Taxonomy of fungi

Taxonomy is the science of classification. It means the assigning of objects to defined categories. However, the great fungal taxonomist R. W. G. Dennis (1960) described taxonomy as the art of classifying organisms: not a science but an art, for its triumphs result not from experiment but from disciplined imagination guided by intuition. A classification has three main functions:

1- It gives a framework of recognizable features by which an organism under examination can be identified.

2- It is an attempt to group together organisms that are related to each other

3- It assists in the retrieval of information about the identified organism in the form of a list or catalogue.

The five kingdoms of life

Living organisms are subdivided into 5 major kingdoms, including the **Monera (Prokaryotic)**, and **Eukaryotic** kingdoms which are the **Protista** (Protoctista), the **Fungi**, the **Plantae**, and the **Animalia**. Each kingdom is further subdivided into separate phyla or divisions. Generally, "animals" are subdivided into phyla, while "plants" are subdivided into divisions. These subdivisions are analogous to subdirectories or folders on your hard drive.

Methods of taxonomy

1- Traditional taxonomic methods: classical methods relying on macroscopic or microscopic observations. These methods depend on characters such as spores (the formation way of a spore, shape, colour, or the size of the spores, the presence or absence of septa in hyphae, etc.)

2- Molecular methods of fungal taxonomy: they are more objective set of criteria based directly on comparisons of selected DNA sequences encoding genes with a conserved biological functions

Microscopic features are still important today for recognizing fungi and making an initial identification which can then, if necessary, be backed up by molecular methods.

Fungi in the widest sense, as organisms traditionally studied by mycologists, currently fall into three kingdoms of Eukaryota, i.e. the Eumycota which contain only fungi, and the Protozoa and Chromista (Straminipila), both of which contain mainly organisms not studied by mycologists and were formerly lumped together under the name Protoctista. The Protozoa are notoriously difficult to resolve by phylogenetic means, and the only firm statement which can be made at present is that they are a diverse and ancient group somewhere between the higher Eukaryota (‘crown eukaryotes’) and the prokaryotes.

The classification scheme adopted in this book, showing mainly those groups treated in some detail.

KINGDOM PROTOZOA-PROTISTS
Phylum: Myxomycota
Phylum: Plasmodiophoromycota

Phylum: Hyphochytriomycota

Phylum: Labyrinthulomycota

Phylum: Oomycota

KINGDOM FUNGI (EUMYCOTA):
The five true phyla of fungi are the Chytridiomycota (Chytrids), the Zygomycota (conjugated fungi), the Ascomycota (sac fungi), the Basidiomycota

(club fungi) and the recently described Phylum Glomeromycota. The Deuteromycota is an informal group of unrelated fungi that all share a common character – they use strictly asexual reproduction.

Hierarchical taxonomy:

Hierarchical taxonomy is the process of arranging various organisms into successive levels of the biological classification either in a decreasing or an increasing order from kingdom to species and vice versa.

An example of the hierarchy of taxonomic terms is the wheat stem rust fungus, *Puccinia graminis*, used as an example:

Kingdom: Fungi

Subkingdom: Eumycota

Phylum: Basidio**mycota**

Class: Uredinio**mycetes**

Order: Uredin**ales**

Family: Puccini**aceae**

Genus: Puccinia

Species: Puccinia graminis

Race: Puccinia graminis f. sp. tritici

Kingdom: Protozoa

Phylum: Plasmodiophoromycota.

Plasmodiophoromycota is monophyletic and contains a single class (Plasmodiophoromycetes). There are two orders of this class which are Plasmodiophorales and Haptoglossales.

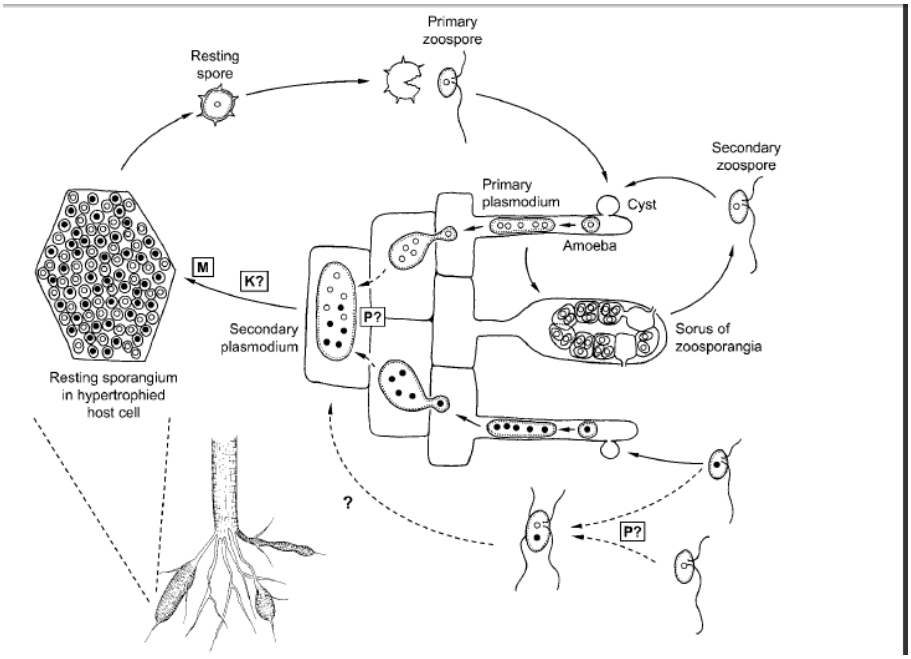
Order: Plasmodiophorales

1- The zoospore of the Plasmodiophorales is biflagellate. The flagella are inserted laterally and are of unequal length, the anterior one being shorter. Both flagella are of the whiplash type
2- Like the zoospore, the main vegetative unit- the amoeba, which enlarges to become a plasmodium -is wall-less.
3- It is present freely within host plant cells, its membrane being in direct contact with the host cytoplasm. The plasmodia possess amoeboid features because they can produce pseudopodia and engulf parts of the host cytoplasm by phagocytosis
4- The walled stages of Plasmodiophorales are confined to the zoospore cysts on the plant surface, and the zoosporangia and resting sporangia inside host plant cells. The wall of resting spores is particularly thick and has been shown to contain chitin

Plasmodiophora brassicae

Plasmodiophora brassicae is the causal organism of club root or finger-and-toe disease of brassicas and was first described by Woronin (1878). The disease is common in gardens where brassicas are frequently grown, especially if the soil is acidic and poorly drained. A wide range of brassicaceous hosts is attacked,

and root-hair infection of some non-brassicaceous hosts can also occur. The disease is widely distributed throughout the world.



Probable life cycle of Plasmodiophora brassicae. A haploid resting spore forms a haploid primary zoospore giving rise to a multinucleate haploid primary plasmodiumupon infection of a root hair. Secondary zoospores are also haploid, and the way in which they meet to forma secondary heterokaryotic plasmodium is not known for sure. Open and closed circles represent haploid nuclei of opposite mating type; the position of the diploid phase in the life cycle is unclear.Key events in the life cycle are plasmogamy (P), karyogamy (K) and meiosis (M). AfterTommerup and Ingram (1971), Buczacki (1983) and Dylewski (1990).

Protistis – Oomycota (filamentous Protists)

Oomycota is a phylum of filamentous protists containing over 500 species. The majority of these organisms are in the groups commonly known as water molds or downy mildew. "Oomycota" means "egg fungi", referring to the oversize oogonia which house the female gametes (eggs). Despite the name and their superficial appearance, oomycetes are not fungi. While some members of Oomycota are relatively harmless, some species are parasitic and negatively affect aquatic plants or organisms. Some parasitic oomycetes have affected the history of human populations through the infection of certain terrestrial plants.

For instance, *Phytophthora infestans*, or late potato blight, spreads so rapidly through the leaves and tubors of potato plants that the disease destroyed almost the entire crop of potatoes in Ireland, leading to the Great Potato Famine of 1846. Another native American parasitic oomycete, *Plasmopara viticola*, was transported to France in 1870 on grapevines which were used to stimulate the struggling French grape industry.

Characters of Oomycota (filamentous Protists):

1. The structural cell wall polymer is cellulose.
2. The inner mitochondrial membrane is folded into tubular cristae but mitochondrial cristae are generally lamellate in the kingdoms Eumycota and Animalia.
3. Golgi stacks (dictyosomes) are present but in the Eumycota the Golgi apparatus is usually reduced to single cisternae.
4. Flagella are usually present during particular stages of the life cycle; they always include one straminipilous flagellum (Lat. stramen = straw, pilus = hair).
5. The amino acid ,lysine, is synthesized via the diaminopimelic acid (DAP) pathway.

Protists: Oomycota

1- The phylum Oomycota, currently comprises some 800-1000 species
2- Most of them produce hyphae forming a mycelium.
3- The hyphae of Oomycota display apical growth and enzyme secretion.

4- The hyphae of Oomycota are coenocytic, i.e. they generally do not form cross-walls (septa) except in old compartments or at the base of reproductive structures.

5- The cytoplasm is generally coarsely granular and contains vacuoles, Golgi stacks, mitochondria and diploid nuclei.

6- The Oomycota are characterized by motile asexual spores (zoospores) possessing one straminipilous and one whiplash-type flagellum.

7- The life cycle of the Oomycota is of the haplomitotic B type, i.e. mitosis occurs only between karyogamy and meiosis. All vegetative structures of Oomycota are therefore diploid. This contrasts with the Eumycota in which vegetative nuclei are usually haploid.

8- Sexual reproduction in Oomycota is oogamous, i.e. male and female gametangia are of different size and shape. Meiosis occurs in the male antheridia and in the female oogonia, and is followed by plasmogamy (fusion between the protoplasts) and karyogamy (fusion of haploid nuclei).

9- Oomycota have a major impact on mankind as pathogens causing plant diseases of epidemic proportions.

10- Oomycota are cosmopolitan and ubiquitous even in terrestrial situations.

11- Most are obligate aerobes, although some tolerate anaerobic conditions

12- Oomycota live either saprotrophically on organic material, or they may be obligate (biotrophic) or facultative (necrotrophic) parasites of plants.

Order: Pythiales

1- The order Pythiales includes two families, the Pythiaceae and Pythiogetonaceae. Pythiaceae is a large family includes over 200 species in approximately 10 genera, of which 2 are of outstanding significance: *Pythium* and *Phytophthora*.

2- *Phytophthora* species are primarily pathogenic to plants from which they can be isolated and grown in pure culture.

3- The genus *Pythium* is best known for its saprotrophic soil-inhabiting members, many of which are opportunistic pathogens especially in young plants. There are also obligately pathogenic *Pythium* spp.

4- Asexual reproduction in *Pythium* and *Phytophthora* is by means of sporangia which vary in shape from swollen hyphae or globose structures (Pythium) to lemon-shaped (Phytophthora). Sporangia are borne on more or less undifferentiated hyphae. In most cases, sporangia germinate to produce zoospores which are of the principal (kidney-shaped) type.

5- In many *Pythium* spp., the final stages of zoospore differentiation take place outside the sporangium in a walled vesicle, followed by breakdown of the soft wall and release of the zoospores. In Phytophthora, in contrast, zoospores differentiate within the sporangium and are released directly or via a very short-lived vesicle which is surrounded only by a membrane.

6- Sexual reproduction is oogamous.

7- Most members of the Pythiaceae are homothallic, although heterothallism and relative sexuality have been reported, e.g. for *Phytophthora infestans* and *Pythium sylvaticum*.

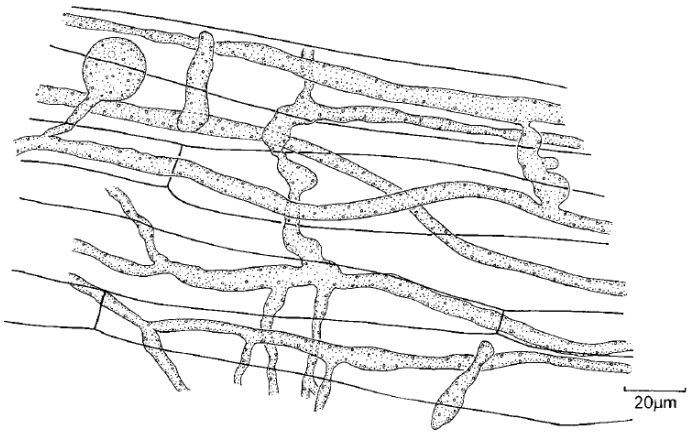
Pythium

Life cycle

Species of Pythium grow in water and soil as saprotrophs, but under suitable conditions, e.g. where seedlings are grown crowded together in poorly drained soil, they can become parasitic, causing diseases such as pre-emergence killing, damping off and foot rot.

Fungal body

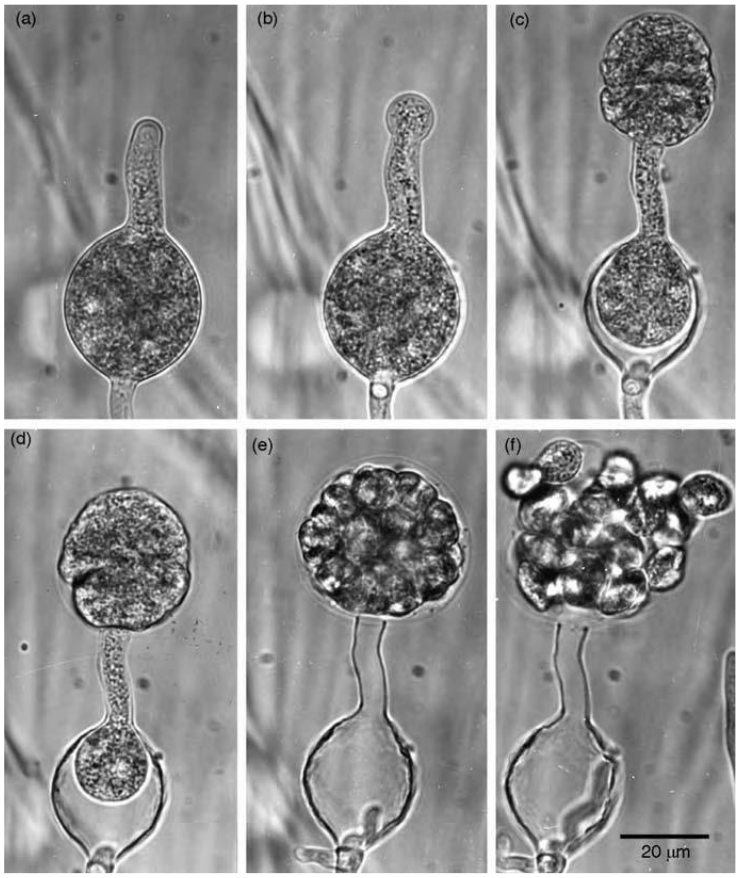
The mycelium is coarse and coenocytic, with typically granular cytoplasmic contents. At first there are no septa, but later cross walls may cut off empty portions of hyphae. Thick-walled chlamydospores may also be formed. There are no haustoria.



Pythium myceliumin the rotting tissue of a cress seedling hypocotyl. Note the spherical sporangium initial and the absence of haustoria.

Asexual reproduction

The mycelium within the host tissue or in culture usually produces sporangia, but their form varies. Discharge of the sporangium occurs by the formation of a thin-walled vesicle at the tip of the papilla from the fibrillar material of the apical cap, and the partially differentiated zoospore mass is extruded (to push with force) into it.



Pythium middletonii. Stages in zoospore discharge. (a) Sporangium shortly before discharge. Note the thickened tip of the papillawhich consists of a cap of cell wall material. (b) Inflation of the vesicle begins. (c,d) Protoplasm is retreating from the sporangium. Note the shrinkage in sporangium diameter as compared with (a). (e) Zoospores have differentiated within the vesicle, with flagella visible between the vesicle wall and the zoospores. (f) Zoospores escape following the rupture of the vesicle wall. The whole process of discharge takes about 20min.

The zoospore

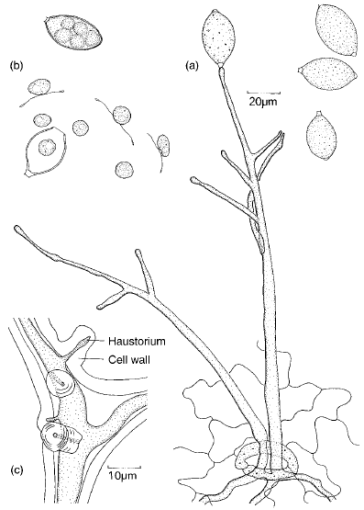
Zoospores of Pythium spp. are always of the principal type. They can swim for several hours in a readily recognizable manner of helical forward movement.

Sexual reproduction

Most species of Pythium are homothallic, i.e. oogonia and antheridia are readily formed in cultures derived from single zoospores.

Phytophthora

The name *Phytophthora* (Gr.: 'plant destroyer') is apt, most species being highly destructive plant pathogens. *Phytophthora* is closely related to Pythium and there are transitional species which may need to be re-assigned as more DNA sequences and other data become available. In general, the two genera can be distinguished morphologically in that the sporangia of *Phytophthora* spp. are typically pear- or lemon-shaped with an apical papilla (Figure), and ecologically by the predominantly saprotrophic existence of Pythium and the predominantly parasitic mode-of-life of *Phytophthora*.



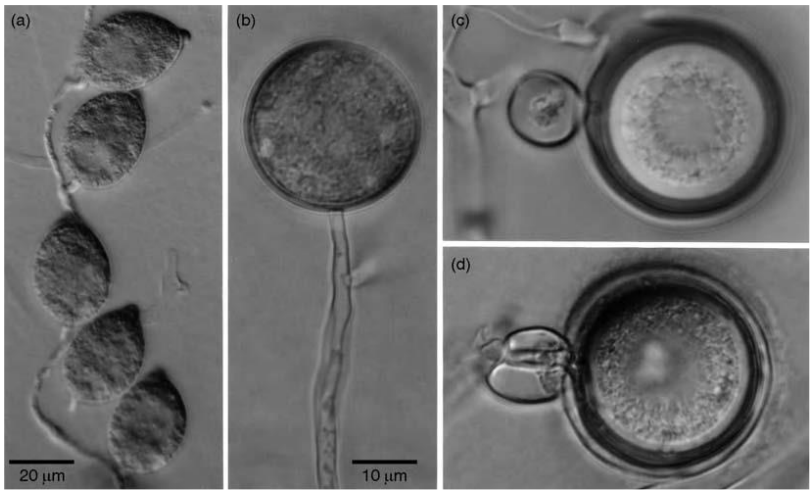
Phytophthora infestans. (a) Sporangiophores penetrating a stoma of a potato leaf. (b)Zoospores and zoospore cysts, one formed inside a zoosporangium. (c) Intercellular mycelium from a potato tuber showing the finger-like haustoria penetrating the cellwalls. Note the thickening of the cell walls around the haustorium..

Vegetative growth

Most species form an aseptate mycelium producing branches at right angles, often constricted at their point of origin. Septa may be present in older cultures. Within the host, the mycelium is intercellular, but haustoria may be formed. Haustoria are typical of biotrophic pathogens such as the Peronosporales but may also be formed during initial biotrophic phases of infections which subsequently turn necrotrophic.

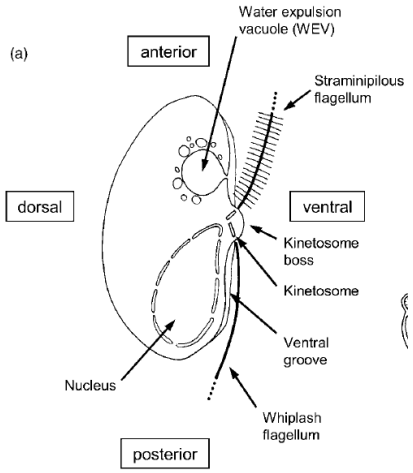
Asexual reproduction

The sporangia of *Phytophthora* spp. are usually pear-shaped or lemon-shaped and arise on simple or branched sporangiophores which are more clearly differentiated than those of Pythium. On the host plant, the sporangiophores may emerge through the stomata, as in *P. infestans*. Thick-walled asexual spherical chlamydospores have also been described for many *Phytophthora* spp. and can survive in soil for several years.

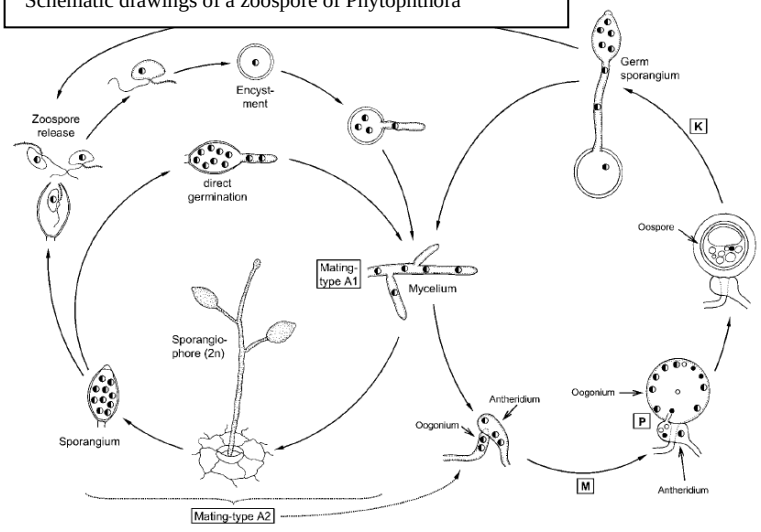


Reproductive structures in Phytophthora cactorum. (a) Sporangia. (b) Chlamydospore. (c) Oospore showing the paragynous mode of fertilization. (d) Oosporewith amphigynous fertilization. (b_d) to same scale.

Zoospores of *Phytophthora* swim for several hours, travelling distances of a few centimetres in water or wet soil, although they can be spread much further by passive movement within water currents. They are attracted chemotactically to plant roots by non-specific root exudates such as amino acids, host-specific substances, or the electrical field generated by plant roots. Zoospores of Phytophthora are kidney-shaped; both flagella arise from the kinetosome boss protruding from within the longitudinal groove at the ventral surface.



Schematic drawings of a zoospore of Phytophthora



Life cycle of Phytophthora infestans

Possible questions of this section

- What are the characteristic features of the kingdom straminipila?
- What are the main characters of oomycota?
- Why the order Pythiales is important?
- What are the differences between Phytophthora and Pythium?
- What does is mean by oogamous fungi?
- What are staminipilous and whiplash flagella?
- What is taxonomy? What are functions of taxonomy?
- What does it mean by saying traditional taxonomic methods?
- What are macro and microscopic features of fungi?
- Why molecular methods is more objective than traditional methods of taxonomy?
- What is hierarchy of taxonomic terms? Give an example
- Give characteristic features of kingdom Protista