

**FACULTY OF AGRICULTURE SCIENCES AND
ALLIED INDUSTRIES**

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LECTURE 6

CLASSIFICATION OF FUNGAL PLANT PATHOGENS

INTRODUCTION

Traditionally, fungi were classified under Thallophyta division of Plantae Kingdom under 4 classes, viz., phycmycetes (also called lower fungi including Oomycetes, Chytridiomycetes and Zygomycetes), ascomycetes, basidiomycetes and deuteromycetes (including fungi imperfecti).

Ainsworth's classification (1966, 1973) included kingdom Fungi with Myxomycota and Eumycota divisions. The Eumycota division was divided into 5 sub-divisions, viz., mastigomycotina, zygomycotina, ascomycotina, basidiomycotina and deuteromycotina which were further sub-divided into (classes, orders and so on).

Classification system based on information on phylogenetic relationships of fungi obtained by small subunit (18 S) ribosomal RNA gene comparison are now used. The classification given by Hawksworth et al. (1995) and partially modified by Kirk et al. (2001) is now universally accepted. According to it, the fungi are placed in three kingdoms: Fungi, Protozoa and Straminopila

All the taxa (kingdom to species) are now italicized in print and underlined when hand written.

Some fungal-like organisms, often referred to as lower fungi, are now considered to belong to the kingdom Protozoa (e.g., myxomycetes and plasmodiophoromycetes) or to the kingdom Chromista (also known as Stramenopiles) (e.g., oomycetes). True fungi, however (i.e., chytridiomycetes, zygomycetes, ascomycetes, basidiomycetes, and deuteromycetes) belong to the kingdom Fungi.

All fungi and fungal-like organisms are members of the Eukaryota and belong to the following groups:

Eukaryota

Mycetozoa - produce a plasmodium or plasmodium-like structures

Fundamentals of Plant Pathology

Dictyosteliida - cellular slime molds
Myxogastria - plasmodial slime molds

Plasmodiophoridae - endoparasitic slime molds Stramenopiles, heteroconts, with two different flagella, one having hollow tripartite hairs

Oomycetes - have elongated nonseptate mycelium, biflagellate zoospores in zoosporangia, oospores

Fungi

Chytridiomycota — have zoospores with a single posterior flagellum, round or elongated mycelium

Zygomycota — produce nonmotile asexual spores in sporangia. Resting spore is a zygospore

Ascomycota — produce sexual spores, ascospores, in asci. Produce nonmotile asexual spores (conidia)

Basidiomycota — produce sexual spores, basidiospores, externally on a basidium

Fungal-Like Organisms

I. Kingdom: Protozoa — Microorganisms that may be unicellular, plasmodial, colonial, very simple multicells, or phagotrophic, i.e., feeding by engulfing their food. The kingdom contains many microorganisms in addition to the fungal-like organisms myxomycetes and plasmodiophoromycetes

Phylum: Myxomycota — Produce a plasmodium or plasmodium-like structure

Class: Myxomycetes (slime molds) — Their body is a naked, amorphous plasmodium. They produce zoospores (swarm cells). May grow on and may cover parts of low-lying plants but do not infect plants

Order: Physarales — Saprophytic plasmodium that gives rise to crusty fructifications containing spores. They produce zoospores that have two flagella

Genus: *Fuligo*, *Mucilago*, and *Physarum* cause slime molds on low-lying plants

Phylum: Plasmodiophoromycota (the Plasmodiophoromycetes — Endoparasitic slime molds)

Order: Plasmodiophorales — Plasmodia produced within cells of roots and stems of plants. They produce zoospores that have two flagella. Obligate parasites

Genus: *Plasmodiophora*, *P. brassicae* causing clubroot of crucifers

Polymyxa, *P. graminis* parasitic on wheat and other cereals. Can transmit plant viruses

Spongospora, *S. subterranea* causing powdery scab of potato tubers

II. Kingdom: Chromista (Stramenopiles) — Unicellular or multicellular, filamentous or colonial, primarily phototrophic (micro)organisms, some with tubular flagellar appendages or with chloroplasts inside the rough endoplasmic reticulum or both. Contains brown algae, diatoms, oomycetes, and some other similar organisms

Phylum: Oomycota — Have biflagellate zoospores, with longer tinsel flagellum directed forward and a shorter whiplash flagellum directed backward. Diploid thallus, with meiosis occurring in the developing gametangia. Gametangial contact produces thick-walled sexual oospore. Cell walls composed of glucans and small amounts of hydroxyproline and cellulose

Class: Oomycetes (water molds, white rusts, and downy mildews) — Have nonseptate elongated mycelium. Produce zoospores in zoosporangia. Zoospores have two flagella. Sexual resting spores (oospores) produced by the union of morphologically different gametangia called antheridia (male) and oogonia (female)

Order: Saprolegniales — Have well-developed mycelium. Zoospores produced in long, cylindrical zoosporangia attached to mycelium. Usually several oospores in an oogonium

Genus: *Aphanomyces*, *A. euteiches* causing root rot of peas

Order: Peronosporales — Mycelium well-developed, nonseptate, branching, inter- or intracellular, often with haustoria. Zoosporangia oval or lemon shaped, borne on ordinary mycelium or on sporangiophores. Sporangia in most species germinate by producing zoospores, but in some they germinate directly and produce a germ tube. Sexual reproduction is by characteristic oogonia and antheridia that fuse and produce an oospore. Oospores germinate by giving rise to a sporangium containing zoospores or to a germ tube, which soon produces a sporangium, depending on the species

Family: *Pythiaceae* — Sporangia, usually zoosporangia, produced along somatic hyphae or at tips of hyphae of indeterminate growth and set free. Oogonia thin-walled. Facultative parasites

Genus: *Pythium*, causing damping-off of seedlings, seed decay, root rots, stem lesions, rotting of vegetable fruit and tubers on/or in the ground, and cottony blight of turf grasses

Phytophthora, *P. infestans* causing late blight of potato; several others causing mostly root and stem rots, rots of fleshy fruits and vegetables, cankers and diebacks

Family: *Peronosporaceae* (the downy mildews) — Sporangia borne on sporangiophores of determinate growth. Sporangia wind-borne. Obligate parasites

Genus: *Plasmopara*, *P. viticola* causing downy mildew of grape

Peronospora, *P. tabacina* causing downy mildew (blue mold) of tobacco

Bremia, *B. lactucae* causing downy mildew of lettuce

Pseudoperonospora, *P. cubensis* causing downy mildew of cucurbits

Peronosclerospora causing downy mildew of corn (*P. philippinensis*), of sugarcane and corn (*P. sacchari*), of sorghum (*P. sorghi*), and others

Sclerophthora causing crazy top (downy mildew) of corn

Sclerospora causing downy mildew of pearl millet and many other grasses

Family: *Albuginaceae* (the white rusts) — Sporangia borne in chains

Genus: *Albugo*, *A. candida* causing white rust of crucifers

True Fungi

Kingdom: Fungi — Produce mycelium, the walls of which contain glucans and chitin. Lack chloroplasts

Phylum: Chytridiomycota — Produce zoospores that have a single posterior flagellum

Class: Chytridiomycetes — Have round or elongated mycelium that lacks cross walls

Genus: *Olpidium*, *O. brassicae* being parasitic in roots of cabbage and other plants. Can transmit plant viruses

Physoderma*, *P. maydis causing brown spot of corn, and ***P.* (= *Urophlyctis*) *alfalfae*** causing crown wart of alfalfa

Synchytrium*, *S. endobioticum causing potato wart

Phylum: Zygomycota — Produce nonmotile asexual spores in sporangia. No zoospores. The resting spore is a zygospore, produced by the fusion of two morphologically similar gametes

Class: Zygomycetes (bread molds) — Saprophytic or parasites of plants, humans, and animals

Order: Mucorales — Nonmotile asexual spores formed in terminal sporangia

Genus: *Rhizopus*, causing bread molds and soft rot of fruits and vegetables

Choanephora*, *C. cucurbitarum causing soft rot of squash

Mucor, causing bread mold and storage rots of fruits and vegetables

Order: Glomales — Fungi forming vesicular–arbuscular mycorrhizae with roots, also known as endomycorrhizae. Arbuscules produced in host root. Chlamydospore-like spores produced singly in soil, in roots, or in sporocarps. Sexual reproduction rare

Genus: *Glomus*, *Acaulospora*, *Gigaspora*, *Scutellospora*

Phylum: Ascomycota (ascomycetes, sac fungi) — Most have a sexual stage (teleomorph) and an asexual stage (anamorph). Produce sexual spores, called ascospores, generally in groups of eight within an ascus. Produce asexual spores (conidia) on free hyphae or in asexual fruiting structures (pycnidia, acervuli, etc.)

I. **Class: Archiascomycetes** — A group of diverse fungi, difficult to characterize

Order: Taphrinales — Asci arising from binucleate ascogenous cells

Genus: *Taphrina*, causing peach leaf curl, plum pocket, oak leaf blister, etc.

II. **Class: Saccharomycetes (yeasts)** — Asci naked, no ascocarps produced. Mostly unicellular fungi that reproduce by budding

Genus: *Galactomyces*, causing citrus sour rot

Saccharomyces, *S. cerevisiae*, the bread yeast

III. Filamentous ascomycetes

Order: Erysiphales (the powdery mildew fungi) — Asci in fruiting bodies completely closed (cleistothecia). Mycelium, conidia, and cleistothecia on surface of host plant.

Obligate parasites

Genus: *Blumeria*, causing powdery mildew of cereals and grasses

Erysiphe, causing powdery mildews of many herbaceous plants

Leveillula, causing powdery mildew of tomato

Microsphaera, one species causing powdery mildew of lilac

Oidium (anamorph only), causing powdery mildew of tomato

Podosphaera, *P. leucotricha* causing powdery mildew of apple

Sphaerotheca, *S. pannosa* causing powdery mildew of roses and peach

Uncinula, *U. necator* causing powdery mildew of grape

A. Pyrenomycetes: Ascomycetes with perithecia — Perithecia or, in some groups, cleistothecia in a stroma, immersed in a loose hyphal mat, or free. Asci have one wall

Order: Hypocreales — Stromata pale to blue, purple or brightly colored. Asci ovoid to cylindrical with an apical pore. Ascospores are spherical to needle like, one to several celled, usually discharged forcibly. Conidia produced from phialidic conidiophores. Some produce substances toxic to humans and animals. Some produce growth regulators. Some are antagonistic or parasitic on other fungi, and some are systemic parasites (endophytes) of many grain crops and grasses, making them poisonous to grazing animals

Genus: *Hypocrea*, some species of which produce the anamorphs *Trichoderma* and *Gliocladium*, which are used as biocontrol agents against several plant pathogenic fungi

Melanospora, whose anamorphs *Phialophora* and *Gonatobotrys* parasitize the mycelium of many fungi, including the important plant pathogens *Ophiostoma*, *Ceratocystis*, *Fusarium*, and *Verticillium*

Nectria, causing twig and stem cankers of trees

Gibberella, causing foot or stalk rot of corn and small grains

Claviceps, *C. purpurea* causing ergot of grain crops, which is poisonous to humans and animals, *C. sorghi*, of sorghum.

Epichloe, endophytic in grasses (its anamorph is *Acremonium*)

Balansia, endophytic in grasses and sedges

Atkinsonella, endophytic in grasses and sedges

Myriogoenospora, endophytic in grasses and sedges

Order: Microascales — Lack stromata. Most have perithecia but some have cleistothecia. Asci are globoid or ovoid, disintegrating. Ascospores one-celled

Genus: *Ceratocystis*, causing oak wilt (*C. fagacearum*); cankers in stone fruit and other trees and root rot of sweet potato (*C. fimbriata*); butt rot of pineapple (*C. paradoxa*); sapstain or blue stain of cut wood surfaces (*C. coerulea* and others)

Monosporascus, *M. cannonballus* causing root rot and collapse of cucurbits

Order: Phyllachorales — Perithecia in stroma, asci oblong to cylindrical, with pores at their tips. Ascospores of varying shapes, hyaline or dark

Genus: *Glomerella*, *G. cingulata* causing many anthracnose diseases and bitter rot of apples; its anamorphic stage is *Colletotrichum gloeosporioides*

Phyllachora, *P. graminis* causing leaf spots on grasses

Order: Ophiostomatales — Perithecia without paraphyses. Asci globose to ovoid, disintegrating. Several species are dispersed by beetles. Some species cause sapstain (blue stain) in wood

Genus: *Ophiostoma*, *O. novo-ulmi*, causing the Dutch elm disease (anamorphs are *Sporothrix* and *Graphium*)

Order: Diaporthales — Perithecia in a stroma of either fungal or plant tissue, or of hyphae on the substrate. Asci cylindrical with pores. Ascospores have one to several septa and may be hyaline to brown

Genus: *Diaporthe*, causing citrus melanose (*D. citri*), eggplant fruit rot (*D. vexans*), soybean pod and stem rot (*D. phaseolorum*); their anamorphs are species of *Phomopsis*

Gnomonia, causing anthracnose and leaf spot diseases

Gaeumannomyces, *G. graminis* causing the take-all disease of grain crops (wheat, rice, oats) and grasses

Magnaporthe, *M. grisea* causing rice blast disease; its anamorph is *Pyricularia oryzae*

Cryphonectria, *C. parasitica* causing the chestnut blight disease

Leucostoma (formerly *Valsa*), causing canker diseases of peach and other trees

Order: Xylariales — Perithecia dark, leathery, hard, sometimes embedded in a stroma. Asci cylindrical to subglobose. Ascospores one to a few celled, hyaline or dark

Genus: *Hypoxyton*, *H. mammatum* causing a severe canker on poplars

Rosellinia, *R. necatrix* causing root diseases of fruit trees and vines

Xylaria, causing tree cankers and wood decay

Eutypa, *E. armeniaca* causing serious canker diseases of fruit trees and vines

B. Loculoascomycetes: Ascomycetes with ascostromata — Produce asci within locules (cavities) preformed in a stroma. Ascstroma may be monolocular (pseudothecium) or multilocular. Asci have a double wall

Order: Dothideales — Locules lack sterile hyphae and open by an apical pore. Asci ovoid to cylindrical, in fascicles. Ascospores one to several celled, hyaline to brown

Genus: *Mycosphaerella*, causing leaf spots on many plants, such as the Sigatoka diseases of banana (*M. musicola* and *M. fijiensis*), leaf spots of cereals and grasses (*M. graminicola*), and leaf spot of strawberry (*M. fragariae*); its anamorphs may be *Cercospora*, *Septoria*, and many others

Elsinoë, causing citrus scab (*E. fawcetti*), grape anthracnose (*E. ampelina*), and raspberry anthracnose (*E. veneta*)

Order: Capnodiales — Ascocarps superficial, produced in a loose mat of dark hyphae

Genus: *Capnodium*, being one of many fungi causing sooty molds on plants

Order: Pleosporales — Asci surrounded by pseudoparaphyses. Ascostroma variable

Genus: *Cochliobolus*, whose anamorphs are *Bipolaris* or *Curvularia*, causes leaf spots and root rots on grain crops and grasses

Pyrenophora, whose anamorph is *Drechslera*, causing leaf spots on cereals and grasses

Setosphaera (anamorph is *Exserohilum*), causing leaf spots on cereals and grasses

Pleospora (anamorph is *Stemphylium*), causing black mold rot of tomato

Leptosphaeria (anamorph is *Phoma*), causing black leg and foot rot of cabbage

Venturia (anamorphs are *Pollaccia* and *Spilocaea*), causing apple scab (*V. inaequalis*) and pear scab (*V. pyrina*)

Guignardia (anamorph is *Phyllosticta*), causing black rot of grapes

Apiosporina, *A. morbosa* (anamorph *Fusicladium*) causing black knot of cherries and plums

C. *Discomycetes*: Ascomycetes with apothecia — Ascocarps shaped like cups, saucers, or cushions and called apothecia. Asci cylindrical to ovoid, often interspersed with paraphyses. Ascospores discharged forcibly

Order: Rhytismales — Ascocarps are black, spherical, discoid, or elongate and are produced in stromata. Asci variable. Ascospores hyaline or brown, ovoid to filiform

Genus: *Hypoderma*, causing pine leaf spot (needle cast) diseases

Lophodermium, causing pine needle cast

Rhabdocline, causing Douglas fir needle cast

Rhytisma, *R. acerinum* causing tar spot of maple leaves

Order: Helotiales — Apothecia cup or disk shaped. Asci with only slightly thickened apices. Ascospores are spherical, elongate, to filiform, and have none to several septa

Genus: *Monilinia*, causing the brown rot disease of stone fruits

Sclerotinia, *S. sclerotiorum* causing the white mold or watery soft rot of vegetables

Stromatinia, *S. gladioli* causing corm rot of gladiolus

Pseudopeziza, *P. trifolii* causing alfalfa leaf spot

Diplocarpon, *D. maculatum* causing black spot of quince and pear and *D. rosae* causing black spot of roses

D. *Deuteromycetes* or mitosporic fungi (imperfect or asexual fungi) — Mycelium well-developed, septate, branched. Sexual reproduction and structures rare, lacking, or unknown. Asexual spores (conidia) formed on conidiophores existing singly, grouped in specialized structures such as sporodochia and synnemata, or produced in structures known as pycnidia and acervuli. The most important mitosporic fungi are listed.

Phylum: Basidiomycota (basidiomycetes, the club and mushroom fungi) — Sexual spores, called basidiospores, are produced externally on a club-like, one- or four-celled spore-producing structure called a basidium

Order: Ustilaginales (the smut fungi) — Basidium has cross walls or is nonseptate. It is the promycelium of the teliospore. Teliospores single or united into crusts or columns, remaining in host tissue or bursting through the epidermis. Fertilization by union of compatible spores, hyphae, etc. Only teliospores and basidiospores are produced

Genus: *Ustilago*, causing smut of corn (*U. maydis*), loose smuts of oats (*U. avenae*), of barley (*U. nuda*) and of wheat (*U. tritici*)

Tilletia, causing covered smut or bunt of wheat (*T. caries*) and Karnal bunt (partial bunt) of wheat (*T. indica*)

Urocystis, *U. cepulae* causing smut of onion

Sporisorium, causing covered kernel smut of sorghum (*S. sorghi*) and loose sorghum smut (*S. cruentum*)

Sphacelotheca, causing head smut of sorghum

Order: Uredinales (the rust fungi) — Basidium with cross walls. Sperm cells called spermatia fertilize special receptive hyphae in spermatogonia. Produce two to several types of spores: teliospores, basidiospores, aeciospores, and uredospores (sometimes called “urediniospores”). Uredospores can be repeating spores. Obligate parasites

Genus: *Cronartium*, several species causing stem rusts of pines

Gymnosporangium, *G. juniperi-virginianae* causing cedar-apple rust

Hemileia, *H. vastatrix* causing coffee rust

Melampsora, *M. lini* causing rust of flax, *M. medousae* causing rust of poplars and conifers

Phakopsora, *P. pachyrrhizi* causing rust of soybeans

Phragmidium, one species causing rust of roses

Puccinia, several species causing severe rust diseases of cereals and of other plants

Uromyces, *U. appendiculatus* causing rust of beans

Order: Exobasidiales — Basidiocarp lacking: basidia produced on surface of parasitized tissue

Genus: *Exobasidium*, causing leaf, flower, and stem galls on several ornamentals

Order: Ceratobasidiales — Basidiocarp is web like, inconspicuous. Basidia without cross walls, with four prominent sterigmata

Genus: *Athelia*, the teleomorph of *Sclerotium* causing Southern blight of many plants, *S. cepivorum* causing the white rot of onions

Thanatephorus, *T. cucumeris* is the teleomorph of *Rhizoctonia solani*, causing root and stem rots, damping-off, and fruit rots in many plants

Typhula, causing typhula blight (snow mold) of turf grasses

Order: Agaricales (the mushrooms) — Basidium without cross walls, produced on radiating gills or lamellae. Many are mycorrhizal fungi

Genus: *Armillaria*, *A. mellea* and other species causing root rots of trees

Crinipellis, *C. pernicius* causing witches'-broom of cacao

Marasmius, causing the fairy ring disease of turf grasses

Pleurotus, causing white rot on logs, tree stumps, and living trees

Pholiota, causing brown wood rot in deciduous forest trees

Pholiota, causing brown wood rot in deciduous forest trees

Order: Aphyllophorales — Basidia without cross walls produced on hymenium-forming hyphae and lining the surfaces of small pores or tubes

Genus: *Athelia* (anamorph is *Sclerotium*), causing root and stem rots of many plants

Chondrostereum, *C. purpureum* causing the silver leaf disease of trees

Corticium, one species causing the red thread disease of turf grasses

Heterobasidion, *H. annosum* causing root and butt rot of many trees

Ganoderma, causing root and basal stem rots in many trees

Inonotus, causing a heart rot of living trees and rot of dead trees and logs

Postia, causing wood and root rots of forest trees

Phellinus, causing tree root rots and cubical rots in buildings

Peniophora, causing decay in coniferous logs and pulpwood

Polyporus, causing heart rot of living trees and rot of dead trees or logs