MYCOLOGY

DEPARTMENT OF PLANT SCIENCES

DR. STANLEY KIMARU

2019

NOMENCLATURE-BINOMIAL SYSTEM OF NOMENCLATURE, RULES OF NOMENCLATURE, CLASSIFICATION OF FUNGI. KEY TO DIVISIONS AND SUB-DIVISIONS

Taxonomy and Nomenclature

Nomenclature is the naming of organisms. Both classification and nomenclature are governed by International code of Botanical Nomenclature, in order to devise stable methods of naming various taxa, As per binomial nomenclature, genus and species represent the name of an organism. Binomials when written should be underlined or italicized when printed. First letter of the genus should be capital and is commonly a noun, while species is often an adjective. An example for binomial can be cited as:

Kingdom = Fungi

Division = Eumycota

Subdivision = Basidiomycotina

Class = Teliomycetes

Order = Uredinales

Family = Pucciniaceae

Genus = *Puccinia*

Species = *graminis*

Classification of Fungi

An outline of classification (G.C. Ainsworth, F.K. Sparrow and A.S. Sussman, The Fungi Vol. IV-B, 1973)

Key to divisions of Mycota

Plasmodium or pseudoplasmodium present. MYXOMYCOTA

Plasmodium or pseudoplasmodium absent, Assimilative phase filamentous.

EUMYCOTA

MYXOMYCOTA

Class: Plasmodiophoromycetes

1. Plasmodiophorales Plasmodiophoraceae *Plasmodiophora, Spongospora, Polymyxa*

Key to sub divisions of Eumycota

Motile cells (zoospores) present, … MASTIGOMYCOTINA Sexual spores

typically oospores Motile cells absent

Perfect (sexual) state present as

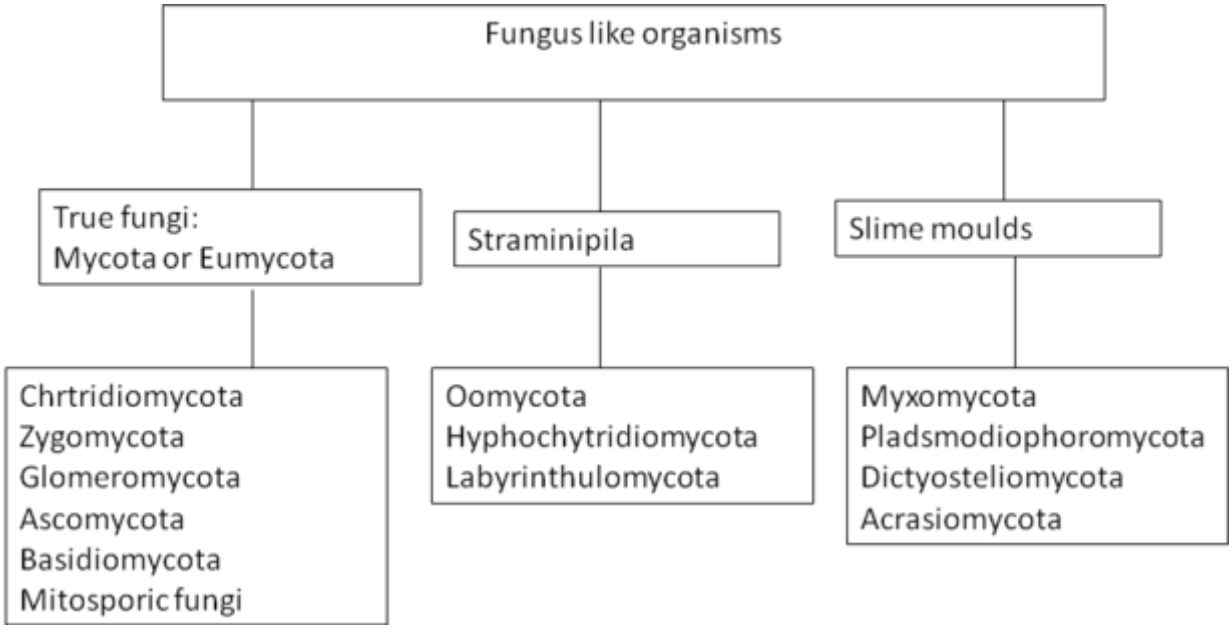
Zygospores… ZYGOMYCOTINA

Ascospores… ASCOMYCOTINA

Basidiospores… BASIDIOMYCOTINA

Perfect (sexual) state not seen … DEUTEROMYCOTINA

Classification of Fungi



DIVISION I: MYXOMYCOTA, CLASS: PLASMODIOPHOROMYCETES, ORDER: PLASMODIOPHORALES

Key to divisions of Mycota

Plasmodium or pseudoplasmodium present - **Myxomycota**

Plasmodium or pseudoplasmodium absent,

Assimilative phase filamentous - **Eumycota**

Myxomycota

Class: Plasmodiophoromycetes

1. Plasmodiophorales

Plasmodiophoraceae *Plasmodiophora, Spongospora, Polymyxa*

Club root of cabbage caused by *Plasmodiophora brassicae*

Systematic position

Kingdom : Protista (Eukaryote)

Sub-kingdom : Mycota

Division : Myxomycota

Class : Plasmodiophoromycetes

Order : Plasmodiophorales

Family : Plasmodiophoraceae

Genus : *Plasmodiophora*

Species : *P. brassicae*

Symptoms

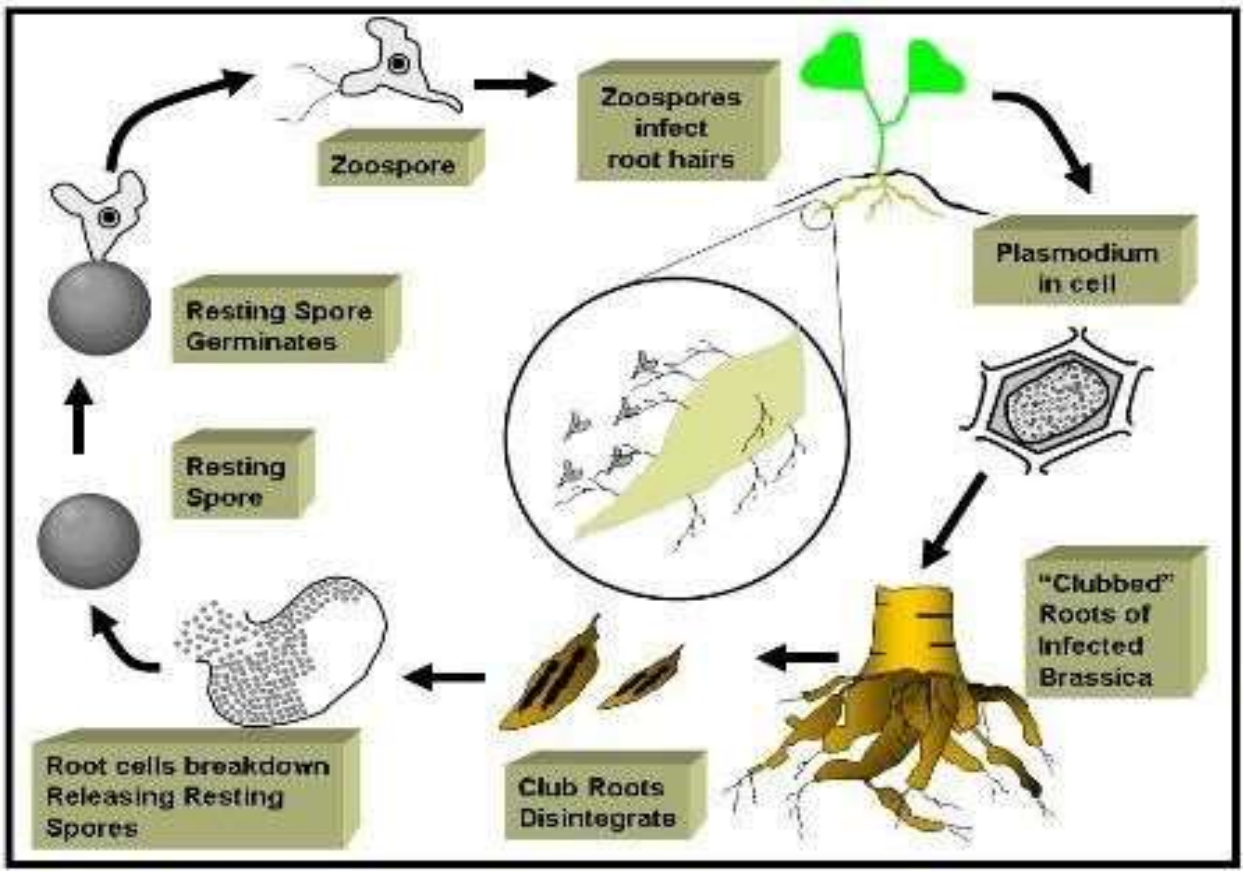
Enlargement of roots, club-shaped roots due to hyperplasia and hypertrophy, gradual and inconspicuous stunting, yellowing and wilting of plant.

Pathogen

The thallus is a plasmodium (a naked mass of nucleated cytoplasm with amoeboid movement), which gives to zoosporangia or resting spore, which on germination produce zoospores. Resting spores are spherical with spiny walls. Zoospores are anteriorly biflagellate, heterokont (unequal in length) and uninucleate, both the flagella are of whiplash type.

Life cycle

Infection of the root hairs occurs during the seedling stage. Resting spores, which lie dormant in the soil upto several years. Germinate and a circular pore is formed on its wall. Al apically biflagellate zoospore comes out. Each resting spore produces single zoospore. The zoospore penetrates the root hair and develops into uninucleate primary plasmodium. The plasmodium cleaves into multinucleate portions. Each portion develops into a zoosporangium containing 4-8 zoospores. The zoospores are discharged outside the host through pores dissolved in the host cell wall. The zoospores fuse in pairs to produce zygotes. These zygotes with four flagella case new infection and produce new plasmodium. This plasmodium penetrates the young root tissues directly or the older roots and underground stems through wounds. Thus the plasmodium spreads to cortical cells in cambium by direct penetration. When the plasmodia establishes in the host cells, they are stimulated to enlarge (hypertrophy) and divide abnormally (hyperplasia). The cells become larger (5 or more times). The plasmodium develops into large



number of resting spores inside the plant tissues, which are released into soil by disintegration of clubbed roots.

DIVISION II: EUMYCOTA SUBDIVISION: MASTIGOMYCOTINA, CLASS: CHYTRIDIOMYCETES (CHYTRIDIALES), OOMYCETES (PERONOSPORALES)

General characters

Members of the class Oomycetes are mostly aquatic but some are facultative or obligate parasites of vascular plants. Majority of them are with filamentous hyaline coenocytic mycelium. Cell wall contains cellulose. They produce asexual spores called zoospores. Oospore is the sexual spores.

Class: Oomycetes

Zoospores biflagellate (posterior flagellum whiplash-type; anterior tinsel-type); cell wall cellulosic.

1. Members of the class comycetes are mostly aquatic but some are facultative or obligate parasites of vascular plants.
2. They are distinguished by the presence of well-developed holocarpic or eucarpic mycelium or rhizomycelium and zoospores bearing two flagella, one whiplash type and the other tinsel type. In some members, Zoospores are not formed and the zoosporangia function as conidia. The cell wall does not contain chitin, small amounts of cellulose are detected but the principal components are glucans.
3. In sexual reproduction the union of antheridia and oogonia produces oospores.

Order: Peronosporales

This order includes highly economically important plant pathogens. The members cause downy mildew and white rust diseases. Hyphae are well developed and aseptate. Cell wall is composed of glucan-cellulose complex and hydroxyproline. Parasites produce haustoria, which may be knob-like, elongated or branched and are found within the host cells. Asexual reproduction is by well-defined sporangia. Sexual reproduction is by means of well-differentiated sex organs, antheridia (male) and oogonia (female). Oospores germinate directly or by producing a sporangium.

Families

Pythiacea*e*

Sporangiophores similar to the vegetative hyphae or if different then of indeterminate growth. Pythiaceae contains genera like *Pythium* and P*hytophthora*

Albuginaceae

Sporangiophores strikingly different from vegetative hyphae, slender or thick, variously club-shaped, arranged in a layer, and bear sporangia in chain at the tip. These are obligate parasites. It contains a single genus, Albugo.

Peronosporaceae

Sporangiophores strikingly different from vegetative hyphae, slender or thick, variously shaped, and with determine growth; sporangia produced singly or in cluster at the tip of sporangiophores or their branches; obligate parasites.

Classification of Peronosporaceae

A. Sporophores determinate, hyphae-like short, unbranched or obpyriform, not maturing synchronously, germinating by zoospores; antheridia always paragynous; oogonial wall thick and confluent with that of the oospores; oospore germinates by germ tube or a sporophore terminated by a sporangium. **-** ***Sclerophthora***

AA. Sporophores determinate, macronemous, stout, 10 or more microns broad, branched or unbranched, oogonial wall thick and rough or ornamented:

B. Sporophores unbranched, apex swollen and with short sterigmata bearing papillate sporangia germinating by zoospores; oospores aplerotic**.-** ***Basidiophora***

BB. Sporophores repeatedly branched in the upper portion, dichotomous; spores mature synchronously; oogonial wall thick; oospore plerotic; sporangia germinate by zoospores or germ tube; oospores germinate by a germ tube**.-** ***Sclerospora***

AAA. Sporophores determinate, narrow, not more than 15 microns broad, usually 8- 10 microns; oogonial wall unornamented except in *Bremiella:*

B. Spore wall uniformly thick (non-poroid), germination typically by germ tube. **-** ***Peronospora***

BB. Spore wall poroid, emerging through an apical pore with or without papilla:

C. Branching of sporophore at right angles, tips or branches blunt.**-** ***Plasmopara***

CC. Branching at acute angles:

D. Tips of branches acute **-** ***Pseudoperonospora***

DD. Tips much enlarged and bearing 3-4 peripheral sterigmata; oogonial wall and oospore wall thin and unornamented.. *Bremia* DDD. Tips of branches blunt and slightly enlarged; oogonial wall thick and ornamented.**-** ***Bremiella***.

Club root of cabbage, damping off and life cycles of *Plasmodiophora, Pythium* and *Phytophthora*

Club root of cabbage caused by *Plasmodiophora brassicae*

Enlarged roots appearing like spindles or clubs due to stimulation of root cells to abnormal enlargement (hypertrophy) and abnormal division (hyperplasia) is called **club root.**

Systematic position

Scientific categorization of the organisms in a hierarchal series of groups. Based on characteristics of the spores, spore bearing structures and mycelium. Many fungi were classified earlier based on the asexual spore and same were reclassified once they produced sexual spore.

Kingdom: Protista (Eukaryote)

Sub-kingdom: Mycota

Division: Myxomycota

Class: Plasmodiophoromycetes

Order: Plasmodiophorales

Family: Plasmodiophoraceae

Genus: *Plasmodiophora*

Species: *P. brassicae*

Symptoms

Enlargement of roots, club-shaped roots due to hyperplasia and hypertrophy, gradual and inconspicuous stunting, yellowing and wilting of plant.

Pathogen

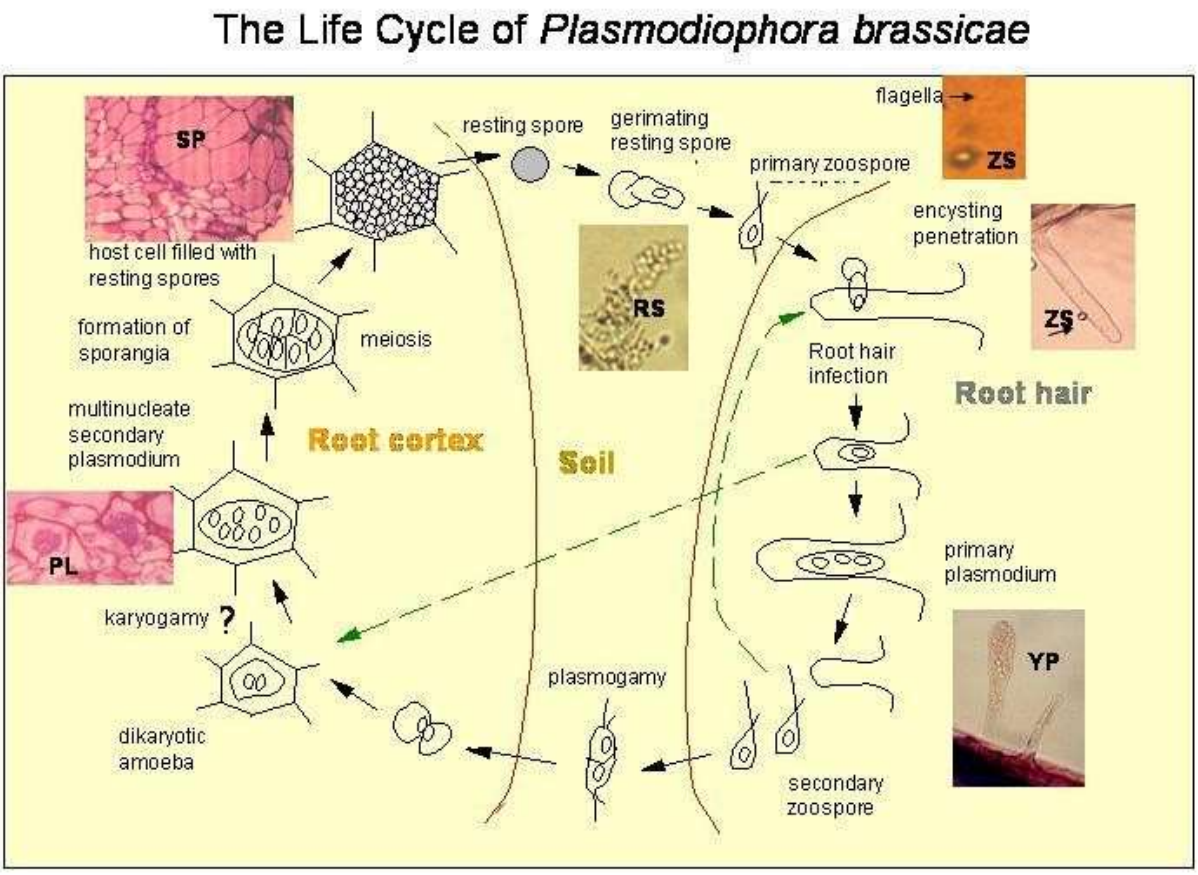
The thallus is a plasmodium (a naked mass of nucleated cytoplasm with amoeboid movement) which gives to zoosporangia or resting spore, which on germination produce zoospores. Resting spores are spherical with spiny walls. Zoospores are anteriorly biflagellate, heterokont (unequal in length) and uninucleate, both the flagella are of whiplash type.

Disease cycle

Infection of the root hairs occurs during the seedling stage. Resting spores, which lie dormant in the soil upto several years, germinate and a circular pore is formed on its wall. An apically biflagellate zoospore comes out. Each resting spore produces single zoospore.

The zoospore penetrates the root hair and develops into uninucleate primary plasmodium. The plasmodium cleaves into multinucleate portions. Each portion develops into a zoosporangium containing 4-8 zoospores. The zoospores are discharged outside the host through pores dissolved in the host cell wall. The zoospores fuse in pairs to produce zygotes.

These zygotes with four flagella cause new infection and produce new plasmodium. This plasmodium penetrates the young root tissues directly or the older roots and underground stems through wounds. Thus the plasmodium spreads to cortical cells in cambium by direct penetration. When the plasmodia establishes in the host cells, they are stimulated to enlarge (hypertrophy) and divide abnormality (hyperplasia). The cells become larger (5 or more times). The plasmodium develops into large number of resting spores inside the. Plant tissues, which are released into soil by disintegration of, clubbed roots.



Damping off of vegetables (tomato, brinjal, chillies, etc.) and tobacco –

Pythium aphanidermatum

Damping off is a special name given to denote wilting of young seedlings in nursery. The rapid death and collapse of very young seedlings in the seedbed is called **damping off**.

Systematic position Sub-kingdom: Mycota Division: Eumycota

Sub-division: Mastigomycotira

Class: Oomycetes

Family: Pythiaceae

Genus: *Pythium*

Species: *P. aphanidermatum*

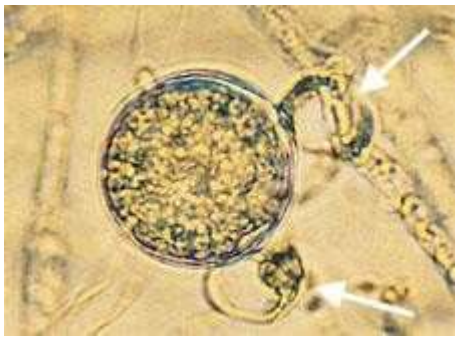
Symptoms

It is generally observed two weeks after sowing. Water-soaked lesions appear on the collar region of seedlings; browning and shriveling of stem tissues at soil level in the collar region; toppling down of seedlings in the nursery; ultimate death of sick seedling.

Pathogen

It is a facultative parasite and homothallic (both male and female gametes are produced in the same mycelium. Mycelium is hyaline, coenocytic (von-septate), branched, inter and intra cellular giving the appearance of a white fluffy cellular mass, does not have haustoria. Cell wall of this fungus contains cellulose. Sporangium is lobed or irregular; it forms vesicle. Sporangiophores are undifferentiated and similar to somatic hyphae.

Zoospores are produced in spherical vesicle and liberated after bursting of vesicle. They are reniform and biflagellate with flagella attached to lateral side, one pointing upward is tinsel type and the other pointing downward is whiplash type. Antheridium (male gametangium) is paragynous, club shaped, terminal or intercalary and it is applied to the side of the oogonium; the hyphal branch bearing antheridium may arise either from oogonial stalk (monoclinous) or from a separate -hypha (diclinous). Oogonium (female gametangium) is globose, generally develops at the tip of hyphal branch and consists of central denser zone called ooplasm or oosphere and peripheral lighter zone called periplasm. Oospores are the sexual spore, which helps to tide over adverse conditions (resting spore). They are spherical, thick walled with yellowish brown wall and does not fill oogonial cavity called aplerotic oospore.

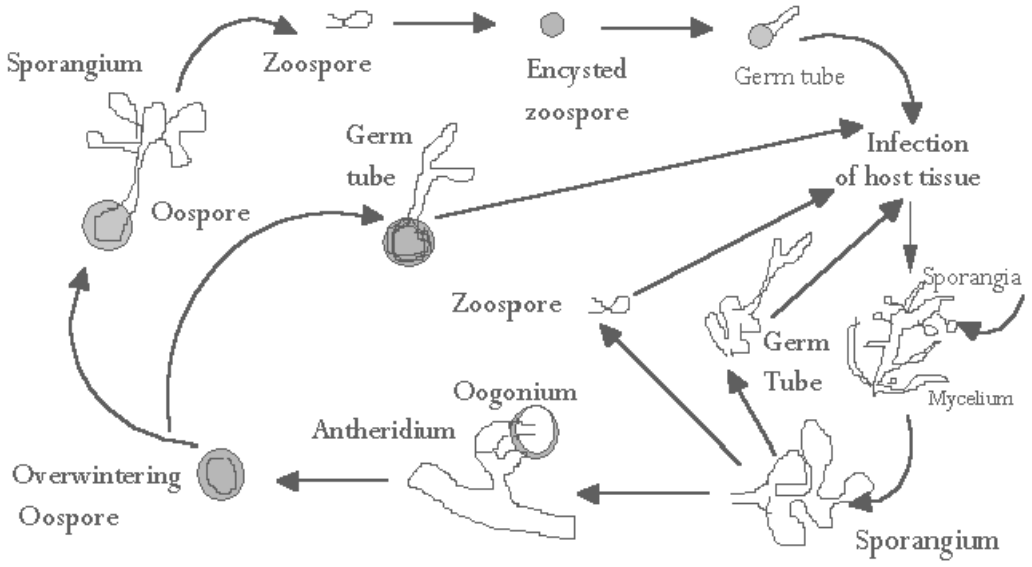


Paragynous arrangement of oogonium and antheridia in *Pythium*. (Courtesy P.B. Hamm) (arrows indicate antheridia)

Disease cycle

In the asexual stage, sporangia are borne terminally on sporangiophore. At the time of zoospore formation, a bubble-like protoplast moves into the vesicle and the zoospores are formed in this vesicle. When the crowded zoospores start rocking motion and bounce on the wall, the delicate vesicle bursts like a soap bubble. In the sexual reproduction oogonia and antheridia are produced. Antheridia get attached to the side of oogonium. On gametangial contact the walls between the sex organs are dissolved and a short tubular projections called fertilization tube is produced by the antheridium.

The fertilization tube passes through periplasm and penetrates oosphere. The contents of the antheridium moves through fertilization tube and evacuated into the oogonial cavity. The protoplasmic content of oogonium and antheridium mixes (plasmogamy). Plasmogamy is soon followed by nuclear fusion (karyogamy). The osphere after fertilization develops a thick mass and it is called oospore.



Life cycle of *Pythium aphanidermatum*

Disease cycle

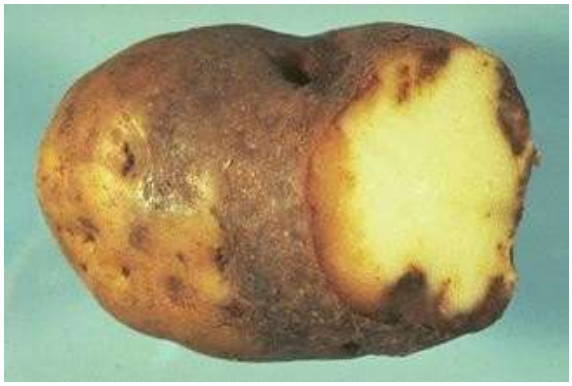
Oospore or encysted zoospore germinates and produce germ tubes or saprophytic mycelium which come in contact with seed or seedling tissues of host plant and enter by direct penetration. Pectinolytic enzymes of the fungus dissolve the pectins (holding cells together) resulting in maceration of tissues. The mycelium grows between and through the cells. Proteolytic and or cellulolytic enzymes causing complete collapse and disintegration of cell walls break down the protoplasts of invaded cells. As a result, the infected seeds / young seedlings are killed and turned into a rotten mass.

Late blight of potato and tomato caused by *Phytophthora infestans*

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Mastigomycotina
Class : Oomycetes
Order : Peronosporales
Family : Pythiaceae
Genus : *Phytophthora*
Species : *P. infestans*

Symptoms

Brown to purplish black water-soaked lesions; enlarge rapidly; lower surface shows whitish mildew growth, severe defoliation; potato tubers show purplish, slightly sunken lesions leading to dry rot.



Late blight of potato on tuber

Late blight of tomato

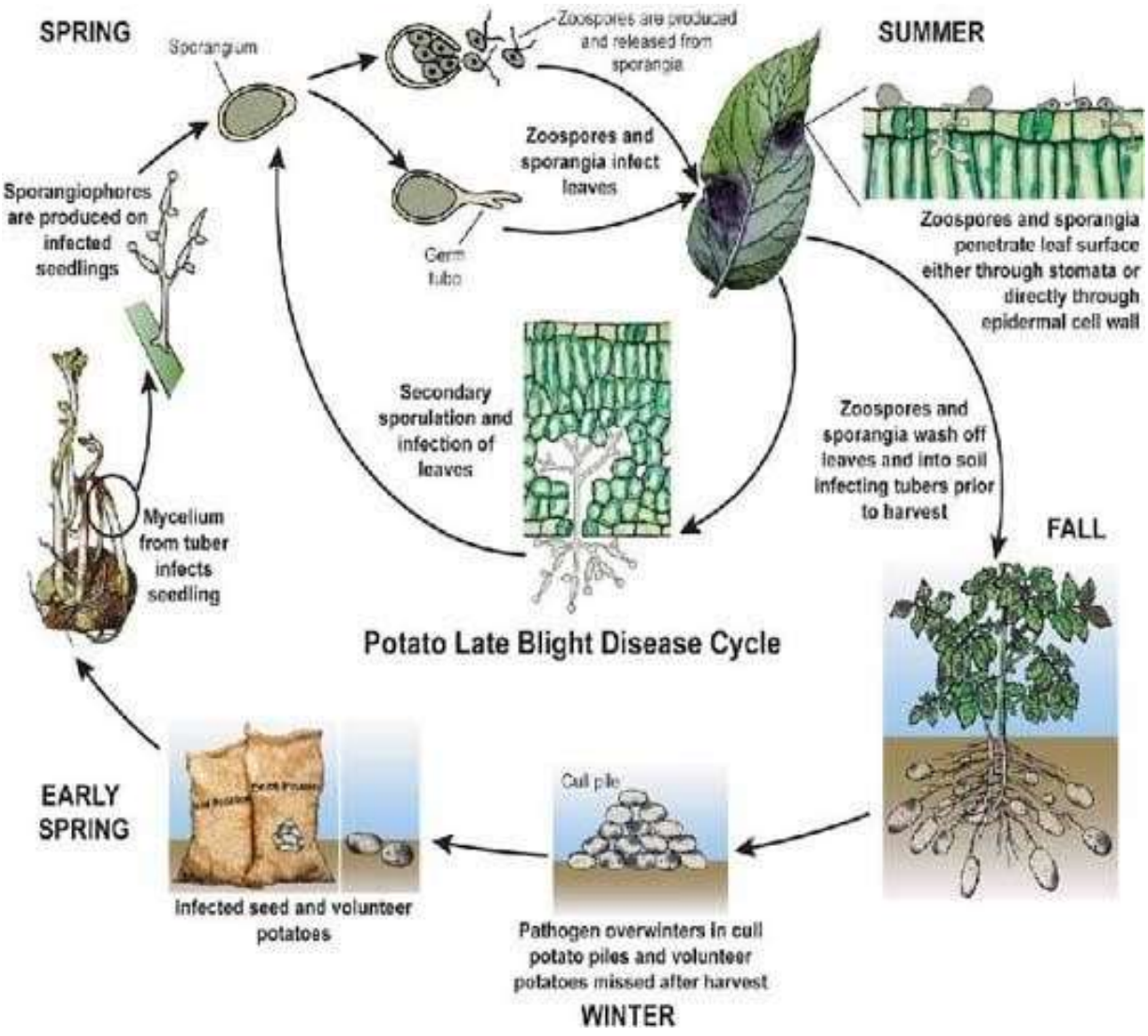
Late blight of potato on leaf

Pathogen

Mycelium is endophytic, coenocytic, hyaline, branched, and inter-cellular. Haustoria club shaped. Sporangiophores are hyaline, branched, indeterminate, thickwalled, arise through stomata on leaves or lenticels on tubers. Sporangia are multinucleate, thin-walled, hyaline, and oval or per shaped with a definite papilla at the apex. Zoospores are reniform, biflagellate (anterior tinsel and posterior whiplash). Oospores are thick-walled and smooth.

Life cycle

Primary infection is through use of infected tubers. Mycelium spreads into shoots produced from infected tubers and reaches the aerial parts of the plant. Sporangiophore emerges through stomata on stem and leaves and produce sporangia, which are spread by rain to wet potato, leaves or stem and cause disease. Large number of asexual generation in a growing season kills the foliage rapidly. The zoospores found in the soil germinate, penetrate through lentils or wounds into the tubers and send intercellular mycelium and haustoria into the cells and cause infection.



Life cycles of *Sclerospora* and *Albugo*

Downy mildew

Appearance of white downy growth in patches on the lower surface of the leaves and yellow discolouration correspondingly on the upper surface. Downy mildew fungi are obligate parasites belonging to the family peronosporaceae of the sub division Mastigomycotina cause downy mildew disease. They produce sporangia during asexual reproduction and oospores during sexual reproduction. Sporangiophore branching characters of genera, which cause downy mildew diseases are given below.

i. Sporangiophore is club-shaped with a swollen head, over which the sporangia are borne on minute sterigmata. e.g., *Basidiophora.*

ii. Sporangiophore is short, stout with many upright branches near the end, bearing the sporangia at tips. e.g., *Sclerospora.*

iii. Sporangiophore is branched at right angles and are irregularly spaced. e.g., *Plasmopara.*

iv. Sporangiophore is dichotomously branched at acute angles and taper to gracefully curved pointed tips on which sporangia are borne. e.g., *Peronospora* and *Pseudoperonospora.*

v. Sporangiophore is dichotomously branched at acute angles and the tips of the branches are expanded into cup-shaped apophyses with four sterigmata. e.g., *Bremia.*

Downy mildew of pearlmillet caused by *Sclerospora graminicola*

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Mastigomycotina
Class . Oomycetes
Order : Peronosporales
Family : Peronosporaceae
Genus : *Sclerospora*
Species : S. *graminicola*

Symptoms

Pale yellow discolouration of leaves; whitish fungal growth on the lower surface of leaves; twisting and crinkling of leaves; drying of leaves; infected seedlings when planted die within 30 days; green ear symptom i.e., transformation of floral parts into green leaf-like structures.

Symptoms often vary as a result of systemic infection. Leaf symptoms begin as chlorosis at the base and successively higher leaves show progressively greater chlorosis. Infected chlorotic leaf areas can support abundant white asexual sporulation on the lower leaf surface. Severely infected plants are generally stunted and do not produce panicles. Green ear symptoms result from transformation of floral parts into leafy structures

Pathogen

It is an obligate parasite. Mycelium is hyaline, coenocytic, intercellular and become systemic. Haustoria are finger- or button - like. Sporangiophores emerge through stomata, short, stout, non-septate with upright branches, crowded with sporangia bearing stalks (sterigmata) with pointed ends at the apex. Sporangia are hyaline, broadly elliptical, thin, smooth walled and papillate. Each sporangium contains 3 to 23 zoospores, which are irregularly reniform and biflagellate. Oospores are spherical, thick walled and yellowish brown.

Disease cycle

Soil borne oospores germinate by put forth germ tube and infect the root hairs / coleoptile of the host seedlings. Inside host tissue, fungus becomes systemic and produces hyaline, coenocytic, highly branched, strictly intercellular mycelium with **finger shaper haustoria**. During dewly nights, hyphae emerge through the stomata and form sporangiophores either singly or in groups. During such period, downy growth is noticed on the diseased area. A single sporangium is formed at the tip of the sterigma. The sporangia are deciduous and are carried by wind. The sporangia germinate by releasing zoospores. Zoospores swim for sometimes, come to rest, encyst and then germinate by germ tube to form new mycelium. Infected plant parts produces sporangia over a considerable period of time under humid condition and then necrosis begins.

In the sexual stage, the sex organs (antheridia and oogonia) develop in the intercellular spaces of the host tissues (leaves and malformed floral organs). It is typically oogamous. The fertilization tube formed by the antheridium carries the male nucleus into the oosphere where the two nuclei fuse to form a diploid zygote nucleus. The oosphere develops a warty wall and becomes the oospore. Oospores have a long period of rest lie in the soil (soil - borne) or on the seed surface. Oospores are liberated by the disintegration of the host tissue .They germinate and infect roots of young seedlings, from where the mycelium spreads systemically in the entire plant.

White rusts or white blisters

White rusts or white blisters are the characteristic pustules fructifications of *Albugo* in Albuginaceae on plant surfaces, especially on leaves.e.g.,white rust of Amaranthus caused by *Albugo bliti*, white rust of crucifers caused by *A. candida* and white rust of sweetpotato caused by *A. ipomeae panduranae.*

White rust of crucifers - *A. candida*

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Subdivision : Mastigomycotina
Class : Oomycetes
Order : Peronosporales
Family : Albuginaceae
Genus : *Albugo*
Species : *A. candida*

Symptoms

The fungus attacks cabbage, cauliflower, mustard, radish and turnip. The disease name is a misnomer. The pustules formed by white rust resembles the aecial stage of true rust belonging to the subdivision Basidiomycotina and hence the name. All aerial plant parts viz., leaf, stem and inflorescence are affected. On the lower surface of leaves it causes white or creamy yellow pustules of various sizes and shape. They are shiny and 1 to 2 mm in dia. Rarely the infection is seen on the upper leaf surface. Very often several of them coalesce to form patches.

They are formed below the epidermis and are unbroken. But with the pressure of sporangia from below, they rupture the epidermis and appear as powdery masses on the surface of leaves. The leaves are not distorted. In severe cases, the infection spreads to the stem, which is uniformly swollen for a length of several centimetres. Lateral buds, which are normally latent, may proliferate resulting in a bushy growth. Flowers and peduncles are also attacked. Peduncles become enormously swol1en. Affected flowers show various discolouration and malformation. The petals become green and stamens turned into leaf-like structures.Some times they may be changed into thickened club-shaped sterile bodies.

The pistil is hypertrophied into a large conical, thick walled sac or transformed into a sterile carpillary leaf. The fungal parasite stimulates cell activity leading to an abnormal increase in cell size (hypertrophy) and abnormal increase in cell division (hyperplasia) and formation of chlorophyll and starch at place where none is usually seen. Sepals become enlarged to several times than the normal sepals. Normally seed development is arrested. Pustules may occur on hypertrophied organ also.

White rust on leaf

White rust stag head symptom

Pathogen

It is an obligate parasite. The thallus is eucarpic and mycelial. Mycelium is well developed, strictly intercellular, hyaline, non-septate (coenocytic) and branched. Haustoria are knob-like or globular. Sporangiophore is club-shaped, short, erect, non-septate, closely arranged, unbranched and thick walled. Sporangia are globose or hexagonal (flattened at the sides), hyaline, smooth, thin walled and produced in basipetal chains (oldest at the top and youngest at bottom) with isthmus.Sporangia are formed at the tip of the sporangiophores. Antheridia are clavate or club shaped, multinucleate and paragynous. Oogonia are globose, terminal or

intercalary. Oospores are reticulate and round. Zoospores are biflagellate and reniform and 4 to 8 per sporangium.

Disease cycle

In the asexual stage, hyphae aggregate at several places under the epidermis. Sporangiospores are formed as a palisade-like layer. These cut multinucleate sporangia, which remain, attached to form a chain at the apex. The oldest sporangia lie at the top and youngest at the base of the chain (called basipetal). The sporangia are separated from each other by a gelatinuous disc-like structure called disjunctor or isthmus. The disjunctors are dissolved by water and the sporangia are set free. The numerous sporangia that are produced at the apical end of sporangiophores push against the epidermis, which bulges out and ultimately breaks.

The areas with broken epidermis and creamy mass of sporangia appear as pustules or blisters on the leaves. Sporangia germinate by means of germ tube (direct germination) or by formation of zoospores (indirect germination). Direct germination is not common. Sexual reproduction occurs when the crop season comes to an end and it is typically oogamous.

The antheridia and oogonia borne terminally on somatic hyphae. Plasmogamy takes place by gametangial contact, where the male nucleus from antheridium is transferred to oogonium through the fertilization tube. Karyogamy occurs and a thin membrane develops around the diploid zygote and a thick warty, tuberculate or roughened epispore. After a resting period, the oospore germinates and forms a vesicle, which contains 40-60 zoospores. The rupture of the vesicle wall releases the zoospores. The zoospore germinates by forming a germ tube, which infects the host plant.

Subdivision: Zygomycotina (Mucorales)

General characters of Zygomycotina

Majority of them are saprobic some are coprophilous some are weak parasites attacking plants. It produces well-developed, branched coenocytic mycelium. Cell wall is composed of chitin –chitosan. Asexual spores are non-motile and are called sporangiospores. Sexual spores are zygospores.

Key to the classes of Zygomycotina

Class: Zygomycetes

Saprobic or, if parasitic or predaceous, mycelium immersed in hot tissues

Order: Mucorales

Asexual reproduction is by means of non -motile, but sometimes appendaged, spores or by sporangioles or conidia. The sporangiospores are formed in sporangia or merosporangia.

Order: Mucorales

Family	**Genera**
1. Mucoraceae	*Mucor, Rhizopus, Phycomyces, Absidia, Zygorhynchus, Syzgites, Rhizomucor*
2. Choanephoraceae	*Choanephora, Blakeslea*
3. Endogonaceae	*Endogone*

Fruit rot of jack caused by *Rhizopus artocarpii, R. nigricans*

It is a soft rot; rotting and decaying of fruits or tubers.

Systematic position

Subkingdom: Mycota

Division: Eumycota

Sub-division: Zygomycotina

Class: Zygomycetes

Order: Mucorales

Family: Mucoraceae

Genus: *Rhizopus*

Species: *R. artocarpi*

Symptoms

It causes soft rot of young fruits and male inflorescens. A large number of the infected fruits fall off early. In the first stage of attack the fungus appears as a greyish growth with abundant mycelia, which gradually becomes denser forming a black growth.

Pathogen

Mycelium is non-septate, brown coloured, profusely branched; aerial hyphae bends at certain points and produce repeatedly branched root - like structure called rhizoids (holdfast) for anchorage on substratum. The hypha in between two groups or rhizoids is called stolon. Sporangiophores are short, stiff, brown, unbranched, erect, arise in groups from stolons, almost opposite to rhizoids, which bear a terminal sporangium; Sporangia are spherical, dark brown or black and contains sporangiospores; Sporangiospores are round, single celled, non-motile, brown individually but black in mass; Zygospore are thick walled black and warty; two layered (outer warty exine and inner intine).

Disease cycle

In the asexual stage, the sporangiospores are produced within the sporangia. The spherical sporangia are separated from the sporangiop40re by a septum which later bulges and projects into the former as a dome-shaped structure called columella. The spherical structure including the columella is called the sporangium. The protoplasm cleaves into numerous multinucleate segments; each of which secretes a wall and becomes a spore called the sporangiospore. When the sporangial wall dissolves on maturity, the spores are released. The aplanospore germinate by forming germ tube and develops into a fluffy well branched white aerial mycelium.

Sexual reproduction occurs through fusion of morphologically similar gametangia designated as plus (+) and minus (-) (gametangial copulation) and subsequent production of a thick walled zygospore. It is heterothallic species and sexual reproduction is effected only when physiologically different strains are brought together. Two hyphal branches lie parallel to each other producing a lateral tubular outgrowth called as progametangium. The tips of the pro gametangia swell and meet each other. A septum is formed in each pro gametangium dividing it into two, the terminal portion becoming the gametangium and the other portion becoming the suspensor.

At the point of contact the walls between the gametangia are dissolved and a single fusion cell results. Plasmogamy occurs in the fusion cell which develops as a zygospore. Zygospore after a resting period of about nine months germinate, produce germ tube which functions as sporangiophore and develops a germ sporangium at its tip. The sporangium is of usual columella type. The germ sporangia contain all plus (+) or all minus (-) spore or mixture of both. These spores called germ spores or microspores. They germinates and form fresh mycelium.

Subdivision: Ascomycotina, class: Hemiascomycetes (Taphrinales), class: Plectomycetes (Eurotiales), class: Pyrenomycetes (Erysiphales, Clavicepitales), class: Loculoascomycetes (Pleosporales)

General characters

Mycelium is well developed branched and septate. Yeast is single celled organism. Septum has a central pore. Cell wall is made up of chitin. Asexual spores are non-motile conidia. Sexual spores are ascospores. Ascospores are usually 8 in an ascus. They are produced endogenously inside the ascus.

Key to the classes of Ascomycotina

Ascocarps and ascogenous hyphae absent, thallus mycelial or yeast-like - **Hemiascomycetes**

Ascocarps and ascogenous hyphae present, Thallus mycelial: Asci bitunicate, ascocarp an ascostroma **- Loculoascomycetes**

Asci typically unitunicate, if bitunicate, ascocarp as apothecium: Ascocarp a cleistothecium, asci evanescent and scattered **- Plectomycetes**

Asci regularly arranged as basal or peripheral layer in the ascocarp

Insect parasites **- Laboulbeniomycetes**

Not insect parasites, Ascocarp perithecium **- Pyrenomycetes**

Ascocarp apothecium **– Discomycetes**

Class: Hemiascomycetes

The class is characterized by the lack of ascocarp, vegetative phase comprising of unicellular thallus or poorly developed mycelium. It is divided into three orders:

1. Asci developing parthenogenetically from a single cell or directly from a zygote formed by population of 2 cells **- *Endomycetales***
2. Asci developing from ascogenous cells, forming a palisade like layer **- Taphrinales**
3. Asci developing in a compound spore sac (synascus), produced singly from thick walled chlamydospores **- Protomycetales**

Order: Endomycetales

Family	Genus
Saccharomycetaceae	*Sacchromyces, Schizosaccharomyces, Saccharomycodes*

Order: Taphrinales

Family: Taphrinaceae **Genus***:* *Taphrina*

Taphrina deformans - Leaf curl or leaf blister of peach

T. maculans -Leaf spot of turmeric and ginger

Order: Protomycetales

Family: Protomycetaceae **Genus:** *Protomyces Protomyces macrosporus*-

Stem gall of coriander

Class: Loculoascomycetes

It comprises the following 5 orders

Myriangiales, Dothideales, Pleosporales (Pseudosphaeriales), Hemisphaeriales (Microthyriales) and Hysteriales

Order: Myriangiales

Family: Myriangiaceae (Genera: *Elsinoe, Myriangium*)

Order: Dothideales

Family: 1. Capnodiaceae (Genera: *Capnodium, Limacinia*)

2. Dothideaceae (Genera: *Mycosphaerella, Guignardia*)

Order: Pleosporales

Family: Venturiaceae

Superficial mycelium lacking. Pseudothecial immersed or erumpent or developing superficially on immersed hypostroma or mycelium arising from it.Pseudothecial wall composed of distinct dark brown cells, ascospores smooth, and bicelled.

e.g., *Venturia inaequalis* -apple scab;

V. pirina -pear scab

Class: Pyrenomycetes

Order: Meliolales

Family: Meliolaceae (Genus*: Meliola*)

Order: Erysiphales

The fungal species in this order cause plant diseases commonly called as powdery mildews. The mycelium is usually ectophytic to partially endophytic. Asexual reproduction is by conidia borne on conidiophores either singly or in basipetal chains. Conidia of powdery mildews germinate at 0 to 100% RH. Their germination at very low RH has been explained due to their very high osmotic pressure, which makes them able to draw sufficient moisture for germination from dry air. The ascocarps are provided with characteristic appendages, which in addition to the number of asci are used in differentiating genera. Many of the powdery mildews are not known to produce ascocarps or these are produced rarely. In the absence of ascocarps, conidia have been utilized for classifying these fungi. It has only one family, Erysiphaceae and it has the following genera.

1. Ascocarps present

A. Mycelium superficial

1. Ascocarp containing one ascus only

a. Perithecial appendages simple, myceloid -*Sphaerotheca*

b. Perithecial appendages dichotomously branched -*Podosphaera*

2. Ascocarp containing many asci

a. Perithecial appendages simples, myceloid -*Erysiphe*

b. Perithecial appendages dichotomously branched -*Microsphaera*

c. Perithecial appendages coiled at the top -*Uncinula*

B. Mycelium partially endophytic

Perithecial appendages simple, imperfect state -Oidiopsis, *Leveillula*

Perithecial appendages coiled at the tip, imperfect state -Oidiopsis –*Pleochaeta* 1 Perithecial appendages with basal swellings, imperfect state -*Ovulariopsis*

II. Ascocarp absent

A. Mycelium superficial

Basal cell of the conidiophore swollen

2. Basal cell of the conidiophore not swollen

a. Conidia borne in chains -*Euoidium*

b. Conidia borne singly -*Pseudoidium*

B. Mycelium partly endophytic

Conidia ovoid, obclavate -*Oidiopsis*

Conidia pyriform -*Ovulariopsis*

Order: Clavicipitales

Family: *Clavicipitaceae* Genus C*laviceps*

Claviceps

The stromatic structures are quite prominent. The perithecia are deeply immersed in stroma which develops as an apical head on an erect stalk (stipe) arising from a dark coloured sclerotium, Perithecia are produced towards the periphery of the stroma. Ascospores are thread like.

Claviceps microcephala (C. fusiformis) -ergot of pearl millet

C. oryzae -sativae -false smut of rice/

Claviceps purpurea -ergot of rye

C. sorghi (Sphacelia sorghi) -ergot of sorghum

Classification, symptoms and life cycle of powdery mildew – *Erysiphe* and *claviceps*

I. Powdery Mildews

Powdery mildew is the appearance of white powdery growth mostly on upper leaf surfaces on stems, floral parts and fruits leading to premature defoliation. Powdery mildews arc caused by members in the order Erysiphales in the subdivision Ascomycotina. There are three types of powdery mildew pathogens have been recognized based on the mycelium and type of conidia the differences are given below.

S. No.	**Description**	***Oidium***	***Oidiopsis***	***Ovulariopsis***
1.	Symptoms	Mostly on upper surface of leaves	Mostly on lower surface of leaves	Lower or upper surface of leaves
2.	Mycelium	Hyaline, septate ectophytic	Hyaline, septate, endophytic	Hyaline,
3.	Haustoria	Present in epidermis only	Present in Epidermis	Epidermal haustoria

			and spongy cells	absent, haustori
4.	Conidiophores	Short, single, club shaped, non septate,	Long, branched, Septate	Long, single, septate
5.	Conidia	Cylindrical or barrel shaped, in chains	Club shaped single celled,	Club shaped, single celled
6.	Examples	Grapes - *Uncinula Necator* Blackgram- *Erysiphe po/ygoni* Bhendi - *Erysiphe cichoracearum* Apple - *Podosphaera Eucotricha* Rose - *Sphae rotheca pannosa var.rosae* Oak - *Microsphaera alphitoides*	Chillies and Pigeonpea - *Leveillula taurica* (syn. *Oidiopsis taurica)*	Muberry *Phyllactillia guttata* (syn. *P. corylea)*

The powdery mildew fungi produces closed ascocarp called cleistothecium. The genera are differentiated based on the number of asci in the cleistothecium and type of appendages on it. They are classified as follows.

I. One ascus in a cleistothecium

i. Myceloid appendages - e.g., *Sphaerotheca*

ii. Dichotomously branched appendages - e.g., *Podosphaera*

II. Many asci in a cleistothecium

i. Myceloid appendages - e.g., *Erysiphe Leveillula.*

ii. Appendage coiled at the tip (circinoid type) - e.g., *Uncinu/a.*

iii. Dichotomously branched appendages - e.g., *Microsphaera*

iv. Appendage with bulbouse base and spear like tip - e.g., *Phyllactinia.*

Powdery mildew of grapevine - *Uncinula necator.*

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Subdivision Class : Ascomycotina

Order : Pyrenomycetes

Family : Erysiphales

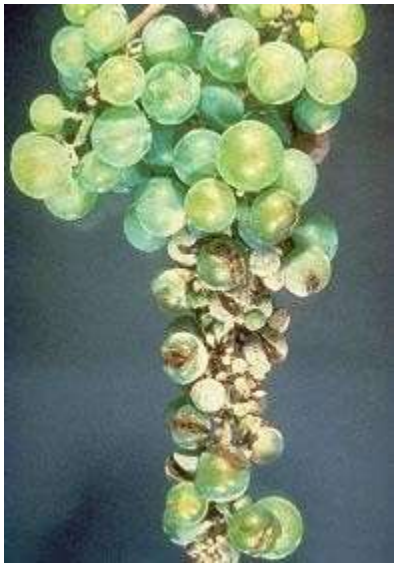
Genus : Erysiphaceae

Species : *Uncinula*

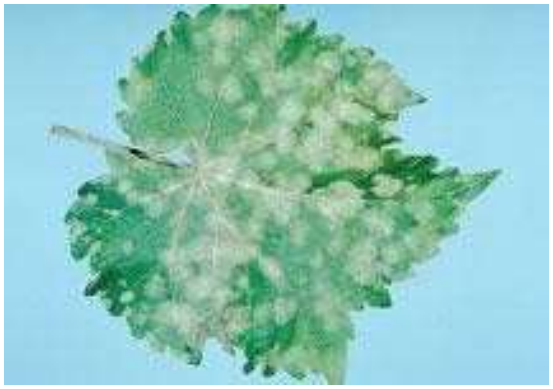
Mycota : *U .necator*

Symptoms

Whitish powdery growth on the upper surface of the leaves and in several cases leaves dry and fall off. On berries also it produce white coloured fungal growth which leads to deformation and cracking of berries.



Powdery mildew symptoms on grape berries (L) and Rachis (cluster stem) (R)



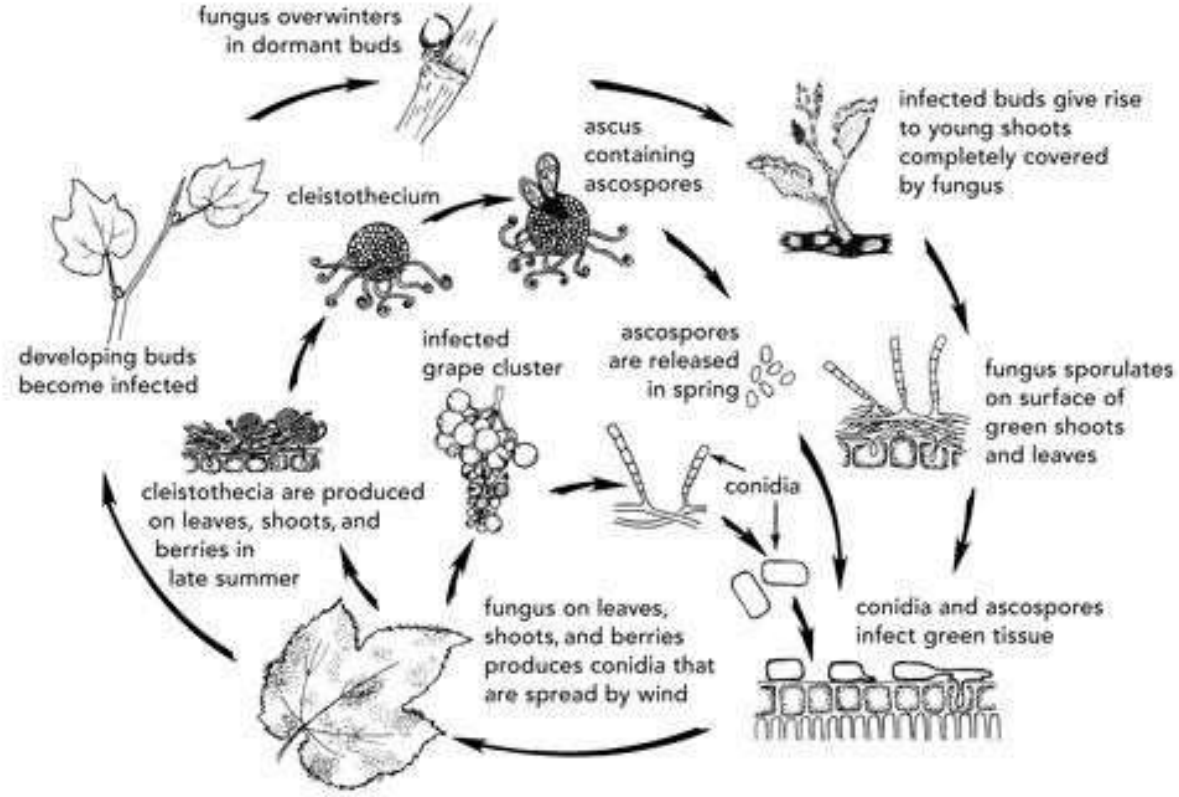
Primary infections of powdery mildew on grape leaf (Left) and powdery mildew covering grape leaf surface (Right)

Pathogen

Mycelium is hyaline, septate, branched and ectophytic. Haustoeia are saclike. Conidiophore is erect, long, hyaline, single celled, simples, club-shaped are barrel shaped, hyaline, thin walled and are produced in chain. 'Cleistothecium is of circinate type, globose and brown or black in colour. Asci are ovate and 4 to 8 asci per cleistothecium .Ascospores are 4 to 6 per ascus, single celled, hyaline and oval.

Disease cycle

The fungus survives through hyphae inside the dormant vegetative buds and through c1eistothecia. The ascospores or the hibernating mycelium in the host buds cause infection and produce enormous conidia. They spread through wind, germinate on the leaf surface and produce germ tubes and appresorium and cause infection. Cleistothecia are formed late in the season on leaves and stem. They are also formed on the fallen leaves. The ascospores in the cleistothecium are released in the spring by the swelling and rupturing of perithecial wall. Ascospores which fall on any green surface of the developing vine cause primary infection.



Powdery mildew of pulses - *Erysiphe polygoni*

Symptoms

Greyish white powdery growth appears on the upper surface of the leaves, stems, petioles and pods. Later the growth becomes brown and the leaves turn yellow and drop.

Pathogen

Mycelium is ectophytic, hyaline, septate and branched. Haustoria are bulbous and sac-like. Conidiophore is simple, erect, hyaline and bear chain of conidia. Conidia are hyaline, thin walled, single celled and ovate or barrel or cylindrical in shape. Cleistothecia are black, round with myceloid appendages and each cleistothecium bears 2 to 8 asci. Asci are ovate and contain 3 to 8 ascospores. Ascospores are hyaline, elliptical and single celled.

Powdery mildew of chillies and pigeonpea - *Leveillula taurica*

Symptoms

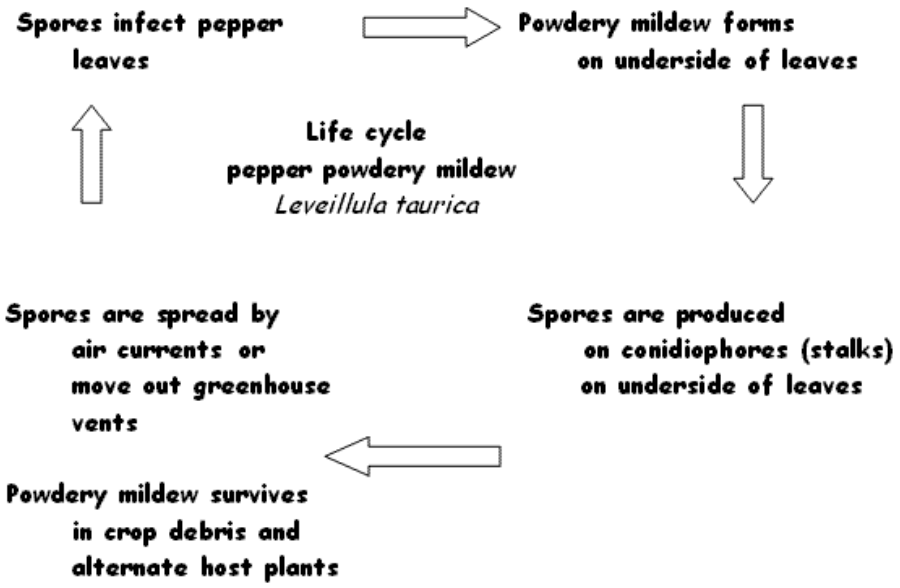
Whitish fungal growth on the under surface of the leaf and the corresponding upper surface show yellow discolouration. Later the disease spreads to entire leaf surface cause yellowing and defoliation of leaves.

Pathogen

Mycelium is endophytic, hyaline, septate and branched. Conidiophores emerge through stomata, single or in groups, branched, septate and bear single conidium at its tip. Conidia are hyaline, single celled and clavate. Cleistothecia are with myceloid appendages. Asci are cylindrical and 9 – 20 / cleistothecium. Each ascus contains two ascospores.

Disease cycle

Ascospores from the perennating cleistothecia infect the lower most leaves near the soil level. The fungus penetrates through stomata. Mycelium sends globular haustoria in to the mesophyll cells and epidermis. C**onidiophores** with a conidium at the tip arise vertically from the plane of mycelial growth. Conidia are wind borne and helps in secondary spread.Later in the season, black, globose **cleistothecia** are produced. Asci are cylindrical and 9 – 20 / ascocarp. **Ascospores** are hyaline, 8 / ascus and are elliptical.



iv. Powdery mildew of mulberry - *Phyllactinia guttata (*syn*. P.corylea).*

Symptoms

White fungal growth on lower surface of leaves and corresponding upper surface shows yellow discolouration; leaves dry and defoliate.

Pathogen

Mycelium is hyaline, septate and branched. Conidiophores are erect,septate, hyaline and simple. Conidia are hyaline, single celled, clavate or flame shaped and borne singly on

conidiophore. Cleistothecia are flat, spherical, black and with bulbous base and pointed spear-like tip appendages. Asci are clavate. Asci are 10-30 in each cleistothecium. Ascospores are two per ascus and oval in shape.

Disease cycle

Ascospores from the perennating cleistothecia infect leaves and penetrate through stomata.mycelium is endophytic and produces conidia which are spread through air. Cleistothecia help in the survival.

II. Sugary disease / Ergot

Exudation of honey-like sticky fluid from spikelets (conidial stage) and later with formation of black scletoria, (ergot) is known as **sugar disease or ergot.**

Sugary disease / ergot of pearlmillet- *Claviceps fusiformis* (syn**. *Claviceps microcephala)***

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Ascomycotina
Class : Pyrenomycetes
Order : Clavicepitales
Family : Clavicepitaceae
Genus : *Claviceps*
Species : C. *fusiformis*

Symptoms

Exudation of small droplets of light pinkish or brownish sticky fluid from the spikelets, trickling down of honey dew secretion; at later stage, black, dark sticky patch may be seen; transformation of ovary to a hard structure consisting of mycelial mat of fungus called **sclerotia**.

Pathogen

Mycelium is septate, hyaline and branched. It produces two types of conidia *viz.*, macroconidia and microconidia. Macroconidia are hyaline, fusiform, and unicellular and germinate by producing one to three germ tubes. Microconidia are hyaline, globular, unicellular and germinate by producing only one germ tube. Sclerotia are dark grey, long and club shaped. Perithecia are pyriform. The asci are long and hyaline. The ascospores are thread-like, hyaline and non-septate.

Disease cycle

The fungus spreads from plant to plant in the conidial stage. The honeydew mixed with the inoculum (conidia) attracts insects, which help in the dissemination of conidia and spread the disease in the field. The sclerotia form at the later stage in the diseased earheads. After harvest when the earheads are thrashed sclerotia are found mixed with seed and reach soil when they (seed and sclerotia) are sown help the fungus to perpetuate from season to season. They may fall and remain in the soil or plant debris and germinate during the next season and produce perithecia containing asci and ascospores. The ascospores, which spread through air, cause infection of the spike, producing the conidial stage.

Sugary disease / ergot of sorghum - ***Claviceps sorghi*** (syn.: ***Sphacelia sorghi)***

Sugary disease / ergot of rye-*Claviceps purpurea*

Symptoms

Droplets of light pinkish / brownish sticky fluid exudes from the spikelets and honeydew secretion trickling down from the earhead. Infected spikelets turn black and finally several sticky patches are seen on the ear. This stage is known as **honeydew / sphacelia stage**. It may continue for 20-25 days.Later, infected ovary is transformed into a hard, black structure called sclerotia, which are projecting out of the spikelet. This stage is called **ergot / sclerotial stage.**

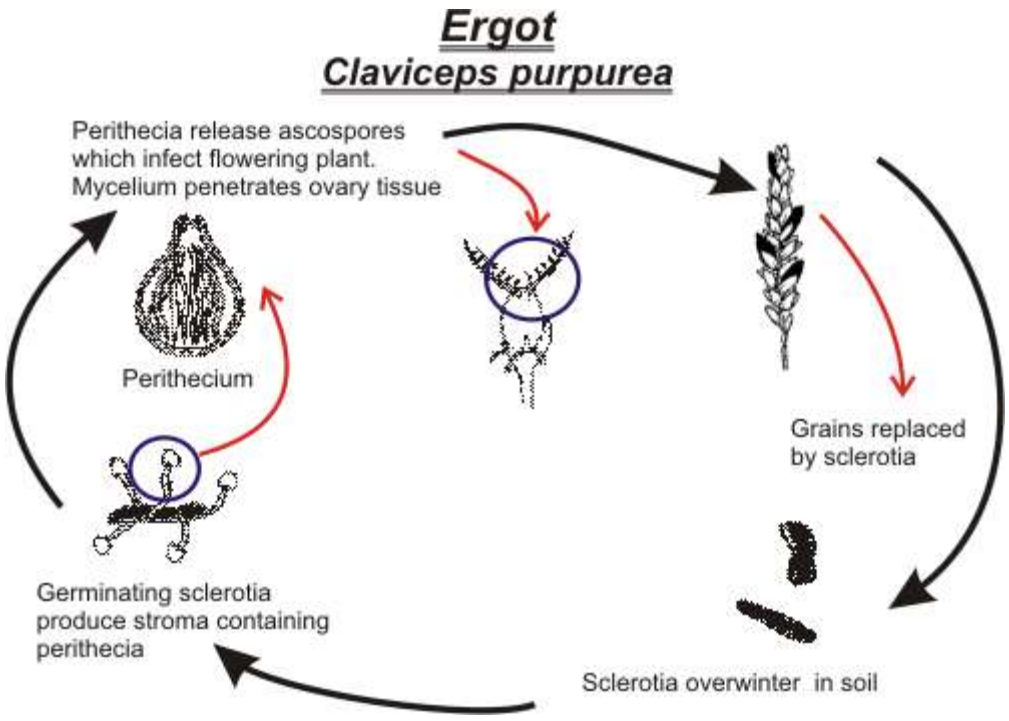
Pathogen

Conidia are hyaline, single celled, oblong with a constriction in the middle. Sclerotia are hard, compact, black, cylindrical, straight or curved.

Disease cycle

Sclerotia germinate under favourable condition and produce vertical column of mass of hyphae called as stromatic stalk or stipe. Pyriform perithecia are arranged in the periphery of the head of the stipe. Perithecia contain hyaline asci. Ascospores are hyaline, aseptate and filiform. Ascospores are ejected with force, spread by wind and reach healthy flowers. These spores germinate on stigma and infection thread reaches the ovary through style. Honeydew stage / sphacelia stage develops as result of infection. Fungus produces dull brown, septate and branched mycelium on the ovary. Generative hyphae comprise of conidiophores and conidia are produced on the surface of the ovary.

Conidiophores are hyaline, short and simple. Conidia are are mixed with honeydew and ooze out. Insects attracted by honeydew carry conidia to healthy flowers and results in secondary infection of new ovaries. Later, ovary has been replaced by sclerotia, which forms horny structures between the glumes. Sclerotia spread along the seed as a contaminant or it falls on the ground and survives in the soil.



Subdivition: Basidiomycotina, class: Teliomycetes (Uredinales, Ustilaginales) class: Hymenomycetes (Aphyllophorales)

General character of Basidiomycotina

Basidiomycotina fungi are highly evolved group. Mycelium is septate. Dolipore septum is present except rusts and smuts. Clamp connections present. Cell wall consists of chitin and glucans. Sexual spores are basidiospores. They are exogenously produced on basidium.

Key to the classes of Basidiomycotina

Basidiocarp lacking and replaced byTeliospores grouped in sori or scatteredwithin the host tissues **- Teliomycetes**

Basidiocarp usually well-developed,Basidia typically organized as a hymenium;Saprobes or rarely parasites **- Hymenomycetes and Gasteromycetes**

Class: Teliomycetes

This class includes many economically important plant pathogens commonly known as rusts and smuts. Mycelial hyphae septate and the septa are of simple type. Asexual reproduction is uncommon, through dikaryotic spores of conidial nature produced in rusts. In smut fungi, haploid sporidia may bud off into daughter cells. Basidiocarps absent. The class is characterized by thick walled, dikaryotic resting spores commonly called as teliospores in rusts and chlamydospores in smuts, Karyogamy takes place in this part and therefore, is actually a probasidium. The resting spores on germination produce promycelium (metabasidium) into which diploid nucleus moves and after meiosis four haploid nuclei are produced. These nuclei later, result in the formation of haploid basidiospores. The class is divided into 2 orders:

This class is divided into 2 orders:

Basidia arising from a thick-walled probasidium

1. Basidia becoming septate, bearing 2 to 4 (mostly 4) basidiospores, one at each septum and one nearly terminal - **Uredinales**
2. Basidia aseptate or septate, number of basidiospores indefinite **– Ustilaginales**

Characters	Smuts	Rusts
Perfect spore	Intercalary	Terminal
Number of basidiospores per promycelium	Many	Definite and four
Basidiospores	Globular	Sickle-shaped, elliptical or hypha like.
Basidiospores are borne on	Short sterigmata	Sessile spores
Basidiospores discharge	Discharged violently	Not discharged violently
Teleutospores	They are formed from terminal cells of binucleate mycelium	They are formed from intercalary cells of the binucleate mycelium.
Basidiocarps	Rare	Absent
Parasitic mycelium	Intercellular with haustoria	Intercellular with haustoria
Clamp connection	Present	Rare
Parasitism	Facultative saprobes	Biotrophs
Sex organs	Absent	Specialized
Heteroecism	Absent	Common
Polymorphism	Absent	Distinct

Order Uredinales (The rust fungi)

The members of this order are commonly called as 'rust fungi' due to the characteristic reddish brown colour of some of their spores. These are obligate parasites and cause great losses to many cultivated crops. The mycelium is septate without clamp connections. It grows intercellularly, frequently producing haustoria. In general, these fungi cause local infections in above ground parts of plants but sometimes these are systemic and may overwinter in roots or other parts. In recent years, rusts have been grown in tissues and axenic cultures e.g., Puccinia malvacearum, *M. lini*.

The rust in which life cycle is short and completed by only two types of spores (teleutospores and basidiospores) called microcyclic rust. The rust which has all the five spore stages (teleutospore, basidiospore, spermatia, pycniospore, aeciospore and uredospore) in its life cycle called macrocyclic rust. A macrocyclic rust in which uredospores are not formed has been named as demicyclic rust. The rust fungi that complete their life cycle in one host are termed as autoecious and those requiring two hosts for the completion of their life cycle are called as heteroecious. The rust fungi produce upto five types of spores in their life cycle, as given below:

Stage 0: Spermagonia with spermatia and receptive hyphae .

Stage I : Aecia with aeciospores

Stage II: Uredia with uredospores

Stage III: Telia with teleutospores

Stage IV: Basidia with basidiospores

(a) Pycniospores Stage(0)

These are the spores produced in a flask-shaped structure called as pycnium, containing a palisade of sporogenous cells which produce spores in nectar exuded from the ostiole. Periphyses and flexuous hyphae (receptive hyphae) are commonly present in pycnia. Pycnia are formed in the host after it is infected by the basidiospores. Pycniospores are single celled and behave as spermatia.

(b) Aeciospores Stage (I)

These are single celled dikaryotic spores produced in chains in cup-like structures known as aecia. The spores are yellow to orange in colour with a hyaline characteristically verrucose wall.

(c)) Uredospores Stage (II)

These are single celled binucleate, pedicellate deciduous spores borne in naked or paraphysate sori breaking through the host epidermis, commonly called as uredia or uredinia. Uredospores are brown, echinulate having almost conspicuous germ pores. They behave as conidia and repeat several cycles in a season and are also called as summer spores.

(d)Teliospores Stage(III)

These are binucleate; pedicellate or sessile; erumpent or embedded in host tissue. They may be single celled, bicelled or more than 2-celled, with dark brown walls, having one or more germ pores. They produce basidium and basidiospores upon germination.

(e) Basidiospores Stage(IV)

They are haploid, unicellular spores borne on sterigma. These arise from cylindrical to club-shaped 2 to 4 celled basidia. Depending on the reproductive stages present in the life cycle of rusts, rusts can be termed as 'macrocyclic'(all 5 stages present), 'demicyclic'(uredial stage absent) or 'microcyclic'(teliospore only as the binucleate spore). Rusts are either homothallic or heterothallic.

In the former case pycnia, are not necessary and frequently absent. Dikaryotic phase starts from two cell nuclei at some point in the life cycle. In the case of heterothallic macrocyclic rusts, basidium bears four basidiospores; two of +type or

two of -type. These basidiospores produce pycnia of + or-type respectively. The pycniospores behave as spermatia and fuse with the receptive hyphae of the opposite sex. The dikaryotic phase thus resulted, leads to the development of aecia.

Classification

There are four families in Uredinales

A. Teliospores sessile

1. Teliospores in single, palisade-like layers or solitary, germinating to produce a septate promycelium; mostly the spores are unicellular **- Melampsoraceae**

2. Teliospores in waxy crusts of one or two layers, becoming septate during germination without forming an external promycelium **- Coleosporiaceae**

3. Teliospores in chains **- Cronartianceae**

B. Teliospores pedicellate, germinating to form a promycelium, which become septate; spores uni -or multicellular, free **- Pucciniaceae**

Family: Pucciniaceae

This is one of the largest family of Uredinales and contains members , which attack a wide variety of angiosperms, often causing destructive diseases of cereals and legumes. The teliospores are pedicellate. Teliospores are never present in the form of layers of crusts. They may be simple (1-celled) or compound (2-or more celled). The uredinia may or may not have paraphyses. The aecia may be cupulate (cup-like) or hyphoid (naked). The peridium may be revolute (curved back). Spermagonia may be subcuticular and flattened or subepidermal and spherical with an ostiole. Both heteroecious and autoecious species are present. The family

contains more than 85 genera and about 3,000 species of which genera *Puccinia* and *Uromyces* account for 1800 and 600 species, respectively. Other genera in Pucciniaceae are *Gymnosporangium, Phragmidium, Hemileia* and *Ravenelia.*

Classification

Important genera in Pucciniaceae are

I. Teliospores single celled.

1. Telia non-gelatinous.

A. Teliospores walls colourless; uredospores reniform, basidia slender, symmetrical - ***Hemileia***

B. Teliospore walls coloured, thickened, ornamented or with visible pores. Telia subepidermal, each pedicel bearing single teliospore

a. Telial pedicel septate - *Trachyspora*

b. Telial pedicel aseptate; uredia and telia non-peridiate

i. Pycnia subepidermal, globose; teliospore wall thicker above than sides or coloured or smooth - ***Uromyces***

ii. Pycnia subcuticular, conical; teliospore usually ornamented, globose to ellipsoid.

On Anacardiacea - ***Pileolaria***

2. Telia gelatinous, telial pedicel aseptate; teliospore cells arranged serially, with pedicel attached to the lower one only. On Cupressaceae - ***Gymnosporangium***

II. Teliospores bicelled, subepidermal, non-gelatinous; uredia and telia non-peridiate; teliospore with one germ pore/cell.

1 .Teliospores in fascicles - ***Tranzschelia***

2. Teliospores not in fascicles. Pycnia globose, subepidermal; teliospores truly pedicellate, sometimes >2 celled - ***Puccinia***

III. Teliospores 3 or >3 celled.

A. Teliospore cells arranged as in phragmospores; teliospore wall coloured with 2 or more germ pores in each cell; pedicel usually long, teliospore without conspicuous outer hygroscopic layer - ***Phragmidium***

B. Teliospore cells arranged as inverted triangle; teliospore wall with 2 or >2 germ pore/cell - ***Nyssopsora***

C. Teliospore cells arranged in a radially discoid head; teliospore pedicels several per head, fused together, telial head with hygroscopic cysts – ***Ravenelia***

Genus 1

***Puccinia*:** In Puccinia the teliospores are brown and are with mostly 2 cells. They are borne on a simple pedicel. Telia are at first embedded in the host tissue but sooner or later the epidermis is ruptured and the spores become free. Spermagonia are subepidermal and spherical with ostiole. Aecia are cupulate with recurved peridium or maturity. Urediniospores (uredospores) are single and stalked, with long pedicel. They are often present in the same sori in which later the teliospores (teleutospores) are formed species are heteroecious.

They mostly parasitize and cause rust diseases in Gramineae and Cyperaceae. It is the largest genus with about 3000 to 4000 species parasitic on angiospermic plants. The important plant pathogenic species are as follows:

Uromyces

Uromyces is the second largest rust genus with about 600 species. It is characterized by the stalked, one celled teliospores on a simple pedicel with a papillum. Uredial, aecial and spermagonial characters are similar to *Puccinia*. The species may be heteroecious or autoecious. The members mostly cause rust disease in leguminous plants. The important species causing pant diseases are given below.

Fungus	**Disease**
P. arachidis	Groundnut rust
P.asparagi	Rust of Asparagus
P. chrysanthemi	Chrysanthemum rust
P. coronata	Crown rust of wheat
P. helianthi	Sunflower rust
P. hordei (P. anomala)	Barley rust
P. kuehnii & P. erianthi)	Sugarcane rust

P.substriata var. penicillariae *(P. penniseti)*	Pearlmillet rust
P. sorghi (P. zeae, P. maydis)	Sorghum rust
P. recondita (P. triticina)	Brown or leaf rust of wheat
P. striiformis (P. glumarum)	Yellow or stripe rust of wheat
P. graminis tritici	Wheat stem or black rust
P. graminis hordei	Barley rust
P. graminis avenae	Oat rust
P. graminis secalis	Rye rust
P. graminis phleipratensis	Timothy rust
P. graminis poae	*Poa pratensis* rust
P. graminis agrostidis	Rust on red top and other *Agrostis* spp.
P. antirrhini	Anirrhinum rust
P. sorghi & P. polyspora, *P . carthami*	Corn rust Safflower rust
P. cacabata P. allii Onion rust	Cotton rust
P. malvacearum	Holly hock rust
P. menthae	Mint (*Piper mentha*) rust
P. psidii	Guava rust

Fungus Diseases

Uromyces ciceris-arietini -Gram rust

U. *dianthi* -Carnation rust

U. *fabae* -Pea rust, *Vicia* rust, lentil rust

U. *phaseoli typica*=(*U. appendiculatus*) -Bean rust, blackgram rust, *Dolichos* and *Vigna* rust.

U. *pisi* -Pea rust

Family: Melampsoraceae

Melampsora lini – Linseed rust

M. ricini -Castor rust

Order: Ustilaginales

There are two families in this order.

Family: Ustilaginaceae

The general characters of the family are same as for the order. The family includes all the smut fungi in which the promycelium is transversely septate into several, usually four, cells with lateral and terminal sporidia, one or more from each cell. Sometimes there may be only one sporidium on the septate promycelium. Occasionally, the basidium (promycelium) develops directly into a mycelium without forming sporidia, as in *Ustilago nuda tritici,* or both conditions may be present (*Sphacelotheca sorghi*). Sometimes two ore more promycelia are produced by the same spore. Important genera are *Ustilago Sphacelotheca*, *Tolyposporium* and *Melanopsichium*.

Ustilago

Sori contain 1-celled teliospores, dusty at maturity and are covered by membrane of host origin. Germination is by means of septate promycelium, which may become infection hyphae or may produce sporidia laterally near the septa. The sporidia germinate easily in water by infection. Hyphae or may multiply by budding.

U*stilago nuda tritici* -Loose smut of wheat

U. zeae -Common smut of corn (syn. *U. maydis)*

U. hordei -Covered smut of barley

U. nuda -Loose smut of barley

U. kolleri -Covered smut of oats

U. avenae -Loose smut of oats

U. scitaminea -Whip smut of sugarcane

Family: Tilletiaceae

The general characters of this family also are same as for the order. However, the family includes only those smuts in which the promycelium is aseptate with terminal whorl of sporidia. The teliospores are single or combined into more or less permanent balls usually including sterile cells. Promycelium is simple, usually nonseptate up to the time of formation of sporidia. Sporidia are longer than in Ustilaginaceae, produced in clusters at the apex of the promycelium, fusing or not fusing in pairs, producing similar or dissimilar sporidia or germinating directly into infection threads. Important genera are *Tilletia, Neovossia, Urocystis, Entyloma* and *Turbicina*.

Class Hymenomycetes

This class is characterized by usually well-developed basidiocarp or fruiting bodies. Basidiocarps are typically gymnocarpic (primordium and mature sporocarp have exposed hymenium) or semiangiocarpic (partially closed till spores are matured). Basidiospores are ejected forcibly i.e. these are ballistospores.

Classification

a. Basidia aseptate -Sub-class Holobasidiomycetidae.

b. Basidia septate -Sub-class Phragmobasidiomycetidae

Holobasidiomycetidae

Holobasidiomycetidae is characterized by an undivided, cylindrical to clavate basidium (i.e. holobasidum), which usually extends into four sterigmata each bearing a basidiospores. The basidiospores produced in this group are non-repetitive. It contains mushrooms, pore fungi, tooth fungi, coral fungi, chantarelles, boletes and bracket fungi.

Phragmobasidiomycetidae

The metabasidium of these is completely or incompletely divided into 4 cells by transverse or longitudinal septa. The basidiocarp is usually gelatinous, waxy or dry. The probasidia may or may not be persistent. The basidiospores are often repetitive and sterigmata swollen.

Sub-class Holobasidiomycetidae

Order: Exobasidales

It is a small order consisting of the gall-forming plant parasites, especially of Ericaceae, Commelinaceae and Theaceae. The order is characterized by the 4-spored basidia, which form a layer (hymenium) on the leaf surface and lack the well-define basidiocarps. This order has a

single family, Exobasidiaceae with five genera. The genus, *Exobasidium* is important. *Exobasidium*: The characteristic feature of the genus is that the basidia, which arise between the epidermal cells of the host, form a more or less continuous hymenium at maturity. The dikaryotic mycelium is devoid of clamp connections, grows intercellularly and produces haustoria. This genus has about 50 species. They are parasitic on leaf, short stem and flowers of Dicotyledonous plants causing hypertrophy and deformation. *E. vexans* is responsible for blister blight of tea. *E. japonica* is responsible for galls of *Azalea*.

Order: Tulasnellales

Family: Ceratobasidiaceae

Ceratobasidium

Metabasidia much wider than pedicels, basidia abruptly narrowed at pedicels, hyphal cells binucleate; sclerotia present or absent.

Thanatephorus

Metabasidia little wider than the pedicels, spores ellipsoid with one side flattened, rarely obpyriform to obovate, hyphal cells multinucleate, sclerotial or sterile mycelia state (Rhizoctonia) present.

Order: Aphyllophorales/ Polyporales

Family: Corticiaceae: (Genera: *Chondrostereum, Peniophora, Athelia, Corticium*):

Family: Ganodermataceae (Genus: *Ganoderma*)

Genus: *Ganoderma*

The fruit bodies of this genus are either sessile or stipitate, the upper surface of the pileus being shiny as if varnished due to the presence of an amorphous waxy substance secreted by the hyphae. The basidiospores are coloured, elliptical, with a wall consisting of two layers, the apex at first rounded but later truncated.

Order: Agaricales

The order Agaricales is commonly called 'gill fungi', which include mushrooms, (edible), toadstools (poisonous) and boletes. Mushrooms are mainly terrestrial or lignicolous mostly growing saprophytically and some enter into mycorrhizal relationship with higher plants. The chracteristic macroscopic basidiocarp or fruit body is fleshy, generally having a stalk i.e. stipulate, and has a pileus bearing hymenium-covering lamellae on the underside. The young basidiocarp may be covered by a universal veil, which becomes broken down by the growth of

the stipe and pileus but part may remain as volva at the base of the stipe and as fragments on the upper surface of the mature pileus.

The developing hymenium may be covered by a partial veil, which later becomes a cortina or an annuals around the mature stipe. The hymenium may consist of cystidia of various kinds, setae, or hyphidia among the basidia the latter producing unicellular, hyaline or coloured ballistospores, typically in fours. Mycelium of Agaricales is typically basidiomycetous with primary, secondary and tertiary mycelia. In few of the Agaricales asexual reproduction takes place by oidia (*Coprinus* spp.) and chlamydospores (*Volvariella volvacea*). Majority of the members are heterothallic and show either unifactorial or bifactorial heterothallism. The compatible thalli are brought together either by hyphal fusion or by means of oidia. The dikaryotic mycelium thus formed ultimately leads to the formation of basidiocarps. The fusion of the dikaryotic nuclei takes place in the basidium (produced in the gills), which is followed by reduction division resulting in the formation of generally uninucleate but sometimes-binucleate basidiospores, which are haploid.

The order Agaricales contains 16 families (Smith, 1973). They are Boletaceae, Hygrophoraceae, Tricholomataceae, Entolomataceae, Amanitaceae, Pluteaceae, Lepiotaceae, Agaricaceae Bolbitiaceae, Strophariaceae, Coprinaceae, Cortinariaceae, Paxillaceae, Gomphidiaceae, Russulaceae and Cantharellaceae.

Family: Tricholomataceae *Armillariella*, *Pleurotus*, *Marasmius*, *Clitocybe*, *Tricholoma*, *Panus*, *Mycena* and *Omphalotus* are the important genera in this family.

***Pleurotus*:** Stripe is generally eccentric and pileus resupinate in some species. They have white or pigmented range fruiting bodies. They grow on wood, on dead or living hosts. This genus contains most valuable edible mushroom.

P. sajor -caju Oyster mushroom

P. ostreatus - Oyster mushroom.

Family : *Amanitaceae*

The characteristic feature of the family is the presence of free gills with bilateral trama and the presence of both outer and inner veil. The basidiospores are white to creamish in colour. The members are found on the ground in woods, on termite nests or on wood. *Amanita, Limacella* and *Termitomyces* are the important general in this family. *Amanita:* The genus is characterized by free gills and the presence of the annulus and volva on the stripe. Remnant of

the volva may persist as volva scales on the cap. More than 5 species are known to be mycorrhizal in habit. Some are more attractive and used in decoration. Some are poisonous and produce toxins called phallotoxin and amatoxins.

A. virosa - called as 'Destroying angel'; or death angel. Decorative by its pure white basidiocarp; poisonous

A. caesarea - Called 'caesar's mushroom', yellow and orange capped and used in decoration

A. muscaria - Called 'fly agaric'; yellow or orange or brilliant red capped and used in decoration; poisonous to flies

A. phalloides - Called 'Depth cap fungus'and it is poisonous.

Family: Pluteaceae

It is characterized by the free gills having bilateral hymenophoral trama, which are convergent toward the center of the trama, and by the production of dull pink basidiospores. The genera *Volvariella, Pluteus* and *Chamaeota* are included in this family.

Volvariella

The genus *Volvariella* contains approximately 25 species reported from tropical, subtropical and temperate regions found growing in shady places on soil and on decaying organic matter. They appear during the rainy season and are recognized by pink spores, free gills forming a ring around the stipe or a stipe which bears no annulus but is enclosed at the base by a cup-shaped persistent 'volva'; The pileus is fleshy, white or pigmented and circular with a central stipe and is responsible for its name *Volvariella.* A few of the species such as *V. volvacea* and *V. diplasia* (commonly called the straw, or paddy straw or Chinese mushrooms) are edible.

Family: Agaricaceae

The family Agaricaceae is characterized by the blackish or brown colour of the basidiospores and the presence of pallid to pink or rosaceous coloured free gills on the pileus.

An annulus is typically present on the stipe. *Agaricus, Cystoagaricus* and *Melanophyllium* are important genera. *Agaricu*s: The characteristic features of the genus are the presence of deep purplishbrown free gills, and an annulus but no volva, and stalk that readily separates from the pileus. They are commonly found growing on ground in pastures. These mushrooms are edible for their delicacy.

A. campestris -Common or Field mushroom; or white button mushroom; edible

A. brunnescens - edible and cultivated mushroom *(=A. bisporus*)

A. placomyces – poisonous

A. silvaticus – poisonous

Edible mushrooms

Mushroom is a fleshy to tough, edible umberella like sporophores (basidiocarp)of certain basidiomycetes fungi. The mushroom consists of **stipe or stalk**, a membranous annular ring called **annulus**, cap or **pileus** arid **gills** or lamellae (plates). Each gill on cross section shows closely packed elongated fungal cells called trauma. On both sides of the trauma a **sub-hymenium** with spherical cells is formed. Over the sub-hymenial layer a fertile layer with palisade like cells called **hymenium** is found. It consists of club shaped **basidia**, sterigmata bearing single-celled basidiospores. In the hymenial layer stout sterile structure called **cystidia** are also found.

Morphology of Mushroom

Morphology of the edible and cultivated mushroom *Agaricus campestris* is given below: *Agaricus campestris* is a field mushroom growing on all organic matter in the fields. The mycelium is highly organized and the hyphae are often found to form rhizomorphs, which are thick strands or rope-like structures. Clamp connections are also formed by the hyphae and chlamydospores may be produced to resist the adverse conditions. The fruiting body or the basidiocarp commonly called as mushroom comes out of the soil and it consists of thick stalk called **stipe** on which an umbrellashaped **pileus**(cap) rest.

The stipe is cylindrical in shape, fleshy and usually swollen at the base. Just above the middle the stipe has a membranous ring known as **annulus**. This represents the remnants of the inner veil, which enclosed the lower surface of the pileus in the initial stages of development. The stipe is constituted by well packed hyphae at the basal portions being loosely placed towards the center permitting the formation of large air space. The pileus on the under surface exhibits numerous structures radiating from the stipe. They are called **lamellae** or **gills**, which are slender, pink when young becoming brown later. The lamellae are suspended from the pileus as thin strips of tissues converging towards the centre with their ends bend towards. The cross- section of a lamella or gills show the central loosely packed elongated fungal cells known as **trama**. On both sides of the trama are found **subhymenial** layers the cells of which will be spherical in shape. Over the sub-hymenial layer a layer of palisade-like cells known as **hymenial layer** is formed.

The hymenial layer consist of club shaped **basidia** which have two to four minute **sterigmata** at their tip. The sterigmata bear the haploid single celled, ink basidiospores. In the hymenial layer there are some stout sterile structures known as **cystidia** (sing. cystidium). The **basidiospores** are released forcibly and fall near the base of the stipe and form a pink mass.

Agaricus* and *Pleurotus

Agaricus

Agaricus spp. are called **white button mushroom** or European mushroom or button mushroom. It has two important commercia1Jy cultivated species viz., temperate mushroom or white button mushroom, *Agaricus bisporus* and hot weather mushrooms, *A. bitorquis*

A .bisporus

It has stout, cylindrical, fleshy umberella-like pileus and possess annulus. Good crop of mushroom comes at low temperature of 15 to 25º C. Well decomposed wheat / paddy straw compost incorporated with nutrients is used as substrate. In a period of 85-100 days, 300-350 kg of mushroom can be harvested from one ton of compost. It ranks first in the world mushroom production.

Pleurotus

Pleurotus spp. are called oyster mushroom as it resembles shell of an oyster. The stipe is eccentric. In India it is called Dhingri. It is a tropical mushroom coming up well between 25-30°C. The colour may be white or grey or pink depending upon the species. Commonly cultivated species in India are *Pleurotus sajor-caju, P. eous, P.citrinopileatus, P.ostreatus, P.eryingii* etc., It is grown on paddy straw (substrate) in polybags. In a period of 30-45 days, it yield 1.0 to 1.4 kg per kg of paddy straw.

Symptoms of rust – Life cycle of *Puccinia*

Rust appears as brown or reddish brown pustules scattered on upper or lower or on both the surfaces of leaves sometimes on the stem also. The rust diseases are in the order Uredinales of the subdivision Basidiomycotina. The rust genera viz., *Puccinia, Uromyces, Hemileia, Phragmidium, Gymnosporangium* in the family *Pucciniaceae* and *Melampsora, Phakopsora, Coleosporium* and *Cronatium* in the family *Melampsoraceae* cause rust disease in crop plants.

There are three types of rusts based on the life cycle. They are,

1. Macrocyclic rust

a. Autoecious rust

b. Heteroecions rust

2. Demicyclic rust

3. Microcyclic rust.

1. Macrocyclic rust: Five spore stages are produced in their life cycle.

a. Autoecious rust: Five spore stages are formed on a single host. e.g., Sunflower rust - *Puccinia helianthi* , Pea rust - *Uromyces fabae* , Linseed rust - *Melampsora lini* and Castor rust – *M. ricini.*

b. Heteroecious rust: Two different hosts (viz., primary host and alternate hosts) are required for completion of its life cycle. **Primary host** is the plant where the teliospores are produced. Alternate host is a plant which is required to complete life cycle without which the pathogen cannot survive. Uredia and uredospores and telia and teliospores are formed on the primary host. Pycnia and pycniospores and aecia and aeciospores are formed on the alternate hosts. e.g., Wheat stem rust – *Puccinia graminis* var. *tritici.* For this rust wheat is the primary host and the barberry is the **alternate host.**

2. Demicyclic rust: Uredial stage absent and spermagonia may be present or absent. e.g., Cedar apple rust - *Gymnosporangium juniperi-virginianae*

3. Microcyclic rust: Teliospore is the only binucleate spore produced in this rust. It may be with or without spermagonia e.g., Holly-cock *rust-Puccinia malvacearum.*

i. Black or stem rust of wheat - *Puccinia graminis* var**. *tritici***

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Subdivision : Basidiomycotina
Class : Teliomycetes
Order : Uredinales
Family : Pucciniaceae
Genus : *Puccinia*
Species : *P.graminis*
Variety : *P.g. var.tritici*

Symptoms

Oblong, reddish brown pustules (raised blisters) are produced mostly on the stem and also on leaves in the initial stage. Later they become conspicuous, linear or oblong, dark brown to black and often merge with one another. Late in the season linear, black telia are formed in the same uredosori or on a separate place; severe infection causes drying of leaves.

Pathogen

It is a heteroecious rust. Primary host is wheat and the alternate host is barberry. The pathogen produces five kinds of spores viz., uredospore and teliospores on wheat, basidiospores from the teliospores found on the infected fallen leaves in the soil, pycniospores and aeciospores on barberry. The characters of different rust spores are described below.

Uredospores

(urediniospore, repeating spores or summer spores) are brown, binucleate, single celled, oval, thick walled with echinulations (thin short spines), borne singly on stalks and with four equatorial germ pores. **Teleutospores** (Teleutospore, resting spores or winter spores) are two celled, pedicellate, dark brown or cheshnut brown, thick and smooth walled. They are at the top rounded and somewhat pointed and thickened apex each cell has a germ pore.

Basidiospores

(Sporidia) are hyaline, haploid; thin walled, single celled and oval. Pycniospores (spermatia) are hyaline, thin walled, small and spherical. Teliospore has a constricted at the septum. Aeciospores are yellow, unicellular, thin walled, hexagonal and produced in chains.

Disease cycle

The fungus overwinters as teliospores on infected wheat debris. They germinate and produce basidia and basidiospores. The basidiospores are ejected forcibly into the air. They are spread through wind and fall on the upper surface barberry leaf, where they germinate and penetrate the epidermal cells. It grows intercellularly and in 3-4 days, the mycelium develops into spermagonia (pycnia), which ruptures the epidermis. The opening of the spermagonia emerges on the upper surface of the leaf. The spermatia are exuded through the opening called **ostiole** and are found embedded in a honey like sticky liquid. Long, flexuous and branched structures called receptive hyphae from the spermagonium extend beyond the opening. Visiting insects spread the spermatia to the receptive hypha of other spermagonia. Rain water or dew running on the plant surface also helps in spreading the spermatia. Spermatization between a

spermagonium of a (+) type when comes in contact with receptive hypha of a (-) type (compatible) or *vice-versa*. It leads to aecial primordial (dikaryote) and formation of aecia on the lower side of the leaf.

The aecia are formed in groups or clusters and called cluster cups and protrude beyond the surface of the barberry leaf. The aecisopores are produced in chains inside the aecium and are released. They are carried by wind to wheat plant on which they germinate and infect stem or leaf sheath or leaf through stomata. The mycelium grows intercellularly and collects below the epidermis as a mat of mycelium. Many short sporophores and uredospores are produced and they exert pressure on the epidermis and pushed out as uredosori. Later, the epidermis breaks irregularly and release 100 thousands of rust coloured uredospores giving a powdery appearance. Uredospores are carried by wind to several kilometres from the point of their origin and infect the wheat plant in the presence of dew or film of water.

They germinate and produce germ tubes, enters through stomata, forms mycelium and leads to formation of uredia in 8-10 days. The uredospores infect wheat plant and produce uredospores till the plant reaches maturity. When the wheat plant approaches maturity telia develop on the wheat leaves or stems separately or from the ured33ia. Teliospores from the telia do not germinate immediately, they overwinter for sometime and do not infect wheat again. In the teliospores fusion of two nuclei takes place. Teliospore germinate and produce promycelium and basidiospores and infects only barberry, the alternate host and not wheat.

ii. Rust of pearlmillet - *Puccinia substriata* var**. *penicillariae***

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Basidiomycotina

Class : Teliomycetes

Order : Uredinales

Family : Pucciniaceae

Genus : *Puccinia*

Species : *P.substriata*

Variety : *P.s. penicillariae*

Symptoms

The uredosori are round, reddish brown and occur in groups on both the surfaces of leaves. The teliosori are black and elliptical. Finally the leaves dry.

Pathogen

It is also heteroecious rust. Primary host is pearlmillet and the alternate post is **brinjal**. Uredospores are oval, yellowish brown, single celled, sparsely echinulated with four equatorial germ pores and pedicellate. Teleutospores are pedicellate thick walled, two celled cylindrical or club-shaped, broad at top and taper towards the base, with single germ pore. Basidiospores are single celled. Pycniospores are hyaline and elliptical. Aeciospores are yellowish orange coloured, polygonal, thin walled, smooth and are formed in chains. Other examples are, rust of groundnut caused by *Puccinia arachidis,* rust of sunflower caused by *P. helianthi*, rust of sorghum caused by *P.purpurea,* rust of maize caused by *P. sorghi*

Rust of black gram / greengram / cowpea / beans /horsegram – *Uromyces phaseoli-typica* (syn. *U. appendiculatus).*

Symptoms

It is an autoecious and macrocylic (long cycle) rust. The uredosori are small, roundish, open, powdery, brown coloured and are formed in groups. Each sorus is surround by a yellow halo. Several sori on a leaf cause premature defoliation. The teliosori are fewer in number, dark brown and linear.

Pathogen

Uredospores are globose, **single celled**, echinulated, Pedicellate, golden brown with two equatorial germ pores. Teliospores are single celled, smooth walled, globose, chestnut brown, pedicellate and with hyaline papilla at the top. Other examples are chickpea rust caused by *U. ciceris-arietini,* Pea rust caused by *U. fabae* and U. *pisi,* coffee rust caused by *Hemileia vastatrix* and cotton tropical rust caused by *Phakopsora gossypii.*

Symptoms of smuts and life cycle of *Ustilago* and *Neovassia* Smut

Smut is a disease caused by the fungi in Ustilaginales of the subdivision Basidiomycotina that is characterized by the transformation of ovary into black dusty or powdery dark spore mass. Smut spores are called teleutospores, chlamydospores or ustilospores. Smut fungi are more dangerous than rust fungi. They are facultative saprophytes. Smut fungi belong to the order Ustilaginales in the subdivision Basidiomycotina.

The order ustilaginales is divided into two families *viz.*, Ustilaginaceae and Tilletiaceae, on the basis of the mode of teliospore germination. The family Ustilaginaceae produces a septate promycelium bearing terminal and lateral basidiospores. *Ustilago, Sporisorium, melanopsichium, Sphacelotheca and Tolyposporium.* In Tilletiaceae, the promycelium is a hollow tube, which bears only terminal basidiospores, are, included in this family *Tilletia, Neovossia, Urocystis and Entyloma are included in Tilletiaceae.*

Covered / kernel / short / grain smut of sorghum- *Sporisorium sorghi.*

(Syn. Sphacelotheca sorghi)

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Basidiomycotina

Class : Teliomycetes

Order : Ustilaginales

Family : Ustilaginaceae

Genus : *Sporisorium*

Species : S *sorghi*

Symptoms

The smut sori are oval, long and dully-grey in colour. Most of the grains of an infected earhead are replaced by the smut sori.

Pathogen

The sorus has a tough wall and a long, hard, central tissue called **columellum**. The columellum is made up of host tissues, including, parenchyma and vascular elements. A dense mass of black to dark-brown, smooth, thick walled, single-celled spores and fills the space between the columellum and sorus wall.

Disease cycle

The smut spores germinate in water by producing four celled promycelium and a single sporidium from each cell. They infect the seedling by penetrating through the radicle or mesocotyl to establish systemic infection that develops along the meristematic tissues. At the

time of flowering the fungal hyphae get converted into spores, replacing the ovary with the soil. If the diseased earheads are harvested with the healthy ones threshed together, the healthy grains become contaminated with the smut spores released from bursted sori. The spores remain dormant on the seed until next season. It is externally seed-borne.

Loose smut of sorghum - *Sporisorium cruentum* (syn. ***Sphacelotheca cruenta)***

Symptoms

The infected plants are shorter than the healthy plants, produce thinner stalks, more tillers and earlier flowering (2 weeks earlier) than the healthy plants. All the spikelets of an infected earhead are malformed and hypertrophied. The sorus replaces the pistil and stamens and is borne on glumes and pedicel. The infected earhead become loose and appears like a leafy or leathery structure.

Pathogen

The smut spores are in the form of masses of spores enclosed by thin sorus membrane. Columellum is longer, bigger and more curved than the columellum of grain smut. The smut spores are spherical to elliptical, dark brown with a minutely pitted spore wall. It is primarily spread by infected seeds (externally seed-borne). Disease cycle is as in grain smut.

Long smut of sorghum -*Tolyposporium ehrenbergii*

Symptoms

Only a few grains are converted into smut sori and are scattered. The sorus is covered by a whitish membrane and is cylindrical and much longer than those of the other two smuts.

Pathogen

The spores are firmly united into **spore balls**, which is characteristic of this genus. They are globose, or angular, brownish green.

Head smut of sorghum -*Sporisorium reilianum* (syn**. *Sphacelotheca reiliana)***

Symptoms

In the place of a normal inflorescence, a sorus fully covered with a greyish-white membrane emerges from the boot leaf when it has fully emerged. The fungal wall ruptures, exposing large mass of black, powdery smut spores. The spores are blown away exposing dark filaments or fibres. Complete destruction of the earhead is common unlike in other smuts.

Pathogen

The smut spores or chlamydospores are angular to spherical, brown. It is both soil-borne and seed-borne.

Smut of pearl millet smut- *Tolyposporium penicillariae*

Symptoms

Florets are transformed into larger green smut sorus. Later sori become dark brown, break and release black smut spore balls. Only few florets in an earhead in affected.

Pathogen

Smut spores are in compact mass of spore balls. The spores are round and light brown.

Loose smut of wheat - *Ustilago nuda tritici*

Symptoms

Infected plants are shorter than the healthy plants. Usually infected ears emerge from the boot leaf, a few days earlier than healthy. All spikelets of an earhead are transfonned into a mass of black powdery spores. Before emergence the smutted spikelet in covered by a thin silvery membrane, which breaks while the ear. Emerges

Pathogen

The smut spores or chlamydospores are pale olive-brown, spherical or oval and are with minute echinulations. It is **internally seed-borne** and viable in stored seeds for more than 15 years.

Whip smut of sugarcane - *Ustilago scitaminea*

Symptoms

Production of a long (up to several feet) whip-like structure (modified inflorescences / stem) from the apex of the infected stalk. In early stage, a thin silvery white membrane covers the whip and it ruptures exposing dense black dust of smut spores.

Pathogen

The smut spores are light brown, spherical and echinulated.

Subdivition: Deuteromycotina: class: Coelomycetes (Sphaeropsidales), class: Hyphomycetes (Hyphomycetales, Agonomycetales)

General characters

Fungi possess branched, septate and multinucleate mycelium. They reproduce through asexual methods. the most common method of reproduction is by conidia. No sexual spores are produced. They are called as Fungi Imperfecti.

Classification

Key to Classes of Deuteromycotina

A. True mycelium lacking or not well-developed, soma is made up of yeast (budding) cells with or without pseudomycelium .. Blastomycetes. AA. Mycelium well-developed, assimilative budding cells absent ... B, BB

B. Reproduction by conidia borne in pycnidia or acervuli ... Coelomycetes BB. Reproduction absent i.e. sterile forms or takes place by conidia produced on separate hyphae or aggregations of hyphae (as synnemata or sporodochia) but not within pycnidia or acervuli ... Hyphomycetes

Class: Coelomycetes

The members are found both in tropical and temperate regions. They are commonly found in cultivated and uncultivated soils, leaf litter organic debris, fresh water and saline water. They may found on other fungi and lichens. They are also pathogens of plants, insects and vertebrates. Coelomycetes is divided into two orders, Melanconiales and Sphaeropsidales. In this class conidia are produced either in acervuli or pycnidia and accordingly the members have been grouped into two orders:

1 Conidia produced in acervuli -Melanconiales

2 Conidia produced in pycnidia –Sphaeropsidales

Order: Melanconiales

In Melanconiales the fructifications are acervuli. It contains a single family, 'Melanconiaceae'which is characterized by the production of acervuli. Acervuli may develop subepidermally or subcuticularly. Conidia may be hyaline to cream, pink, orange or black. Acervuli develop by simple meristogenous, compound meristogenous or sympogenous methods. More than 120 genera are included in this family and they cause plant disease known as anthracnose. The important genera are

1. *Colletotrichum*
2. *Coryneum*
3. *Cylindrosporium*
4. *Entomosporium*
5. *Marssoninia*
6. *Melanconium*
7. *Monochaetia*
8. *Pestalotia*
9. *Pestalotiopsis*
10. *Gloeosporium*
11. *Sphaceloma*
12. *Didymosporium*
13. *Septogloeum*

Colletotrichum

Acervuli may be subcuticular, epidermal or subepidermal. They may be either separate or confluent. Conidiophores are hyaline to brown, septate, smooth, branched at the base. Conidia are hyaline, unicellular, falcate or lunate (sickleshaped) or cylindrical.. Perfect state of the fungus belongs to *Glomerella.* The important plant pathogenic species of *Colletotrichum* are given below:

C. capsici-Fruit rot and dieback ofchillies, anthracnoseand boll rot of cotton.

C. circinans -Smudge of onion

C. coffeanum -Coffee berry disease

C. falcatum -Red rot of sugarcane

*C. gloeosporioides*Anthracnose of citrus andbanana.

C. graminicola Anthracnose of corn and sorghum .

C. lindemuthianum-Anthracnose of cowpea and*Phaseolus* spp.

C. musae -Anthracnose of banana*(Gloeosporium musarum)*

C. truncatum -Anthracnose of legumes.

Pestalotia (Pestalozzia)

The genus is characterized by the conidia which are fusiform, straight or slightly curved and five septate, with four median cells brown and end cells hyaline lacking cytoplasm. There

may be 3-9 apical, cellular, simple or dichotomously branched appendages and one basal endogenous cellular, simple or branched appendage. The conidiophores are long, branched and septate. The fructifications are dark brown.

Pestalotiopsis

Pestalotiopsis differ from *Pestalotia* in the production of 4 septate conidia (5 celled) with two or more apical appendages and conidiogenous cell with several proliferations. The fructifications eustromatic and cupulate. Acervuli are subepidermal and are irregularly erumpent through the epidermis or longitudinal cracks may appear. They are either found on decaying leaves. Many are important plant pathogens.

P. palmarum -Grey blight of coconut (*Pestilential palmarum)* and other palms.

P. theae -Grey blight of tea and blight of *(Pestalotia theae)* mango, palms and cotton.

P. mangiferae -Grey blight of mango *(Pestalotia mangiferae)*

Order: Sphaeropsidales

In this order the conidia and conidiogenous cells or conidiophores are produced in pycnidia. Mycelium may be immersed in the substrate or superficial. Conidia are produced in several ways from phialides, annellides etc. Conidia are solitary, sympodial catenate etc. Sphaeropsidales is divided into four families based on the colour, shape and texture of the pycnidia. They are Sphaeropsidaceae ,Nectrioidaceae (Zythiaceae), Leptostromataceae and Excipulaceae (Discellaceae).

Family : Sphaeropsidaceae

This is a large family consisting of both saprobes and a stroma. These are tough, leathery to brittle, globose, ostiolate and dark coloured. The spores are hyaline spherical or oval and often exude from the ostiole in damp weather in a worm like mass or citrus.

Macrophomina

Mycelium superficial or immersed, hyaline to brown, branched, septate, often tree like in form (dendroid). Pycnidia separate, globose, dark brown, immersed, with one cavity, thick-walled; wall consisting of an outer layer of darkbrown; thick walled, closely packed polyhedral cells, becoming hyaline towards the inside. Ostiole central, circular, papillate. Conidiophores absent. Conidiogenous cells enteroblastic, phialidic, determinate, lageniform to doliform, hyaline, smooth with aperture and minute collarette, formed from cells lining the pycnidial cavity.

Conidia (Pycnospores) hyaline, aseptate, obtuse at each end straight cylindrical to fusiform, thin-walled, smooth with aperture and minute collarette, formed from cells lining the pycnidial cavity. Conidia (Pycnospores) hyaline, aseptate, obtuse at each end, straight cylindrical to fusiform, thin-walled, smooth, may be guttulate. Forming mainly sclerotia in cultures, which are black, smooth, hard, formed of dark-brown thickwalled cells. The genus *Macrophomina* is monotypic and contains the only species, *M. phaseolina*, *Macrophomina phaseolina* (syn .*Rhizoctonia bataticola).* This fungus causes charcoal rot, ashy stem blight, Dry root rot, canker, damping off and leaf lesions on hosts like sorghum, pearl millet, soybean, groundnut, cotton, *Phaseolus* spp., tomato, potato etc.,

Ascochyta

It is a very large and widely distributed genus containing about 350 species. Most of them are plant pathogens. Mycelium immersed, branched, septate, hyaline to pale brown. Pycnidia are amphigenous, separate, globose, brown, immersed, unilocular and thin-walled. Ostiole central, circular, slightly papillate. Conidiophores are absent. Conidiogenous cells enteroblastic, phialidic, determinate , discrete, doliform to lageniform, hyaline, smooth, formed from the inner cells of pycnidial cavity. Conidia hyaline, thin-walled, cylindrical, ovoid, oblong to irregular, medianly one-septate, continuous or constricted at the septum. Conidia may be guttulate.

The important plant pathogens are as follows:

A. abelmoschi -Leaf, fruit and stem spot of lady's finger.

A. caricae-papayae -Fruit rot of papaya

A. fabae -Leaf and pod spot of broad beans

A. melongenae -Leaf spot of lady's finger

A. phaseolorum -Leaf and pod spot of common bean and other legumes.

A. pisi -Leaf and pod spot of pea.

A. pinodes -Foot rot or blight of pea

A. rabiei -Blight of chickpea

A. sorghi -Leaf spot of sorghum

Septoria

It is a large and cosmopolitan genus with 1000 species, which are parasitic causing leaf spot diseases in plants. The pycnidia are immersed in the substratum and are either separate or

aggregated and not confluent. They are globose, ostiolate, thin walled and brown. . Conidia are hyaline, smooth, filiform (scolecospore), continuous or constricted at septa. The perfect states in Ascomycotina genera are *Mycosphaerella* and *Leptosphaeria*.

Septoria apii -Celery leaf blight

S. chrysanthemella -Black leaf spot of sweet potato

S. bataticola -Leaf spot of sweetpotato

S. glycinea -Brown spot of soybean

S. lycopersici -Leaf spot of tomato

S. nodorum -Speckled leaf blotch of wheat

S. thespesiae -Leaf spot of Portia tree

S. tritici -Leaf spot of wheat

Family: Excipulaceae (Discellaceae) (Genera: *Excipula, Discula, Dinemosporium, Sporonema*)

Class: Hyphomycetes

Hawksworth *et al.* (1983) classified Hyphomycetes into four orders, Agonomycetales, Hyphomycetales, Stilbellales and Tuberculariales. The orders have been separated on the basis of presence of absence of conidia and the degree of aggregation of the conidiophores into specialized structures such as synnemata or sporodochia.

Classification of Hyphomycetes

Conidia absent except for chlamydospores - Agonomycetales or Mycelial sterilia Conidia present Conidiophores are not organized as synnemata or sporodochia- Hyphomycetales (Moniliales) Conidiophores are organized as synnemata or sporodochia.

a. Synnemata formed **- Stilbellales**

b. Sporodochia formed **– Tuberculariales**

Order: Agonomycetales or Mycelia sterilia

1. Leaf parasites and forming sclerotia that are immersed in leaf tissue - *Dactuliphora*

2. Sclerotia not immersed in leaf tissue, if leaf parasites:

(a)) Sclerotia formed of loosely woven hyphae; irregular in shape - *Rhizoctonia*

(b) Sclerotia formed of compact hyphae; large - *Sclerotium*

(c)) Compact cells arranged in cluster like forms; true sclerotia absent – *Populaspora*

The fungi included in this order are referred as Mycelia sterilia as they lack even the imperfect state (spores) and reproduce only by fragmentation of mycelium. They do form sclerotia or chlamydospores, which help in perpetuation and dissemination of the pathogen. Agonomycetales may be states of Basidiomycetes, Ascomycetes or other Deuteromycetes. It has a single family Agonomycetaceae containing 42 genera. *Aegerita, Arbuscula, Dactuliophora, Papulaspora, Rhizoctonia* and *Sclerotium* are important genera.

Rhizoctonia

The form-genus *Rhizoctonia* has about 15 species. They are facultative necrotrophs i.e. they are capable of prolonged existence as saprophyte in the soil. Under suitable conditions they cause diseases like damping off and root rots. Important characters of this are the formation of sclerotia of irregular size and shape but of uniform texture brown or black, more or less loosely packed. The cells of the hyphae are barrel shaped, anastomosing frequently, branching more or less at right angles, and pale brown to brown in colour. Perfect states of *Rhizoctonia* are *Ceratobasidium* and *Thanatephorus* (of Basidiomycotina) and *Macrophomina* (Pycnidial state).

R. bataticola - Dry root rot of pulses, cotton etc. (Pycnidial state: *Macrophomina phaseolina)*

R. solani - Root rot of cotton. (Perfect state: *Thanatephorus cucumeris)*

Sclerotium

It is a large genus with about 100 species. They cause important plant diseases. It is characterized by hard, brown to black, fairly large sclerotia with pseudoparenchymatous rind. These are produced on sterile, cotton, white mycelium provided with clamp connections. The perfect states of *Sclerotium* are *Pellicularia* (Hymenomycetes of Basidiomycotina) and *Sclerotinia* (of Ascomycotina)

Sclerotium cepivorum -White rot of onion

S. oryzae-Stem rot of rice (Perfect state: *Magnaporthe salvinii* Conidial state: *Nakataea sigmoidea*)

S. rolfsii - Root rot of soybean, black pepper groundnut, cotton, cabbage tomato etc. (Perfect State: *Corticium rolfsii*(syn.*Pellicularia rolfsii)*

Order: Hyphomycetales (Moniliales)

This order has important saprobes used in decomposition of organic matters. It has pathogens on plant, animal and human beings. In this order the conidiogenous cells are produced on the conidiophores, which may be either micronematous. i.e morphologically similar to vegetative hyphae or macronematous. i.e. which are morphologically very different from purely

vegetative hyphae but are always mononematous i.e. they are sporodochia. The order is divided into two families, Moniliaceae and Dematiaceae.

The order is divided into 2 families:

1 Conidia and conidiophores hyaline or brightly coloured -*Moniliaceae*

2 Conidia or conidiophores or both with distinct dark pigment –*Dematiaceae*

Form-family 1: Moniliaceae

Most of the members in this family are saprobes in soil, dead organic matter and foodstuffs. Some are plant, human and animal pathogens whereas some others are predaceous fungi on nematodes. The members of this form-family are characterized by the production of free conidiophores or conidiogenous cells from the somatic hyphae and all the structures i.e. hyphae, conidiophores and conidia are hyaline. A key to important plant pathogenic genera is given here:

I. Conidia unicellular, globose to cylindrical, conidiophore distinct:

(a)) Conidia almost similar to apical cells of conidiophores *Monilia*

(b) Conidia not as above; borne in chains; dry:

(i) Phialides in heads on simple conidiophores -*Aspergillus*

(ii) Phialides bush like; upright -*Penicillium*

(c) Conidia not borne in chains; conidiophores verticillate, phialospores in mucilaginous mass -*Verticillium*

(d) Conidiophore branching irregularly or dichotomously; conidia dry, borne on inflated **apical cells -*Botrytis***

II. Conidia bicelled, ovoid to cylindrical:

(a) Conidiophores reduced to stromal cells - *Rhyncosporium*

(b) Conidiophoredistinct, rarely branched, in clusters; conidia cylindrical, in short chains -*Ramularia*

III. Conidia 3 or more celled:

(a) Conidia usually of 2 types, multiseptate macroconidia canoe shaped; unicellular microconidia often present -*Fusarium*

(b) Conidiophores rarely branched, conidia simple, attenuated at the apex - *Cercosporella*

(c) Conidiophores usually simple; conidia on denticles –*Pyricularia Aspergillus* and *Penicillium* belong here, Imperfect stages of the Erysiphales (powdery mildews) viz. *Acrosporium* (formerly known as oidium) is also placed here.

Imperfect stage of Ascomycetes -*Neurospora* and *Monilinia* and *Botryotinia* also belong here and placed in the form genera *Monilia* and *Botrytis* respectively. The genera *Verticillium* and *Trichoderma* are known to have Trichoderma as imperfect states. Pathogens of man and animals viz., *Microsporium* (Imperfect state: *Arthroderma*), *Trichophyton* (Imperfect state: *Nannizzia*), *Histoplasma* (Imperfect state: Ajellomyces), *Geotrichum, Sporothrix, Coccidioides, Paracoccidioides* and *Epidermophyton* belong to his family. *Arthroderma (Microsporium), Phymatotrichum,* Predaceous fungi like *Dactylaria, Arthrobotrys* and *Monacrosporium* are also included in the family Moniliaceae.

Verticillium

The genus is characterized by the production of balls of amerospores on verticillately arranged phialides. The conidiophores are erect, hyaline or slightly pigmented and simple or branched. Chlamydospores, aleuriospores and microsclerotia are also produced by some species. *V. albo-atrum* -Wilt of cotton, tobacco, cowpea, tomato, brinjal, potato, lucerne. *V. dahliae* -Wilt of tobacco and brinjal Form-family 2: Dematiaceae.

This family is characterized by the production of dark-conidia and/or conidiophores. Conidiophores are simple and not produced in any type of fruiting body. Many members are saprobic found in soil and on dead organic matters. Others are pathogens of plants. *Alternaria , Bipolaris, Cladosporium, Cercospora, Curvularia, Drechslera, Helminthosporium* and *Pyricularia* are important genera in this family.

A key to important genera is given below:

I. Conidia single celled, globose to cylindrical in shape.

(a) Conidia hyaline to sub-hyaline, *phialosporous,* endogenous; phialides often single; aleuriospores dark, borne singly or in short chains - ***Thielaviopsis***

(b) Conidia blastospores, dark, borne acropetally in long chains; ovoid to oblong, sometimes >2 celled - ***Cladosporium***

(c)) Conidia dark, in short chains:

(i) Mycelium subcuticular, conidia annelospores, acute at apex, sometimes 2-celled - ***Spilocaea***

(ii) Conidia blastospores, dry, borne in apical clusters - ***Periconia***

(d) Conidiophore simple, intertwined; conidia holoblastic, spherical; in ovaries of individual grains of Gramineae - ***Ustilaginoidea***

II. Conidia usually bicelled, borne singly on conidiophores. Mycelium subepidermal, without forming stroma, apical cell of conidia narrower than basal cell - ***Passalora***

III. Conidia more than 3 celled, not borne in chains, only transversely septate.

A. Conidiophores in clusters, simple or rarely branched, conidia long cylindrical to filamentous:

(i) Stroma well developed -***Cercosporidium***

(ii) Stroma not developed -***Cercospora***

B. Conidiophores packed together, arising from a well-developed stroma. Conidia annellospores, ellipsoid ovoid -***Strigmina***

C. Conidiophores single; stroma absent:

1. Conidia porosporous.

(i) Conidia borne apically -**Corynespora**

(ii) Conidia borne laterally and apically -***Helminthosporium***

2. Conidia sympodulospores.

(i) Conidia typically bent, middle cell enlarged -***Curvularia***

(ii) Conidia straight, sometimes curved slightly

(a)) Conidial germination by any of its cells -***Drechslera***

(b) Conidial germination by end cells only -***Bipolaris***

IV. . Conidia several celled, longitudinal as well transverse septa present.

(a)) Conidia borne in acropetal chains -***Alternaria***

(b) Conidia borne singly, apical, sub-globose, obovate or broadly ellipsoid - *Stemphylium*

Alternaria

It is a polyphagous fungus and occurs most frequently as a saprobe on dead and decaying organic materials, on or in seeds and is responsible for causing leaf spots of economically important crop plants. Conidiophores are dark, septate, sometimes inconspicuous, simple or branched, bearing conidia at the apex. Conidia (Porospores) solitary or more often produced in acropetal succession to form simple or branched chains, muriform, darkly pigmented, ovate to obclavate, tapering abruptly or gradually towards the apex, smooth or roughened.

Important plant diseases caused by *Alternaria* spp. are

Alternaria alternata - Black point disease of wheat grains

A. brassicae - Leaf spot of crucifers

A. brassicola - Leaf and pod spot of Crucifers

A. carthami - Leaf spot of safflower

A. cucumerina - Leaf spot of cucurbit

A. citri - Black rot of oranges, fruit rot of lemons and tangerines, leaf spot of rough lemon and mandarin.

A. longipes - Brown spot of tobacco

A. macrospora - Leaf spot of cotton

A. padwickii - Stackburn, seedling blight or leaf spot (=*Trichoconis padwickii*) of rice

A. porri - Purple blotch of onion

A. solani - Early blight of potato and leaf spot of tomato, chillies and tobacco

A. triticina - Leaf blight of wheat

Cercospora: They are weak parasites on dead or drying plant tissues or pathogens of plants or human beings. This genus is characterized by long, hyaline or pigmented conidia borne in acropetal succession from a usually simple, sympodially extending, cicatrized (i.e. with conspicuous scars), pigmented conidiophores which are frequently aggregated in fascicles . The conidia are filiform and several celled.

Cercospora apii - Leaf spot of celery

C. arachidicola - Early leaf spot of groundnut

C. beticola - Leaf spot of sugar beet

C. coffeicola - Leaf spot of coffee and spinach

C. nicotianae - Frog -eye spot of tobacco

C. kikuchii - Purple stain of soybean

Cercospora musae - Sigatoka leaf spot

C. personata - Late leaf spot of groundnut

Helminthosporium

Colonies effuse, dark and hairy. Mycelium immersed stromata usually present. Conidiophores often in fascicles, erect, brown to dark brown. Conidia develop laterally, often in verticils, through pores beneath the septa of the conidiophore while the tip of the conidiophores continues to grow but growth cases with the formation of terminal conidia. Conidia sub-hyaline to brown, usually obclavate, pseudoseptate and frequently with a dark brown to black protruding

scar at the base. This genus contains approximately 20 species. *Helminthosporium* imperfect state is produced in *Pseudocochliobolus* belonging to the Dothideales.

List of *Helminthosporium* transferred to *Drechslera*

***Helminthosporium* sp.**	***Drechslera* sp.**	**Ascigerous state**
H. carbonum	*D. zeicola*	*Cochliobolus carbonum*
H. gramineum	*D. graminea* (Leaf stripe of Barely)	*Pyrenophora graminea*
H. heveae	*D. heveae* *(Birds eye spot of rubber)*	
H. maydis	*D. maydis* (Leaf blight of corn)	*Cochliobolus heterosporus*
H. nodulosum	*D. nodulosus*	*C. nodulosus*
H. oryzae	*D. oryzae* (brown leaf spot of rice)	*C. miyabeanus*
H. sacchari	*D. sacchari* (seedling blight of sugarcane)	
H. sativum	*Bipolaris*	*C. sativum*
H. sigmoideum	*Nakataea sigmoidea*	*Leptosphaeria salvinii*

Drechslera

It is characterized by the sympodially extending conidiophore, which produces an acropetal succession of multiseptate porospores, which are cylindric in shape and germinate from any or all cells. Conidiophores are indeterminate, extending by sympodial growth. The cells of conidium are capable of germination. Conidiophores are brown and produce the conidia singly at the apices. Conidia are cylindrical, multiseptate and dark. *Cochliobolus, Pyrenophora, Pleospora* and *Trichometasphaeria* are imperfect states of *Drechslera.*

Bipolaris

Bipolaris is characterized by germination of conidia from the end cells only. Conidiophores brown, producing conidia through an apical pore and forming a new apex by growth of the sub-terminal region. Conidia fusoid, straight or curved, germinating by one germ tube from each end cell. Exosporium smooth, rigid and brown. Endosporium hyaline, amorphous, separating cells of the mature phragmospores. They are pathogenic on members in grass family. The perfect state is *Cochliobolus*.

Pyricularia

There are only few species, which are causing important plant diseases. Conidiophores are more or less erect, simple or rarely branched, septate, hyaline to lightly pigmented, ultimate cells sympodulae. Conidia borne singly and terminally at the apex of conidiophore with successive conidia being produced in acropetal succession by sympodial extension of the sporogenous cell. Abscission of conidia leaves pronounced denticles on the spore-bearing apex. Conidia ellipsoid or more often pyriform, broader and truncated at the attachment point, tapering towards the distal end, mostly one septate or two septate, hyaline to lightly pigmented.

Pyricularia oryzae -Blast of rice

P. setariae -Blast of fox-tail millet

P. grisea -Blast of ragi / finger millet

Order: Tuberculariales

The characteristic features of this order is the production of sporodochia (sing. sporodochium; Gr. spora = seed + dochien = container) in which the spore mass is supported by a superficial, cushion -like (pulvinate) mass of conidiogenous cells or short conidiophores. The order contains a single family, Tuberculariaceae that has more than 160 form-genera. Following genera are important:

I. Conidia unicellular, hyaline to bright coloured.

(a)) Sporodochia stromatic, parasitic on grains -*Sphacelia*

(b) Sporodochia pulvinate, sometimes with prominent, hyaline setae, Conidia in chains, usually greenish in mass –*Myrothecium*

II. Conidia multicellular, long slender, setae absent in sporodochia.

(a)) Macroconidia canoe shaped -*Fusarium*

(b)Conidia curved with short side branches –*Ramulispora*

III. Conidia dictyospores, dark, globose to subglobse.

(a) Sporodochia pulvinate -*Epicoccum*

(b)Sporodochia convoluted -*Cerebella*

Fusarium, Tubercularia, Volutella, Epicoccum and *Exosporium* are important genera.

Fusarium

The macroconidia (phialospores) are produced on conidiophores, which may be solitary and simple or aggregated (sporodochia) and with complex branching and the ultimate branched terminating in sporogenous cells. The sporogenous cells. The sporogenous cells are phialides, sometimes with an apical collarette. In addition to macroconidia in some fusaria another type of conidia, i.e. microconidia are produced.

Microconidia are non-septate or one-septate, ovoid to short cylindric, gathering in short chains or more commonly in spore balls. Thick walled chlamydospores are also produced either terminally or intercalarily on the somatic hyphae. The mycelium, microconidia, macroconidia and sporodochia are bright in colour. Perfect state of *Fusarium* is found in Ascomycetes in the family Hypocreaceae in which the genera, *Nectria, Calonectria, Gibberella* and *Micronectriella* are found. The genus *Fusarium* contains about 50 species, which are widely distributed in soil and organic substrates. Some of the species, which are serious plant pathogens are listed below.

F. avenaceum(syn.*F. roseum*) -Damping off of seedlings, seedling blight, foot and root rot, ear blight of wheat, barley, oats, corn etc.

F. coeruleum -Dry rot of potato

F. moniliforme -Foot rot of rice

F. oxysporum f.sp. *batatae* -Wilt of sweet potato

F. oxysporum f.sp. *betae* -Wilt of beetroot

F. oxysporum f.sp. *carthami* -Wilt of safflower

F. oxysporum f.sp. *cepae* -Wilt of onion

F. oxysporum f.sp. *ciceris* -Wilt of chickpea

F. oxysporum f.sp. *conglutinans* -Cabbage yellows

F. oxysporum f.sp. *coriandri* -Wilt of coriander

F. oxysporum f.sp. *cubense* -Panama disease of banana

F. oxysporum f.sp. *cucumerinum*-Wilt / foot rot of cucumber

F. oxysporum f.sp. *cumini* -Wilt of cumin

F. oxysporum f.sp. *fabae* -Wilt of broad bean

F. oxysporum f.sp. *glycines* -Wilt of soybean

F. oxysporum f.sp. *lagenariae*-Wilt of bottlegourd

F. oxysporum f.sp. *lathyri* -Wilt of *Lathyrus sativus*

F. oxysporum f.sp. *lentis* -Wilt of lentil

F. oxysporum f.sp. *lini* -Wilt of linseed

F. o. f.sp. *lycopersici* -Wilt of tomato

F. o. f. sp. *Melongenae* -Wilt of brinjal

F. o. f.sp. *phaseoli*-Dry rot or wilt or *Phaseolus vulgaris*

F. o. f.sp. *pisi*-Wilt of pea

F. o. f. sp. *psidii* - Wilt of guava

F. o. f.sp. *sesame* - Wilt of sesame

F. o. f.sp. *sesbaniae* - Wilt of *Sesbania aegyptiaca*

F. trachephilum - Wilt of cowpea

F. o. f.sp. *vasinfectum* - Wilt of cotton, banana, citrus, tomato and cucurbits, Damping off of tomato.

F. semitectum - Storage rot of groundnut

F. solani - Root rot and wilt of legumes, citrus and coffee

F. solani f.sp. *aurantifolia* - C*itrus aurantifolia*

F. solani f.sp. *batatae* - Wilt of sweet potato

F. solani f.sp. *coeruleum* - Wilt of clusterbeans.

F. solani f.sp. *cucurbitae* - Wilt of C*ucurbita* spp

F. solani f.sp. *enmartii* - Wilt of potato

F. solani f.sp. *fabae* - Wilt of Vicia faba

F. solani f.sp. *phaseoli* - Wilt of *Phaseolus* spp.

F. solani f.sp. *piperis* - Wilt of black pepper

F. solani f.sp. *pisi* - Wilt of peas

F. udum - Wilt of pigeonpea

F. udum f.sp. *crotalariae* - Wilt of sunnhemp

Symptoms

Enlargement of roots, club-shaped roots due to hyperplasia and hypertrophy, gradual and inconspicuous stunting, yellowing and wilting of plant.

Symptoms of leaf spots, leaf blights, root rots and wilts and disease cycles of *Alternaria*, *Helminthosporium*, *Colletotrichum*, *Pyricularia*, *Macrophomina* and *Fusarium*

Leaf Spot

In leaf spot a well marked necrotic area of grey, brown, purple or black tissues in green leaves.

i. Blast of rice - *Pyricularia oryzae*

Systematic position Sub-kingdom : Mycota Division : Eumycota

Sub-division : Deuteromycotina

Class : Hyphomycetes

Order : Moniliales

Family : Moniliaceae

Genus : *Pyricularia*

Species : *P. oryzae*

Symptoms: Spindle shaped spots on the leaves (leaf-blast); spots are with dark brown margin and grey centre; spots on the node and neck are black; breaking of neck of earhead (neck blast) and nodal regions in stem (nodal blast). Grain infection shows brown spots on the seed coat.

Pathogen: Mycelium is septate, branched and hyaline to olivaceous, both inter-and intra- cellular. Conidiophores emerge through stomata or by rupturing the cuticle, single or grouped (2- 3), 2 to 4 septate, geniculate and olivaceous. Conidia borne sympodially, hyaline to pale olive, pyriform, three celled with a small basal appendage called **hilum**.

Disease cycle: The conidia are spread through wind and cause infection. The grasses like *Panicum repens, Digitaria marginata, Echinochloa crusgalil,* etc. act as collateral hosts (alternative hosts) and help in perpetuation of the disease and act as primary source of inoculum. The conidia from the grasses on the bunds help on initiation of the disease in the nursery or main field.

ii. Brown spot of rice- *Helminthosporium oryzae* (syn. ***Bipolaris oryzae, Drechslera oryzae;*** Perfect stage: ***Cochliobolus miyabeanus)***

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Deuteromycotina
Class : Hyphomycetes
Order : Moniliales
Family : Dematiaceae
Genus : *Helminthosporium*
Species : *H. oryzae*

Symptoms: Oval shaped, dark brown to black spots on the leaves; black spots on the grains.

Pathogen: Mycelium is brown, septate, branched, inter are and intracellular.

Conidiophores are long, septate, darker and geniculate. Conidia are borne singly, 2 to12 are celled, brown, slightly curved with a bulge in the middle and tapering towards the ends. Perithecia are globose, dark yellowish brown with ostiolar beak. Asci are cylindrical, slightly curved and bear 4-6 ascospores. Ascospores are hyaline, long, cylindrical and 6-15 septate

Disease cycle: The fungus overwinters in infected plant parts. The fungus survives on *Cynodon dactylon, Echinochloa colona, Digitaria sanguinalis* (collateral hosts) from which the conidia 33spread to rice crop in the nursery. Ascospores from perithecia found on dead straw in heaps, which also serve as source of infection. In the field wind-borne conidia cause secondary infection.

iii. Sigatoka leaf spot of banana- *Cercospora musae* (Perfect stage: ***Mycosphaerella musicola)***

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Deuteromycotina
Class : Hyphomycetes
Order : Moniliales
Family : Dematiaceae
Genus : *Cercospora*

Species : C. *musae*

Symptoms: Yellowish green streaks are formed on interveinal areas; the streaks enlarge into cylindrical spots with grey centre, brown margin and each spots surrounded by yellow halo. The lesions coalesce and leaves dry up.

Pathogen: Mycelium is hyaline, septate and branched. Conidia are elongated, narrow and multiseptate. Perithecia are dark brown to black and ostiolate. Asci are oblong and clavate. Ascospores are hyaline, two celled, obtuse to ellipsoid

iv. Early leaf spot of groundnut - *Cercospora arachidicola* (Perfect stage: ***Mycosphaerella arachidis)***

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Deuteromycotina

Class : Hyphomycetes

Order : Moniliales

Family : Dematiaceae

Genus : *Cercospora*

Species : C. *arachidicola*

Symptoms: Spots are irregular or circular, 1 to 10 mm in diameter (bigger), brown; chlorotic halo around the spots present; lower surface of the spot is light brown; premature shedding of leaves.

Pathogen: Mycelium is septate, branched, inter and intracellular. Conidiophores are multi septate, yellowish brown and dense. Conidia are hyaline, obclavate, 3 to 12 septate, fascicles base rounded and tip sub-acute. Perithecia are black, globose, ostiolate. Asci are cylindrical, stipitate and bitunicate. Ascospores are two celled, (upper cell larger, slightly curved), hyaline and 8 in an ascus

v. Late leaf spot of groundnut - *Phaeoisariopsis personata*

(syn. ***Cercospora personata;*** Perfect stage: ***Mycosphaerella berkeleyii)***

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Deuteromycotina

Class : Hyphomycetes

Order : Moniliales

Family : Dematiaceae

Genus : *Cercospora*

Species : C. *personata*

Symptoms: Spots are smaller (1-6mm), **circular and black** in colour yellow halo absent; premature defoliation.

Pathogen: Conidia are olivaceous, obclavate, usually straight or slightly curved, rounded at the apex, base shortly tapered with a conspicuous hilum, mostly 3 to 4 septate, shorter than C. *arachidicola.* Perithercial characters are similar as in C. *arachidicola.*

vi. *Alternaria* leaf spot of cotton - *Alternaria macrospora*

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Deuteromycotina

Class : Hyphomycetes

Order : Moniliales

Family : Dematiaceae

Genus : *Alternaria*

Species : *A. macrospora*

Symptoms: Circular to irregular brown leaf spots with concentric rings; spots coalesce resulting in blight symptom.

Pathogen: Mycelium is dark, septate, branched. Conidiophore is single or in groups, erect, simple, septate, brown. Conidia are produced singly or in chains of two, obclavate with a narrow beak (twice the length of the body), reddish brown; or with both horizontal and vertical septa (muriform conidia)

Leaf Blights

Necrosis of a larger area of leaf lamina including veins is called leaf blight.

i. **Early blight of potato and tomato - *Alternaria solani***

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Deuteromycotina
Class : Hyphomycetes
Order : Moniliales
Family : Dematiaceae
Genus : *Alternaria*
Species : *A. solani*

Symptoms: Circular to irregular, brown spots with concentric rings; spots coalesce leading to blighting, drying of leaves and defoliation of leaves.

Pathogen: Mycelium is light brown to dark, septate, branched and inter-and intracellular. Conidiophores are dark coloured, emerge through stomata. Conidia are beaked, muriform, dark coloured, borne singly or in chains and are with 5 to 10 transverse and a few longitudinal septa

ii. Late blight of potato and tomato - *Phytophthora infestans*

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Mastigomycotina
Class : Oomycetes
Order : Peronosporoales
Family : Pythiaceae
Genus : *Phytophthora*
Species : *P. infestans*

Symptoms: Brown to purplish black water-soaked lesions; enlarge rapidly; lower surface shows whitish mildew growth, severe defoliation; potato tubers show purplish, slightly sunken lesions leading to **dry rot**.

Pathogen: Mycelium is endophytic, coenocytic, hyaline, branched, inter-cellular. Haustoria club shaped. Sporangiophores are hyaline, branched, indeterminate, thick walled, arise through stomata on leaves or lenticels on tubers. Sporangia are multinucleate, thin-walled, hyaline, oval

or pear shaped with a definite papilla at the apex. Zoospores are reniform, biflagellate (anterior tinsel and posterior whiplash). Oospores are thick-walled and smooth.

Disease cycle: Primary infection is through use of infected tubers. Mycelium spreads into shoots produced from infected tubers and reaches the aerial parts of the plant. Sporangiophore emerges through stomata on stem and leaves and produce sporangia, which are spread by rain to wet potato leaves or stems and cause disease. Large number of asexual generation in a growing season kills the foliage rapidly. The zoospores found in the soil germinate, penetrate through lentils or wounds into the tubers and send intercellular mycelium and haustoria into the cells and cause infection.

iii. Northern corn leaf blight of sorghum - *Exserohilum turcicum.* (syn. ***Helminthosporium turcicum;*** Perfect stage: ***Trichometasphaeria turcica)***

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Deuteromycotina

Class : Hyphomycetes

Order : Moniliales

Family : Dematiaceae

Genus : *Exserohilum*

Species : *E. turcicum*

Symptoms: Narrow, **elongated spots** develop initially, later turns to **straw coloured**, lesions with **reddish brown margin**; matured spots are with several cm long; later coalesce and cause extensive drying of leaves.

Pathogen: Mycelium is inter or intracellular, multinucleate and septate. Conidiophores emerge through stomata in clusters, simple, olivaceous, septate and straight or bent. Conidia are long, spindle shaped, straight or slightly curved and 3-7 septate. **Pseudothecia** are black and globose. Asci are clavate and bitunicate. Ascospores are hyaline, fusoid, straight or slightly curved and four celled.

iv. Grey blight of mango - *Pestalotiopsis mangiferae*

Systematic position

Sub-kingdom : Mycota

Division : Eumycota

Sub-division : Deuteromycotina

Class : Coelomycetes

Order : Moniliales

Family : Melanconiaceae

Genus : *Pestalotiopsis*

Species : *P. mangiferae*

Symptoms: Minute brown spots develop at the margin and tip of the leaf initially. They gradually increase in size and become dark brown. Black dots appear at the centre of the spots represent the acervuli.

Pathogen: Mycelium is branched, septate and brown. Acervuli are black. Conidiophores are short, simple or branched, septate, hyaline and smooth. Conidia are five celled, oblong to **clavate,** upper two cells are slightly darker than the lowest olivaceous cells. Upper cell has three setulae.

Grey leaf blight of coconut - *Pestalotiopsis palmarum*

Symptoms: Minute yellow spots surrounded by greyish margin appear on leaf lets, which enlarge to become elliptical with greyish white centre, dark brown margin and yellow halo. Large number of globose / ovoid, black acervuli appear on the upper surface of the spots as black dots.Many spots coalesce into irregular grey necrotic patches. Complete drying and shrivelling of leaf blade occur giving a blighted / burnt appearance.

Pathogen: Mycelium is septate, branched, light brown, inter and intra cellular. Fungus produces acervuli as it's asexual fruiting body during sporulation. Acervuli are black, cushion shaped, sub epidermal and break open to expose conidia and black sterile structures called setae. Conidiophores are hyaline, short, simple and bear a conidium at the tip. Conidia are five celled, middle three cells are coloured, basal and tip cells are hyaline. Tip cells have 3 -5 slender elongated appendages.

Root Rot

Root rot is disintegration or decay of part or all of the root system of a plant. Pathogen belonging to *Aphanomyces, Pythium, Phytophthora, Rhizoctonia, Sclerotium, Phymatotrichum, Thielaviapsis, Macrophomina, Helicorbasidium, Ophiobolus, Armillaria,* etc. are reported to cause root rot disease in various crop plants.

i. Root rot of pulses/ oilseeds/ cotton. - *Macrophomina phaseolina* (Pycnidial stage) *Rhizoctonia bataticola* (Sclerotial stage)

Systematic position: *Macrophomina phaseoloina*

Sub kingdom : Mycota

Division : Eumycota

Sub-division : Deuteromycotina

Class : Coelomycetes

Order : Sphaeropsidales

Family : Sphaeropsidaceae

Genus : *Macrophomina*

Species : *M .phaseolina*

Systematic position: *Rhizoctonia bataticola*

Sub kingdom : Mycota

Division : Eumycota

Subdivision : Deuteromycotina

Class : Aganomycetes

Order :Aganomycetales

Family : Aganomycetaceae

Genus : *Rhizoctonia*

Species : *R.bataticola*

Symptoms: Sudden and complete wilting of plants in patches; rotting of entire root system except taproot and few laterals; shredding of barks of roots; presence of minute black bodies on the surface of the infected bark of roots/stem which represents the sclerotia of the pathogen; stem near the soil level shows large number of black pycnidial bodies.

Pathogen: Mycelium is septate, branched, stout and brown; lateral branches from main hypha are constricted at the point of origin. Selerotia are dark brown or black, round, mustard-like. Pycnidia are small, dark brown, globose, ostiolate, found on stem, erumpent, solitary or gregarious. Pycnidiospore are hyaline, obovoid, single celled and borne on hyaline, cylindrical conidiophores (phialides).

Disease cycle: It survives as sclerotia in the infected debris in soil. Primary spread is through seed-borne and soil-borne sclerotia. Secondary spread is through wind-borne pycnidiospores.

Surviving sclerotia or pycnidia in the soil or in the seed initiate the infection. They germinate and penetrate the host directly. Fungus produces cellulolytic, pectinolytic and other enzymes, which kill and disintegrates the tissues in advance of penetration, resulting in rotting of tissues. It is a facultative saprophyte and it lives saprophytically in the dead tissue and produce greyish white, inter and intracellular, septate, thick walled mycelium, which branches at right angles near the septum. During asexual reproduction, it produces dark brown, globose **pycnidia** with an ostiole on the surface of the stem above ground level. Inner wall of the pycnidium is lined with **pycnidiophore** and pycnidiospore.

Pycnidiophores are hyaline, short and rod shaped. **Pycnidospores** are hyaline, single celled, oval shaped and thin walled. Pycnidia will act either as secondary inoculum for the spread with in the field or as primary inoculum for the initiation of the disease after period of survival in the seed or plant debris. At the end of the growing season the fungus produces spherical, black and smooth walled **sclerotia** (resting bodies) on the inner walls of the root bark. At this stage the roots exhibit bark shredding with numerous sclerotia. Sclerotia survive and initiate new infection.

Stem Rot

In stem rot the stem tissues show disintegration and decay

i. **Stem rot of rice - *Sclerotium oryzae*** (perfect stage: ***Leptosphaeria salvinii****)*

Systematic position Sub-

kingdom : Mycota Division

: Eumycota

Sub-division : Deuteromycotina

Class : Hyphomycetes

Order : Aganomycetales

Family :Aganomycetaceae

Genus : *Sclerotium*

Species : S. *oryza*

Symptoms: Initially small, blackish, irregular lesions are observed on the outer leaf sheath near water line at later growth stages of plant. The lesions enlarge as the disease advance, the fungus penetrates the inner leaf sheath and finally the leaf sheath rots and sclerotia are formed. Later, the infection spreads to stem. One or two internodes of the stem rot and collapse. These infected

stems lodge. Small black sclerotia are seen near on the inner side of the culm amidst greyish weft of mycelium.

Pathogen: Mycelium is hyaline, septate and branched. Sclerotia are spherical, smooth and black. Perithecia are globose and black. Asci are clavate and short stalked. Ascospores are eight in each ascus, fusiform, three septate, middle cells larger and dark and the end cells lighter.

Disease cycle: The fungus is found to survive under unfavorable conditions in the selerotial stage. The sc1etoria germinates from rice stubbles under favorable conditions and is carried from field to field by irrigation water. The sc1etoria can cause primary infection .

Foot-Rot

In foot rot the basal portion of the stem is infected and shows rotting.

Foot-rot of rice - ***Fusarium moniliforme*** (Perfect stage: ***Gibberella fujikuroi)***

Systematic position Sub-
kingdom : Mycota Division
: Eumycota
Sub-division : Hyphomycetes
Class : Deuteromycotina
Order : Moniliales
Family : Tuberculariaceae
Genus : *Fusarium*
Species : *F. moniliforme*

Symptoms: The most conspicuous and common symptom is the bakanae, an abnormal elongation of the plants in the nursery of the field. The infected plants are taller than normal plants, lean lanky and yellowish green. A whitish or pink fungus growth may appear on the lower portion of the drying plants. The basal portion of the infected plant becomes black and rotten. The infected seedlings reveal formation of aerial adventitious roots from the nodes above the ground level. Root system becomes fibrous and bushy. Infected seedlings die in large numbers in patches. In the transplanted crop the plants are killed before earhead formation or even if the inflorescence is formed it will be sterile. If the culm is split open brown discolouration of spongy tissues in nodular region is seen.

Pathogen: Mycelium is hyaline, septate and well branched. Microconidia are hyaline, single celled or two celled, oval and borne in chains. Microconidia are hyaline, 3-5 septate, sickle -

shaped formed on sporodochia. Chlamydospores are absent Perithecia are dark blue, spherical or ovate. Asci are cylindrical, piston shaped and 4-6 spored. Ascospores are two celled.

Disease cycle: The diseases in externally seed-borne and the seeds contaminate with the spores form the primary source of infection. It is also soil-borne (survives for four months as hyphae are macro conidia). The fungus mycelium and micro conidia infect seedlings at an early stage of their development. It becomes systemic in the plants infection also takes place through conidia and mycelium left in the water used for soaking seeds. The funguses in the seedling grow upward and produce mycelium and conidia and infected plant parts. The fungus infects hosts like sorghum, maize, sugarcane, *Panicum miliaceum* and *Andropogon sorghum.*