Introduction

This group of fungi comprises over 20,000 species and is very important in breaking down organic matter, as plant and animal pathogens and for industrial importance. They are all higher true fungi, which lack a known perfect stage. Their mycelium is like that in the Ascomycota and vegetative reproduction structures are common to both groups. Over 90 percent of the important fungi that have been shown to possess a perfect, or sexual, stage have been Ascomycota. Most of the Deuteromycota produce conidia of one kind or another. There is substantial evidence that at least the majority of these fungi are of Ascomycetous affinities. Indeed, it is probable that a great many of them are Ascomycota whose perfect stages have simply escaped discovery. Mycologists continue to report finding ascigerous stages of several fungi previously included in this group. Thereafter these drop out of the Fungi Imperfecti and are renamed and reclassified on the basis of the newly acquired information. How many other members of the Fungi Imperfecti will in a similar way ultimately be eliminated from the group can only be conjectured. However, it seems likely that among the large number of species at present catalogued as Deuteromycota, there are some that never do produce a perfect stage, perhaps having lost the ability in the course of evolution, reproduction by conidia or other vegetative means having proved adequate for survival. Four orders that will be discussed here are Sphaeropsidales, Melanconiales, Moniliales and Mycelia Sterilia.

In 1952 Alexopoulos gave a detailed narrative of the Deuteromycota, and the following description is derived therefrom [Alexopoulos, C. J. 1952. *Introductory Mycology*. John Wiley & Sons, NY. 482 p.].

A great many fungi are known which have septate mycelium and which, so far as anyone has been able to discover, reproduce only by means of conidia. Since these fungi apparently lack a sexual phase (perfect stage), we call them commonly "imperfect fungi," and technically "Fungi Imperfecti." Many of these are saprobic, but many are of great importance to us because they are parasites that cause diseases of plants, animals, and human beings.

The conidial stages of most of these fungi are very similar to conidial stages of some well-known Ascomycota, and we presume that, with relatively few exceptions, the imperfect fungi represent conidial stages of Ascomycota whose ascigerous stages are either rarely formed in nature and have .not been found, or have been dropped from the life cycle in the evolution of these organisms. Indeed, in some cases we have found the sexual stages in nature or have produced them in culture many years after the fungi were first described as imperfect fungi. In such cases, the organisms can be classified in the ascomycete genera in which the characters of the ascigerous stage place them.

In a few cases, the perfect stages, which have been discovered, have proved to be

Basidiomycota. The Fungi Imperfecti are, therefore, conidial stages of Ascomycota, or, more rarely, Basidiomycota, whose sexual stages have not been discovered or no longer exist.

Because there are thousands of such fungi which do not fit our classification system, because it is based on the characters of the sexual stage, a practical need has arisen for a convenient system, artificial though it be, the chief purpose of which is to 'provide a method of identifying and naming these organisms. Accordingly, we group all these fungi into the form-class Deuteromycota, which we subdivide into a number of form-orders, form-families, form-genera, and form- species. In each of these categories we group fungi which have in common some morphological characteristics of their conidial stages, and which we can, therefore, conveniently identify and catalog. By such groupings, however, in no way do we imply that the organisms we place in anyone group are related, for we cannot surmise relation- ships in fungi unless we know the sexual stages. Two fungi whose conidial stages are almost exactly alike, and which, therefore, we would classify in the same form-genus, might have sexual stages, which are sufficiently different to place them in different ascomycetous genera. For example, Septoria rubi and Septoria avenae, two "imperfect fungi" which we had classified in the form-genus Septoria on the basis of their conidial stages, were found to have perfect stages, one of which belongs to the ascomycetous genus Mycosphaerella (MycosPhaerella rubi), and the other to the ascomycetous genus Leptosphaeria (Lepto-sphaeria avenaria). Similarly, two Ascomycota belonging to the same ascomycetous genus may have vastly different conidial stages. For example, *Mycos Phaerella fragariae* on strawberry forms its conidia at the tips of long, loosely produced, unorganized conidiophores, whereas the aforementioned Mycosphaerella rubi on raspberry, bears its conidia on very short conidiophores inside a pycnidium. In accordance with our artificial system of classification of the Deuteromycota, we would place the conidia of Mycosphaerella fragariae in the form-genus Ramularia that belongs in the form-order Moniliales, but those of Mycsphaerella rubi in the form-genus Septoria that belongs to the form- order Sphaeropsidales. Because of these facts, it is clearly impossible to devise a system of Classification of the Deuteromycota, which will indicate relationships. Once you understand this situation you will have no difficulty in grasping and accepting the seemingly complicated and confused state of affairs arising from the existence of this large group of fungi.

The convenience of such a system of classification for the imperfect fungi has been carried further to include the conidial stages of known Ascomycota. Since many Ascomycota, particularly the parasitic ones form their ascocarps but once a year, we are much more likely to en- counter these fungi in their conidial stages. By including these stages in the general scheme of classification of the Deuteromycota, we can identify a fungus by its conidial stage without having to wait for it to develop its ascus stage. This, of course, results in two names for each Ascomycete whose conidial stage was discovered before its perfect stage: one name-the valid one-which we give to the ascigerous stage to indicate its relationships, and one name-a synonym-which indicates the type of conidia the fungus produces. For example *Venturia inaequalis,* the cause of apple scab, produces one- or two-celled, brown conidia on short conidiophores. As these are the characters of the form-genus *Fusicladium,* we often refer to the imperfect stage of *Venturia inaequalis* as *Fusicladium dendriticum,* which name was given to the

fungus before the perfect stage was discovered. Since, according to the International Rules of Botanical Nomenclature, a member of the Plant Kingdom may have but one valid name, *Venturia inaequalis* is the valid name of the fungus. But, since the name *Fusicladium* indicates to the mycologist the precise type of conidial stage produced, mycologists find it more convenient to say that *Venturia inaequalis* has a *Fusicladium* imperfect stage than to describe the conidia and conidiophores in many words. For this reason we often write the name of the imperfect stage of an ascomycete in parenthesis after the valid name thus: *Venturia in- aequalis* (= *Fusicladium dendriticum);* or still more properly: *Venturia inaequalis* (Cke.) Wint. [= *Fusicladium dendriticum* (Wal.) Fcl.]. The naming of the conidial stages is so convenient and has been adopted so widely that the International Botanical Congress decided at its Stockholm meeting in 1950 to legalize the use of form-names for conidial stages, still recognizing, of course, the name of the perfect stage as the official name for the entire organism. Thus, when we speak or write about the apple scab fungus *as a whole,* or of its ascus stage in particular, we use the name *Venturia inaequalis,* but when we are dealing with the conidial stage of this fungus it is convenient- and now legal and proper- to refer to it as *Fusicladium dendriticum.*

General Morphology: Before discussing the classification of the Deuteromycota, it is well to review the various methods of conidial production and to say something about the morphology of the structures concerned.

The Conidiophor*:* Conidia are generally borne on conidiophores, which may be produced loosely and indiscriminately by the somatic hyphae or grouped in various types of asexual fruiting bodies. Fungi that produce conidia on more or less loose, cottony hyphae we often term Hyphomycetes. Such cnidiiferous hyphae may be simple or variously branched. They may be little different from the somatic hyphae and indistinguishable from them, or they may be characteristically marked and provided with sterigmata or specialized branches on which they bear the conidia. Some conidiophores are inflated at the tips, as we have seen in *Aspergillus;* others are inflated at intervals, forming knee-like structures in which the conidia are grouped *(Gonatobotrys);* still others have many branches that are characteristically arranged in whorls *(Verticillium),* in a sympodium *(Monopodium),* or in various other ways (Plate 102). In fact, we can find almost every conceivable variation in the branching or marking of reproductive hyphae among the more than 10,000 species that produce their conidia in this fashion.

A group of conidiophores often unite at the base and part way up toward the tip, and form a structure we call a synnema (Plate 103d). The top of the synnema is often much branched, the conidia arising at the tips of the numerous branches. In some synnemata the stalk of the fructification is longer in comparison to the branched top, and the fruiting body resembles a long-handled feather- duster. When a large number of conidiophores arise from the surface of a cushion-shaped stroma, the resulting structure is a sporodochium.

Besides true conidia, some fungi, especially animal and human pathogens, produce other types of asexual spores such as microconidia, blastospores, and arthrospores. Microconidia are very small conidia. Blastospores (Gr. *blastos* = bud,

shoot + *sporos* = seed, spore) are asexual spores formed by budding either directly from a hypha, or from any other cell. Arthrospores (Gr. *arthron* = joint + *sporos* = seed, spore) are formed by the breaking up of the hyphae into their component cells. They are no different from oidia. All three of these germinate to form mycelium and function the same as conidia.

The Pycnidium: In a certain group of imperfect fungi, the conidia arise in globose or flask-shaped bodies known as pycnidia. The conidiophores in the pycnidia are generally very short *(Phyllosticta)* in some cases almost absent *(Plenodomus).* In the pycnidia of other fungi, on the contrary, the conidiophores are quite long and distinctly branched *(Dendrophoma)* (Plate 102b*).* In all cases, they arise from the internal cells of the pycnidial wall. In external appearance, some pycnidia resemble perithecia of some of the Pyrenomycetes, and the only way you can be certain of their nature is to crush them and examine their contents under the microscope. The perithecia, of course, contain asci, whereas the pycnidia contain conidia.

The pycnidial wall is pseudoparenchymatous. Approximately the same variations in configuration can be found in pycnidia as have been described for perithecia. Pycnidia may be completely closed or may have an opening (ostiole); they may be provided with a small papilla or with a long neck leading to the opening; they vary greatly in size, shape, color, and consistency of wall; they may be superficial or sunk in the substratum; they may be uniloculate, simple or labyrinthiform; they may be formed directly by the loose mycelium or may be definitely stromatic. This great variation in pycnidial structure serves to delimit the various genera of the pycnidial Deuteromycota (Plate 150).

Kempton (1919) found that this group of fungi utilizes three methods of pycnidial production. According to the first of these, which Kempton calls simple meristogenous, the pycnidium originates from the division of a single cell or a number of adjacent cells in the same hypha (Plate 151a). In the compound meristogenous type the pycnidial origin is traced to the division and merging of several cells from several closely appressed hyphae (Plate 151b*).* Finally, in the symphogenous type of development, a number of hyphal branches from different hyphae grow toward a common point and interweave to form the pycnidial initial (Plate 151c). From this the pycnidial wall develops, a cavity is formed in the center, and the conidiophores grow out of the inner wall cells lining the cavity. The conidia, also called pycnidiospores when they are borne in pycnidia, are produced at the tips of the conidiophores.

The Acervulus: The acervulus is typically a flat, open bed of generally short conidiophores growing side-by-side and arising from a more or less stromatic mass of hyphae. Conidia are borne at the tips of the conidiophores. Some authors do not consider any such structure an acervulus unless it is formed underneath the cuticle or epidermis of a host plant and eventually becomes erumpent. Such a concept, which would define a fungal structure not in terms of its own morphology but rather in terms of its relation to the host, should probably be avoided.

In addition to the conidiophores and interspersed with them, some acervuli produce long, stiff, pointed, dark structures that look like bristles; these are the setae (sing. seta; L. *seta* = bristle). Setae may be abundantly formed by certain form-species

or may be very sparse. As a matter of fact, it appears that the type of substratum and environmental factors influence this characteristic considerably.

The same methods employed for the formation of pycnidia also serve for the formation of. acervuli, the origin of which may be simple meristogenous, compound meristogenous, or symphogenous. This undoubtedly explains the fact that intermediate forms, between pycnidia and acervuli are produced by some fungi which ~re, therefore, difficult to classify.

Characteristics Used In Classification: The characteristics we use for the classification of the Deuteromycota are the type of fructification and the shape, color, 'and septation of the conidia. Types of fructification form the basis for separation of form-orders. We place those fungi which produce their conidia in pycnidia in the form-order Sphaeropsidales; all those which form acervuli, in the Melanconiales; and. those which reproduce in any other way (budding, fragmentation of hyphae into oidia, loose conidiophores, sporodochia, or synnemata), in the Moniliales. A group of fungi also exists in which no conidia or other reproductive cells are known. These we place in the form-order Mycelia Sterilia. Many of the Mycelia Sterilia, when their perfect stages were discovered, proved to be Basidiomycota.

The Sphaeropsidales and Moniliales are subdivided into a number of form-families, the first on the basis of pycnidial characters such as shape, color, and consistency of wall, the second on the basis of conidiophore grouping and color. The Melanconiales comprise only one form-family, the Melanconiaceae, and the Mycelia Sterilia are an assemblage of form-genera so heterogeneous that we make no attempt whatever to organize them into form-families.

Form-genera of the Deuteromycota are based on such characters as type of conidiophores, and color, shape, and septation of conidia. Form-species are based almost entirely upon the host on which they are found and the size of their conidia.

Conidial Sections: Because of the great number of form-genera in the Deuteromycota (Bender listed 1335 in 1931), Saccardo (1899) proposed a breakdown of the classification into groupings (sections) of form-genera in accordance with conidial characters. This is a very convenient system and one that mycologists the world over have adopted.

The "section" is not an official category in the classification system, but rather a convenient group of form-genera under each form-family, which exhibit the same conidial characters as far as shape, color, and septation are concerned.

Sphaeropsidales In this order the spores are borne in a flask-shaped pycnidium on the inside of which are conidiophores bearing conidia (pycnospores).

Four form-families have been distinguished as follows: (1) **Sphaeropsidaceae** (pycnidia dark colored, leathery to carbonous, stromatic or non-stromatic generally provided with a circular opening). (2) **Zythiaceae** (pycnidia as in the Sphaeropsidaceae but light colored instead of dark, and soft or waxy instead of leathery). (3) **Leptostromataceae** (pycnidia shield-shaped or elongated, flattened). (4) **Excipulaceae** (mature pycnidia somewhat deeply cup-shaped).

In the family Sphaeropsidaceae species of the genus *Darluca* are hyperparasitic on rusts. Species of *Cicinnobolus* are hyperparasites of powdery mildew. Their mycelium is grown longitudinally in the mycelium of their hosts.

Please refer to the following plates for characteristic structures in the Sphaeropsidales:

Deuteromycota (Fungi Imperfecti): Sphaeropsidales

Plate 150 = Pycnidia types: ***Zythis fragariae, Dendrophoma abscurans, Chaetomella atra, Diplodia zeae,***

Fusicoccum viticolum & Endothia parasitica.

Plate 151 = Pycnidial development: ***Phoma herbarum, P. pirina & Zythia fragariae.***

Plate 153 = Sphaeropsidales: Pycnidiospore types.

Plate 240 = Example Structures: Deuteromycota: Sphaeropsidales: Sphaerioidaceae

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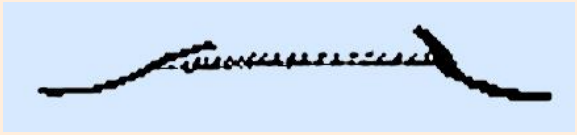
Melanconiales Spores are borne on an acervulus in this order (as in the genus *Higginsia* of the Ascomycota)



Only one form-family has been designated: **Melanconiaceae**. Many species are parasitic on plants and cause a group of diseases called **anthracnoses**. The acervuli that are the characteristic structures of this family usually develop below the cuticle or below the epidermis of the host plant. They release their conidia in characteristic droplets, which may be white, cream-colored, pink, orange or black depending on the pigmentation of the conidia.

In the family **Melanconiaceae** the genus *Gloeosporium* has setae, the genus *Colletotrichum* does not have setae and *Cylindrosporium* is lit the genus *Higginsia* of the Ascomycota: Helotiales.

Please refer to the following plates for characteristic structures in the Melanconiales:

Deuteromycota (Fungi Imperfecti): Melanconiales

Plate 152 = Acervuli: *Gloeosporium sp.* & *Colletotrichum lindemuthianum*.

Plate 154 = Melanconiales: Conidia types.

Plate 241 = Example Structures: Deuteromycota: Melanconiales & Mycelia Sterilia

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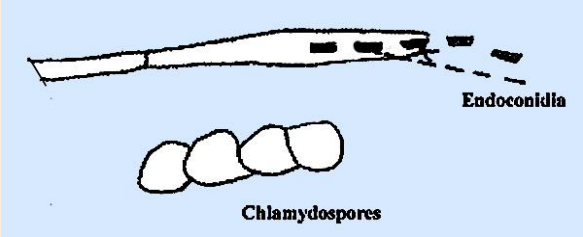
Moniliales This order includes all the other spore-producing forms and contains the greatest number of species. Many species are of great importance and the group contains most of the **fungal pathogens of humans**. It is also the group that has many of the fungi that or of industrial importance. Species of *Penicillium* and *Aspergillus* that are not known to form cleistothecia are included. The so-named "false yeasts" that are not known to produce ascospores are grouped here. There are a number of serious plant pathogens as well and some common contaminants of the biological laboratory and many soil fungi what are saprobic and may play a significant role in the soil economy. Eight family are included here.

The family Stilbaceae has a coremium or synnema. The majority of species are saprobic. The form-genus *Graphium* is economically important because several species are responsible for **blue stain of lumber** that reduces market value. The imperfect stage of *Ophiostoma ulmi* (= *Graphium ulmi*) belongs here also.

The family Tuberculariaceae has a sporodochium, which is a cushion-like mass of hyphae. The genera *Tubercularia*, *Volutella* and *Fusarium* are well known. In *Tubercularia* the sporodochium is usually shaped like a mushroom, with a very short stalk and a smooth surface. In Volutella the sporodochium produces setae that arise here and there over the entire fructification. *Volutella fructi* causes **Dry Rot of Apples**. The form-genus *Fusarium* is the largest in this family and taxonomically one of the most difficult of all fungal groups. *Fusarium* produces long, crescent-shaped, multiseptate macroconidia usually borne on sporodochia, and very small spherical, oval elongated or crescent shaped microconidia on simple or branched single hyphae. Chlamydospores are also regularly produced by the mycelium, and sclerotia are often formed. Parasitic species are generally vascular parasites that cause wilts of plants by plugging the conducting tissues and by toxin secretions. Among the most destructive species are *Fusarium solani* on potato, *Fusarium cubense* on banana and *Fusarium lini* on flax (Plate 159).

The families Moniliaceae and Dermatiaceae have spores scattered over the mycelium. The Moniliaceae have hyaline spores whereas the Dermatiaceae have dark pigmented spores. The genus *Thielaviopsis* has endoconidia, but they may also produce macroconidia or chlamydospores in chains.



The Moniliaceae is the larges of all the form-families. It includes all imperfect fungi that produce conidia on unorganized, hyaline conidiophores or directly on the somatic hyphae. Most species are saprobic, but many are important plant parasites and others are human pathogens. The imperfect stages of *Aspergillus* and *Penicillium* belong here (Plate 102,f).

The family Dermophyta is related to Gymnoascaceae of the Ascomycota.

In the family Cryptococcaceae there are asporagenous yeasts, which are related to *Saccharomyces* of the Ascomycota. The Genus *Candida* incites a human disease called "Thrush." The Genus *Cryptococcus* includes animal pathogens and *Torulopsis* is a food yeast that is used for animal food.

The family Rhodotorulaceae is asporagenous yeasts that are possibly related to the Basidiomycota: Dacryomycetales.

The family Sporobolomycetaceae is also asporagenous yeasts that are possibly related to the Basidiomycota: Dacryomycetales. *Sporobolomyces* species have pink or orange-pigmented forms. They may reproduce by simple budding or they may produce sterigmata with spores that are shot off forcibly (= ballistospores).

Please refer to the following plates for characteristic structures in the Moniliales:

Deuteromycota (Fungi Imperfecti): Moniliales

Mycelia Sterilia includes a group of fungi in which no conidia or other reproductive cells are known. Sclerotia are formed, but there are no fruiting bodies (= spores). Many of the Mycelia Sterilia proved to be Basidiomycota when their perfect stages were discovered. Of the over two form-genera in this group, *Rhizoctonia* and *Sclerotium* are the best known and most widely

distributed. *Rhizoctonia* is usually found in soils causing **damping-off and root rot** of their host plants. *Pellicularia filamentosa*, a basidiomycete, has *Rhizoctonia solani* as its imperfect stage. It causes **Black Scurf of potatoes** and attacks other plants as well. *Sclerotium cepivorum* known in the form of small black slcerotia produced on white, cottony hyphae, causes white rot of onions and garlic. *Sclerotium rolfsii* is omnivorous and can be very destructive on plants.

Please refer to the following plates for characteristic structures in the Mycelia Sterilia:

Deuteromycota (Fungi Imperfecti): Mycelia Sterilia

Plate 241 = Example Structures: Deuteromycota: Melanconiales & Mycelia Sterilia

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Recognition of Tribes And Sub-Tribes

The final subdivision of most of the families into the equivalent of tribes and sub-tribes is done on the basis of spore form, structure and color, and utilizing the "Saccardo Spore Sections" (= Italian mycologist: 1880-1925) with the following possibilities:

Amerosporae = spores 1-celled but not long, notstellate, spiral, or filiform

- **Hyalosporae = spores hyaline**
- **Phaeosporae = spores dark**

Didymosporae = spores 2-celled, not stellate, spiral, or filiform

- **Hylodidymae = spores hyaline**
- **Phaeodidymae = spores dark**

Phragmosporae = spores more than 2-celled (variable), not stellate, spiral, or filiform

- **Hyalophragmiae = spores hyaline**
- **Phaeophragmiae = spores dark**

Scoloecosporae = spores long and slender (scolecospores) septate or non-septate

Dictyosporae = spores muriform

- **Hyalodictyae = spores hyaline**
- **Phaeodictyae = spores dark**

Helicosporae = spores spirally coiled, continuous or septate

Staurosporae = spores stellate (star-shaped) or radiate, continuous or septate

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