CHAPTER

2

Classification of Fungi

Classification is assigning the species into different categories basing on their relatedness and differences with others. Classification has three functions:

(*i*) It provides a framework of recognizable features by which an organization under examination can be identified.

(*ii*) It is an attempt to group together organisms that are related to each other, and

(*iii*) It assists in the retrieval of information about the identified organisms in the form of a list or catalogue.

Ideally, a classification scheme should be 'natural' in the sense that all organisms in a given taxon (a taxonomic rank) should be related to each other by common ancestry. Traditionally this was not necessarily the case with fungi because taxonomic approaches were mainly based on morphological and microscopic characters such as:

(*i*) Differentiation into plasmodium or mycelium,

(*ii*) Presence of septa or absence,

(*iii*) Structure and production of sexual spores,

(*iv*) Nature of reproductive structures (or fruiting bodies)

(*v*) Presence or absence of complete life cycle etc.

Traditional classification which dominated upto the middle of the twentieth century are even told as arbitrary in the sense that different fungal taxonomists proposed widely differing classification schemes depending on features which they regarded as relevant at which taxonomic levels. However, now these schemes are also termed as unnatural as most of the phylogentically related members have been placed apart. Even, the non-fungal members have been included in the kingdom fungi.

From the latter part of twentieth century new approaches in fungal taxonomy have evolved with imports from recent technologies, ultra structural studies, DNA and RNA sequencings, biochemical analysis and new phylogenetic systems have come up. However,

the traditional schemes are not ignored as they provide detailed descriptions and morphological features of different species and groups. In this section both the traditional and modern classification of fungi have been discussed.

Like other groups of plants, the fungal taxonomic and nomenclature is governed by the International Code of Botanical Nomenclature (ICBN). As per the ICBN, the basic rank of biological classification in the **species**. Species are then grouped into **genera** and genera are grouped into family the name of which ends with the suffix- **ceae**. Then the orders which end with—**ales**, then the subclass which ends with—**mycetidae**. The next higher taxon is class that ends with—**mycetes**, then subdivision whose name ends with—**mycotina**, and then the division that ends with **mycota**. Thus the hierarchical arrangement of different taxons in fungal classification with their suffixes are:

Kingdom

Divition	-	mycota
Subdiviton	-	mycotina
Class	-	mycetes
Subclass	-	mycetidae
Order	-	ales
Family	-	ceae
Genus, Species	}	as suffixes

2.1. TRADITIONAL CLASSIFCITIONS

Earlier philosophers classified matters into the three kingdoms:-Animal, Vegetable and Mineral. Fungi were placed in the vegetable kingdom because of certain similarities to plants such as: lack of mobility, absorptive mode of nutrition and reproduction by spores.

Until the latter half of twentieth century, fungi were classified as a Division fungi under the subkingdom Cryptogamia in Plantkingdom. Fungi were further separrated into four classes–Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. The slimemoulds, all grouped under the subdivision Myxomycotina, were also included under fungi.

A chronological developments in the traditional schemes of classification of fungi is given below.

2.1.1. Gwynne-Vaughan and Barnes (1926)

They divided the fungi division into four classes on the basis of the nature of vegetative thallus and character of the principal spores. The four classes are:

(*a*) **Phycomycetes :** Mycelium aseptate, sexual spore an oospore or zygospore.

(*b*) **Ascomycetes:** Mycelium septate, characteristics spores are endogenous and ascospores.

(*c*) **Besidiomycetes:** Mycelium septate, spores exogeneous and are basidiospores.

(*d*) **Deutero mycetes:** Mycelium septate, sexual spores absent.

They did not consider slimemoulds (myxomycetes) as fungi, so excluded them. They were placed by them as 'Forms resembling fungi'.

2.1.2. Gaumann and Dodge (1928)

They also did not include myxomycetes in the fungi. They recognized four classes of fungi on the basis of the life cycles and the development which their thalli and organs of fructification have attainded during the life cycle. The four classes are:

(*a*) **Archimycetes:** Naked thallus,

(*b*) **Phycomycetes:** Thallus with cell wall. The diploid stage is the zygote only in the life cycle and meiosis occurs in the germination zygote.

(*c*) **Ascomycetes:** Thallus developed with cell wall, plasmogamy results in the formation of dikaryotic phase. Meiosis occurs in special sporangium called ascus.

(*d*) **Basidiomycetes:** Thallus similar to Ascomycetes, meiosis occurs in conidiophores that produce exogenous spores called basidiospores.

There is no Deuteromycetes in their classification:

2.1.3. Bessey (1950)

Bessey did not consider myxomycetes as fungi so placed them under the name **Mycetozoa** outside the limits of vegetable kingdom. He divided the true fungi into lower and higher fungi and then into classes on the basis of extent of thallus development, life cycle potterns, and flagellation of reproductive structures.

(I) Lower Fungi: Class I. Phycomyceteae- Thallus one celled, coenocytic mycelium, sexual reproduction forms oospore or zygospore.

(II) Higher Fungi: Plant one celled, not producing planocytes or producing cellular mycelium, 3 classes.

(*a*) **Ascomyceteae** – Fruiting body is ascus.

(*b*) **Basidiomyceteae** – Fruiting body is basidium.

(*c*) **Fungi Imperfecti** – Sexual reproductive stage not known.

2.1.4. G.W. Martin (1961)

Martin included slimemoulds in the fungi. He divided the division fungi (called *Mycota*) into two subdivision.

Mycota (Division) :

↓

2 subdivision:

1. **Myxomycotina** (that includes all slimemoulds)
2. **Eumycotina** (the true fungi)

Myxomycotina (Slimemoulds) has a single class-*Myxomycetes* which is divided into 2 subclasses:

(*a*) **Ceratiomycetidae** with only one order *Ceratiomyxales*.

(*b*) **Myxogastromycetidae** with 5 orders *Licales, Echinosteliales, Trichiales, Stemonitales, Physarales.*

Subdivision *Eumycotina* is divided into 4 classes:

(*a*) Phycomycetes; (*b*) Ascomycetes; (*c*) Basidiomycetes; (*d*) Deuteromycetes.

(*a*) **Class Phycomycetes** has 3 subclasses:

(*i*) **Trichomycetidae** with 5 orders Harpellales, Amoebidicales, **Eccrianales, Asellariales** and **Genistellales.**

(*ii*) **Oomycetidae:** has a 9 orders – Hypochytriales, Chytridiales, Blastocladiales, Monoblepharidiales, Plasmodiophoerales, Saprolegniales, Leptomitales, Legenidiales and Peronosporales

(*iii*) **Zygomycetidae:** has 2 orders- Mucorales and Entemophthorales.

(*b*) **Class Ascomycetes:** Which is characterized by septate mycelia, perfect stage characterized by spores borne in asci. It has been divided into 2 subclasses:

(*i*) Subclass ***Hemiascomycetidae*** (Asci or ascus are formed singly) has 3 orders- Protomycetales, Endomycetales, Taphrinales.

(*ii*) Subclass ***Euasiomycetidae :*** Asci borne in ascocarps. It has been divided into 22 orders- Myriangiales, Microthyriales, Dothideales, Pleosporales, Hysteriales, Ostropales, Coryneliales, Coronophorales, Laboulbeniales, Melioles, Erysiphales, Eurotiales, Microascales, Onygenales, Hypocreales, chaetomiales, Diaporthales, Xylariales, Phacidiales, Helotiales, Pezizales, and Tuberales.

(*c*) **Class *Basidiomycetes:*** Mycelia septate, Segments 1-2 nucleate, perfect stage characterized by spores in basidia.

It has been divided into two subclass:

(*a*) **Subclass Hetrobasidiomycetidae** (basidia septate or deeply divided). It has three orders—Tremellales, Uredinales and Ustilaginales.

(*b*) **Subclass Homobasidiomycetidae :** (Basidia simple)

It has been divided into 8 orders—Exobasidiales, Polyporales, Agaricales, Lycoperdales, Phallales, Lymenogastrales, Nidulariales, and Sclerodermatales.

(*d*) **Class Deuteromycetes:** (Mycelia septate with uni or multinucleate cells, perfect stage not known)

It has been divided into 4 orders:

(*a*) Sphaeropsidates (with 4 families)

(*b*) Melanconiales (with only one family)

(*c*) **Moniliales** (with 6 families)

(*d*) **Mycelia sterilia** (no spores are found)

2.1.5. C.J. Alexopoulous (1962)

C.J. Alexopoulous first proposed his classification into book 'Introductory Mycology'. He included slimemoulds in the fungal division. He first divided Mycota into 2 sub division:

(*i*) **Sub division Myxomycotina** (wall less forms) and

(*ii*) **Sub division Eumycotina** (true, walled fungi)

While there is only one class Myxomycetes in the subdivision Myxomycotina, there are 8 classes under subdivision *Eumycotina* and one form class. The classes are:-

(*i*) Chytridiomycetes
(*ii*) Hypochytridiomycetes
(*iii*) Oomycetes
(*iv*) Plasmodiopheromycetes
(*v*) Zygomycetes
(*vi*) Trichomycetes
(*vii*) Ascomycetes
(*viii*) Basidiomycetes
(*ix*) the form class Deuteromycetes.

However in 1979 **Alexopoulous with Mims modified** the previous classification. They removed fungi from the kingdom Plantae and gave them a kingdom status called *Myceteae* which was further divided into Division, Subdivision, Classes etc. They included all fungi including slime moulds in the kingdom *Myceteae* of the super kingdom **Eukaryonta**.

The outline of Alexopoulous & Mims classification is :

Kingdom- Myceteae divided into 3 division:

Division (*i*) **Gymnomycota** (thallus lack wall, Phagotropic)

It is further divided into 2 subdivision.

Subdivision (1) Acrasiogymnomycotina with one class only

Subdivision (2) Plasmodiogymnomycotina with 2 classes.

Division (*ii*) **Mastigomycota** (Flagellated cells present, thallus unicellular to filamentous, asexual reproduction by zoospores.

It is divided into 2 subdivisions

Subdivisions (1) Haplomastigomycotina which has 3 classes.

Subdivisions (2) Diplomastigomycotina which has only 1 class Oomycetes.

Division (*iii*) **Amastigomycota** (No motile cells, thallus unicellular to mycelial, zygotic meiosis)

It is divided into 4 subdivisions

(*i*) Zygomycotina with 2 classes.

(*ii*) Ascomycotina with 1 class which has been divided into 5 subclasses.

(*iii*) Basidiomycotina with one class Basidiomycetes divided into 3 subclasses.

(*iv*) Deutromycotina with one class called form class divided into 3 form sub classes.

2.1.6. G.C. Ainsworth (1971)

Ainsworth (1971) put forth the classification of fungi in his book 'Dictionary of Fungi'. This classification is based on the features like

(*i*) Presence or absence of cell wall

(*ii*) Presence or absence of motile cells

(*iii*) Nature and types of sexual spores.

(*iv*) Number of flagella and their position on the zoospores.

(*v*) Nature of the sporophores.

(*vi*) Presence and absence of fruiting bodies and their nature of present.

The outline of Ainsworth's classification (1971) is given here:

Kingdom fungi is divided into 2 divisions

Division 1. Myxomycota (with a single class Myxomycetes)

Division 2. Eumycota which is divided in to 5 subdivision.

Subdivision 1. Mastigomycotina (It has 4 classes)

Classes (*a*) Chytridiomycetes
(*b*) Hypochitridiomycetes
(*c*) Oomycetes
(*d*) Plasmodomphoromycetes.

Subdivision 2. Zygomycotina (It is divided into 2 classes)

Classes (*a*) Zygomycetes (3 orders)
(*b*) Trichomycetes (4 orders)

Subdivision 3. Ascomycotina (It is divided into 6 classes on the basis of ascocarps, nature of ascus etc.)

Classes (*a*) Hemiascomycetes (3 orders)
(*b*) Loculoascomycetes (5 orders)
(*c*) Plectomycetes (3 orders)
(*d*) Laboulbeniomycetes (1 order)
(*e*) Pyrenomycetes (5 orders)
(*f*) Discomycetes (3 orders)

Subdivision 4. Basidiomycotina (it is divided into 3 classes)

Classes (*a*) Teleiomycetes (2 orders)
(*b*) Hymenomycetes (It is divided into 2 subclass)
Subclass (i) Phragmobasidiomycetidae (3 orders)
(*ii*) Holobasidiomycetidae (3 orders)
(*c*) Gastromycetes (9 orders)

Subdivision 5. Denteromycotina: It is divided into 3 classes.

Classes (*a*) Blastomycetes.
(*b*) Hyphomycetes
(*c*) Coelomycetes

2.2. MODERN CLASSIFICATION

In the traditional classification schemes adequate attention was not given for the phylogenetic relationship between different groups which might be due to a distance between or due to the lack of coordination between the fungal phylogeneticists and the fungal taxonomists. In most of the traditional schemes of classification, taxa now thoughts to be non-fungal, have been included in the fungal kingdom and some protozoans are also grouped under fungi. The loosely used term 'lower fungi' is now no longer in use. Moreover, the morphological features of organisms, especially fruiting bodies, which looked alike are now found to be anatomatically different and reproduction in different ways lead them to be placed apart.

Considering the confusions in the groups, deviation from the ICBN rules, and the new features gained form the moleular phylogeny, several workers have attempted in a coordinated manner since the last decade of twentieth century to decide phylogenetic classification of fungi with a broad scope on the following principles : (Hibbett and Donoghue, 1998)

(*i*) Classification should not be misleading about the phylogeny of the organism they represent,

(*ii*) Methods of classification should efficiently promote the translation of phylogenetic hypotheses into classification. That is to say, once a monophyletic group has been discovered by a systematist, it should be possible to name it quickly and simply;

(*iii*) Classification should be stable.

Nevertheless, classification must be able to change to reflect advances in understanding. Therefore, methods of classification should accommodate changes in phylogenetic hypotheses with minimal perturbation of system of names.

Some classification schemes based on this are discussed here.

2.2.1. D.J. McLaughlin and E.G. Mc Laughlin (2000)

A book 'The Mycota' edited by McLaughlin *et al.* (2000) is a combination of phylogenetic and classical systematics. In this edited volume several authors have incorporated the knowledge of species and development of taxonomic characters. According to them phylogenetic systematics first determines organism relationships, then constructs a systematic classification that reflects the phylogeny. Molecular characters have made possible establishment of a monophyletic and a more permanent classification of the fungi.

The taxonomic outlines used in 'The Mycota' volume VII reflects current mycological systematics. According to them the term 'Fungi' has assumed an ecological meaning for all organisms with a similar nutritional mode and therefore they preferred to use the term 'Eumycota' for members of the phylum that ecompasses a monophyetic group of these organisms. A new term **'Pseudo fungi'** is used which implies the organism that lie outside the Eumycota but possess the fungal life style in an ecological sense but not in structural features.

The outline of classification is:

Mycota is divided into two groups: