALLED.

EG.BEAN RUST-UROMYCES APPENDICULATUS

HEMILEIA

UREDOSPORES: RENIFORM, CONCAVE SMOOTH, CONVEX ECHINULATE, RESMBLE ORANGE SEGMENTS.

TELEUTOSPORES: TURNIP SHAPED, THICK WALLED, HYALINE, STALK CLUB SHAPED, SMOOTH. LEPTOSPORES. 1 CELLED.

EG. COFFEE RUST - HEMILEIA VASTATRIX

FAMILY: 2.MELAMPSORACEAE

IMP CHA: TELEUTOSPORES LATERALLY UNITED TO FORM LAYERS, SESSILE.

MELAMPSORA

TELEUTOSPORES : SINGLE CELLED, SESSILE, LATERALLY UNITED.

EG. LINSEED RUST - MELAMPSORA LINI

FAMILY: 1 USTILAGINACEAE

EG.USTILAGO, SPHACELOTHECA, MELANOPSICHIUM,

TOLYPOSPORIUM

Key for identification of genera

Teleospores singles

A.Sori dusty at maturity

Sori covered by peridium (membrane), host origin-
Eg. Ustilago

TELEUTOSPORES: SEPARATE, SPHERICAL, BLACK, TUBERCULATE, 1 CELLED,

Sori covered by peridium – fungal cells
Central columella present-
Eg.Spacelotheca

TELEUTOSPORES: DARK BROWN , SMOOTH WALLED, 1 CELLED, OVAL,

B. Spores more or less agglutinated at maturity

Spores firmly agglutinated into irregular hard galls , no columella
Eg: Melanopsichium

C.Spores in balls

Spore balls permanent, adhering by thickenings of exospore-
Eg: Tolyposporium

TELEUTOSPORES: PERMANENT SPORE BALLS, GLOBOSE,
BROWNISH GREEN, WARTY WALL,