

Kirk *et al.* (2001, 2008) have modified and edited Ainsworth's and Bisby's 'Dictionary of Fungi' where they have dealt with the classification of fungi.

2.3.3. Outline of Modern Classification of Fungi: (D.S. Hibbett *et al.*, 2007)

D.S. Hibbett *et al.* (2007) have put forth a comprehensive phylogenetic classification of fungi which is discussed here.

The following are the basic features of this classification:

1. Fungi and animals are considered as sister groups; they are each other's closet relatives and share a common ancestor known as the **opisthokont clade** (posterior flagellum).
2. The phylum Zygomycota is not accepted in the most recent classification because of doubt about the relationships between the groups that have been traditionally placed in this phylum.
3. This is replaced by a term Glomeromycota phylum.
4. This is based on evolutionary consideration of groups. Chytridomycota or water moulds are considered to be primitive.
5. The evolution of higher fungi took place first by loss or withdrawal of chytrid flagellum and the development of branching, aseptate fungal filaments.
6. Septate filaments evolved by divergence from the Glomeromycota as a combined prebasidiomycota/preascomycota clade about 500 million years ago.
7. It considers Basidiomycota and Ascomycota as sister groups that have diverged about 300 million years ago and hence placed under subkingdom Dikarya.
8. An aerobic chytrids have given rise to symbiotic fungi residing in the lumens of grazing mammals helping in their digestion recently perhaps 60-80 million years ago.
9. The members whose phylogenies have not been ascertained have been placed in **incertae sedis** of that class or phylum.
10. The system has covered 98000 species but estimates the existence of a total of 0.5 to 9.9 million species on the earth.
11. It has separated the pseudo fungi or fungi like organisms from the true fungi and classified them under subkingdom Chromista and subkingdom Protozoa.
12. The traditional class 'Phycomycetes' has been totally removed and similarly Myxomycetes of traditional classification is now considered under kingdom Protozoa.
13. True fungi which make up the monophyletic clade is called as Kingdom Fungi and has been classified into 7 phyla.

Kingdom Fungi: Comprises 7 phyla.

Phylum 1: Chytridiomycota

Water-moulds, aquatic saprotrophs/parasites produce motile zoospores, simple posterior flagellum, unicellular/filamentous, holocarpic/eucarpic, zygotic meiosis, considered most ancestral).

Classes—Chytridiomycetes (3 orders) and Monoblepharidomycetes (1 order)

Phylum 2. Neocallimastigomycota

Thallus mono/polycentric, anaerobic, found in digestive systems of large herbivores mammals, zoospores positively uniflagellate/polyflagellate one class—**Neocallimastigo-mycetes** (1 order).

Phylum 3. Blastocladiomycota

Similar to chytrids, sporic meiosis, saprotrophs, parasites on algae/plants, invertebrates, all have zoospores, thallus monocentric/polycentric sometimes mycelial.

One class—**Blastocladiomycetes** (1 order)

Phylum 4. Microsporidia

Unicellular parasites of animals, considered as sister group of rest of the fungi.

It is not further divided due to lack of well sample multigene phylogenies with the group.

Phylum 5. Glomeromycota

It includes the glomalean fungi that form mutualistic symbiosis. Prior to this arbuscular mycorrhizal (AM) fungi were included in the Zygomycota but they do not form zygospore. This phylum has the name derived from the type genus *Glomeris* (instead of *Glomus*). It has one class—**Glomeromycetes** with 4 orders.

The other members whose phylogeny has not been ascertained are kept in subphyla **incertae sedis**.

Incertae sedis (to assign to any phylum but represents the traditional Zygomycota which are saprotrophs/parasite that produce non-motile asexual sporangiospores in sporangia and sexual spores as zygospores). The taxon includes the common moulds such as *Mucor*, *Rhizopus*, and *Phycomyces*. At one time, the Chytridiomycota, Oomycota and Zygomycota were classified together in the class 'Phycomycetes' which is no longer valid. The problem is that Zygomycota is polyphyletic and the name was published without a Latin diagnosis so invalid.

1. **Subphylum Mucoromycotina** (3 orders Mucorales, Endogonales and Mortierellales).
2. **Subphylum Entomophthoromycotina** (1 order Entomophthorales).
3. **Subphylum Zoopagomycotina** (1 order—Zoopagales).
4. **Subphylum Kickxellomycotina** (4 orders—Kickxellales, Demargaritales, Harpellales and Asellariales.)

Subkingdom Dikarya: The members are:

- (i) Unicellular or filamentous
- (ii) Lack flagella
- (iii) Often remains in dikaryotic state,

It include 2 phyla.

Phylum 6. Ascomycota

- (i) It is the largest group of fungi and the life styles adopted to cover the complete range from saprotrophs, to symbionts (Lichens) and to parasites.
- (ii) Sexual spores are known as ascospores formed endogenously within an ascus. Except for yeasts, asci are produced in complex fruiting bodies.
- (iii) It contains 64,000 species under 6355 genera.
- (iv) The basic type genus is *Peziza*.
- (v) It is further divided into 3 subphyla.

Subphylum 1. Taphrinomycotina (divided into 4 classes)

Subphylum 2. Saccharomycotina (has only 1 class with one order)

Subphylum 3. Pezizomycotina (has been divided into 10 classes)

Subphylum 1. Taphrinomycotina — is divided into 4 classes

Classes (a) Taphrinomycetes — one order Taphrinales

(b) Neoelectomycetes — one order Neoelectales

(c) Pneumocystidomycetes — one order Pneumocystidales

(d) Schizosaccharomycetes — one order Schizosaccharomycetales which includes *Schizosaccharomyces*.

Subphylum 2. Saccharomycotina (It has only one class)

Class (a) **Sachharomycetes** — One order Sachharomycetales

It includes genera like *Saccharomyces*, *Candida* etc.

Subphylum 3. Pezizomycotina

It has been divided into 10 classes):

Class 1. **Arthoniomycetes** (1 order — Arthoniales Ex-*Rocella*)

Class 2. **Dothideomycetes**

Subclass = Dothideomycetidae (3 orders)

Subclass = Pleosporomycetidae (1 order) and Dothideomycetes incertae sedis (not placed in any subclass) has 4 orders (Botryo sphaeriales, Hysteriales, Patellariales and Jahnules)

Class 3. **Eurotiomycetes** (It has 3 subclasses)

Subclass = Chaetothyriomycetidae (with 3 orders)

Subclass = Eurotiomycetidea (with 3 orders)

Subclass = Mycocaliciomycetidae (one order)

Class 4. **Laboulbeniomycetes** (It has two orders)

Class 5. **Lecanoromycetes** (It has 3 subclass)

Subclass = Acarosporomycetidae (1 order)

Subclass = Lecanoromycetidae (3 orders)

Subclass = Ostropomycetidae (4 orders)

Lecanoromycetes incertae sedes—include genera not placed in the above subclasses. It was 2 orders.

Class 6. **Letiomycetes** (It has 5 orders)

Class 7. **Lichinomycetes** (It has one order Lichinales)

Class 8. **Orbiliomycetes** (1 order)

Class 9. **Pezizomycetes** (1 order Pezizales)

Class 10. **Sordariomycetes** (It has 3 subclass and 2 incertae sedis)

Subclass = Hypocreomycetidae (4 orders)

Subclass = Sordariomycetidae (7 orders)

Subclass = Xylariomycetidae (1 order)

Soradiomycetes incertae sedis (not placed in any subclass) has 4 orders and

Pezizomycotina incertae sedis (not placed in any class) has 3 orders.

Phylum 7. Basidiomycota

Saprotrophs, parasite on plants and insects, filamentous, hyphae septate, septa having central pore (dolipore), filaments two types—primary (homokaryotic) uninucleate cells, secondary (heterokaryotic) with dikaryotic cells, asexual reproduction by fragmentation, oidia, or conidia, sexual reproduction by somatogamy, basidiospores found. It contains 1600 genera and 32000 species.

It is divided into 3 subphyla :

Subphylum 1. **Pucciniomycotina** (equivalent to traditional Urediniomycetes)

Subphylum 2. **Ustilaginomycotina** (equivalent to traditional Ustilaginomycetes)

Subphylum 3. **Agaricomycotina** (equivalent to Hymenomycetes)

Subphylum 1. Pucciniomycotina

It is divided into 8 classes with 18 orders:

Class 1. Pucciniomycetes (5 orders)

Class 2. Cystobasidiomycetes (3 orders)

Class 3. Agaricostilbomycetes (2 orders)

Class 4. Microbotryomycetes (4 orders)

Class 5. Atractiellomycetes (1 order)

Class 6. Classiculomycetes (1 order)

Class 7. Mixiomycetes (1 order)

Class 8. Cryptomycocolacomycetes (1 orders).

Subphylum 2. Ustilaginomycotina

It is divided into 2 classes with 8 orders :

Class 1. Ustilaginomycetes (2 orders)

Class 2. Exobasidiomycetes (6 orders)

Ustilaginomycotina incertae sedis (which are not placed any class) with 1 order.

Subphylum 3. Agaricomycotina

It is divided into 3 classes with—21 orders

Class 1. Tremellomycetes (3 orders)

Class 2. Dacrymycetes (1 order)

Class 3. Agaricomycetes

Subclass (a) Agaricomycetidae (3 orders)

Subclass (b) Phyllomycetidae (4 orders)

Agaricomycetes incertae sedis (not included in any subclass) has 10 orders.

Basidiomycota incertae sedis — (not placed any sub phylum)

Class 1. Wallemiomycetes (1 order)

Class 2. Entorrhizomycetes (1 order)

The above classification is that of true fungi. However, there are many organisms which are not fungi in true nature but studied by mycologists as fungi and this includes such organisms from two other kingdoms—**Chromista** and **Protozoa**. So the following is the classification of such group of organisms.

Kingdom Chromista (126 genera, 1040 species)

This includes common microorganisms and important plant pathogens like *Phytophthora* causing late blight of potato. They have motile spores, two flagella, and grow as hyphae with cellulose containing walls. The majority are in the Oomycota.

This is divided into 3 phyla:

Phylum 1. Hyphotriomycota (1 order Hyphochytriales)

Phylum 2. Labyrinthulomycota (2 orders)

Phylum 3. Oomycota (1000 species in 110 genera)

Economically important pathogens like *Saprolegnia*, *Pythium* and *Phytophthora* belong to this group. It has 13 orders from Leptomitales to Haptoglossales.

Pythium, *Phytophthora* belong to order Pythiales; *Saprolegnia* and *Achlya* belong to Saprolegniales; *Albugo*, *Peronospora*, *Plasmopora* belong to order Peronosporales.

Kingdom Protozoa

Protozoa is a vast group of unicellular organisms which are thought to have descended from different unicellular ancestors. Slime-moulds belong to this kingdom. They do not form hyphae lack cell wall, phagocytic nutrition but produce fruiting bodies that superficially resemble to those of fungi and for this reason they are called as **moulds** and studied under fungi by many mycologists.

This is divided into 4 phyla:

Phylum 1. Plasmodiophoromycota (15 genera, 50 species)

Class 1. Plasmodiophoromycetes (1 order)

Phylum 2. Myxomycota (82 genera, 888 species)

Class 1. Dictyosteliomycetes (1 order)

Class 2. Myxomycetes (5 orders)

Class 3. Protosteliomycetes (1 order)

Phylum 3. Acrasiomycota (Amoeboid Slime-mould, 6 genera, 14 species)

Class 1. Acrasiomycetes (1 order)

Phylum 4. Choanozoa

Class 1. Mesomycetozoa (2 orders)

2.4. CRITICAL APPRAISAL

Fungi are now thought to be the sister group of animals sharing a common ancestor known as the **Oposthokont** clade. They have a single posterior flagellum which applies to chytrid zoospores and animal sperms. In other eukaryotes that have motile cells propel them with one or more anterior flagella (called heterokonts). It is often viewed that the first terrestrial eukaryotes might have been fungal (Blackwell, 2000).

Evolution of fungi is associated with mutualism or coevolution. Lichens have been found in some of the oldest fossils. Fully formed mycorrhizas can also be found in the most ancient plant fossils and today 95% of all terrestrial plants depend on this fungal infections of their roots to provide the plants with phosphorous and other nutrients. The ability of fungi to recycle the dead remains of other organisms is thought to be the key point of their success throughout the geological time. That is the extinction events of other organisms in the past are just ways of providing additional nutritional resources for fungi.

Moreover, fungi are ancient group of organisms and have a monophyletic origin. The modern classification is broad and has the scope to accommodate the future fungal species to be discovered. The names of taxa are also based on type genus as per ICBN which is not found in the traditional classification. It is also based on the modern technological analysis to form the phylogentic tree of fungi. Overall, it is a broad based phylogenetic classification of fungi having worldwide acceptance.

QUESTIONS**A. LONG ANSWER QUESTIONS**

1. Give an account of the modern classification of fungi.
2. Discuss the classification of fungi as proposed by Ainsworth and Martin.

B. SHORT ANSWER QUESTIONS

1. Classification of fungi by Alexopoulos.