Fungi

Fungi are organisms having no chlorophyll, reproducing by sexual and asexual spores, not by fission like bacteria, and typically possessing a mycelium or mass of interwoven threads (hyphae) containing well-marked nuclei. According to Hawksworth (1991), there are about 4,300 valid genera, and many more that are synonyms, and about 70,000 species living as parasites or saprophytes on other organisms or their residues. More than 8,000 species cause plants disease. Fungi are divided into three kingdoms and eleven phyla.

Kingdom: Fungi
Phylum: Chytridiomycota
Phylum: Zygomycota
Phylum: Ascomycota
Phylum: Basidiomycota
Kingdom: Stramenopila
Phylum: Oomycota
Phylum: Hyphochytriomycota
Phylum: Labyrinthulomycota (slime molds)
Kingdom: Protists
Phylum: Plasmodiophoromycota (endoparasitic slime molds)
Phylum: Dictyosteliomycota (Dictyostelid slime molds)
Phylum: Acrasiomycota (Acrasid slime molds)
Phylum: Myxomycota (true slime molds)

Oomycetes, Zygomycetes and Chytridiomycetes were formerly listed as subclasses within the class Phycomycetes. Oomycota, Zygomycota and Chytridiomycota are now generally accepted as separate phyla of fungi. The mycelium of these three phyla has many nuclei which are not marked off by cross-wells (or nonseptate mycelium) except where reproductive structures arise, a condition known as coenocytic. Asexual reproduction is by means of spores borne in sacs called sporangia. The Zygomycota have sexual spores called zygospores which are formed by the union of two similar sex cells or gametes; the Oomycota have sexual spores called oospores formed from dissimilar gametes; the Chytriodiomycota have neither type of sexual spore; the Ascomycota have septate mycelium and sexual spores in asci; the Basidiomycota have septate mycelium, frequently with clamp connections, and sexual spores; the Myxomycota have thalli as a motile mass of protoplasm (a plasmodium or myxamoeba – no mycelium) which is transformed into a mass of small, aseptate resting spores that on germination form motile cells with or without flagella. The Myxomycota include protists with amoeboid thalli and their status as fungi often has been questioned. The thalli of the Myxomycota are naked, amoeboid, plasmotic masses without cell walls and are termed plasmodia or pseudoplasmodia. They are also able to move by the formation of pseudopodia and by plasma-streaming. The Plasmodiophoromycetes is the only class of the Myxomycota which includes parasites of vascular plants. The best known species is *Plasmodiophora brassicae*, which causes "club root" of cabbage.

R.K. Horst, *Westcott's Plant Disease Handbook*, DOI 10.1007/978-94-007-2141-8_10,

Chytridiomycota

The thalli are usually vesicular, occasionally filamentous, and are transformed to sporangia, gametangia or resting spores. The Chytridiomycetes are the only members of the kingdom Fungi that produce motile cells. Motile cells may function as zoospores, or as gametes, are radially symmetrical, with a single, posteriorly directed whip-lash type flagellum. The Chytridiomycetes are the only class in this phylum.

Chytridiales

This order is defined on the basis of zoospore ultrastructure. Most members are water-or soil-inhabiting fungi; many of the former are parasitic on algae and water molds, many of the latter on vascular plants. A few parasitize animal eggs and protozoa while others are saprobic on the decaying remains of dead plants. Simple fungi which have almost no mycelium, the thallus at maturity acting as a single sporangium, or dividing to become a sorus of sporangia; zoospores posteriorly uniflagellate.

Spizellomycetales

Members of this order are diverse and include plant and fungal parasites and free-living saprobes inhabiting both soil and water. There is great morphological variation in the group, and examples of both endogenous and exogenous development. Most species are monocentric.

Blastocladiales

Saprophytes in water or soil; genera are characterized by thick-walled, resistant sporangia, usually with pitted walls. Another feature is the prominent membrane-bound nuclear cap present in zoospores and planogametes.

Monoblepharidales

Saprophytes in water, most of which grow on submerged twigs and fruit; thallus of much-branched delicate hyphae.

Plasmodiophorales

The placement of this order has always been uncertain. Some put it with the Myxomycetes, the slime molds, others between the Myxomycetes and the true fungi. Some have considered it a family in the Chytridiales. This single class is placed in the kingdom, Protists, phylum, Plasmodiophoromycota which contains a single class, Plasmodiophoromycetes. There is also only one family, Plasmodiophoraceae, in this order. Parasitic, assimilative phase a multinucleate thallus within host cells, chiefly of vascular plants, often causing hypertrophy; germinating in place by amoeboid, occasionally uniciliate, zoospores.

Plasmodiophoraceae The only family in this order but with two important genera: *Plasmodiophora*, causing club root, and *Spongospora*, causing potato scab.

Oomycota

The thalli may be vesicular, often irregular, but are usually filamentous. Sporangia on germination release biflagellate zoospores. One flagellum is the whip-lash type and the other the tinsel type. Motile sex cells are absent. Sessile gametangial cells conjugate and form an oogonium containing one or several egg cells (see Fig. 1).

The Oomycota are related to autotrophic algae with similar characters. The Oomycetes are the only class in this phylum; however, the small classes Hyphochytriomycetes and Labrinthulomycetes may also be included.

Hyphochytriales

Zoospores anteriorly uniflagellate, usually formed outside the sporangium. The order

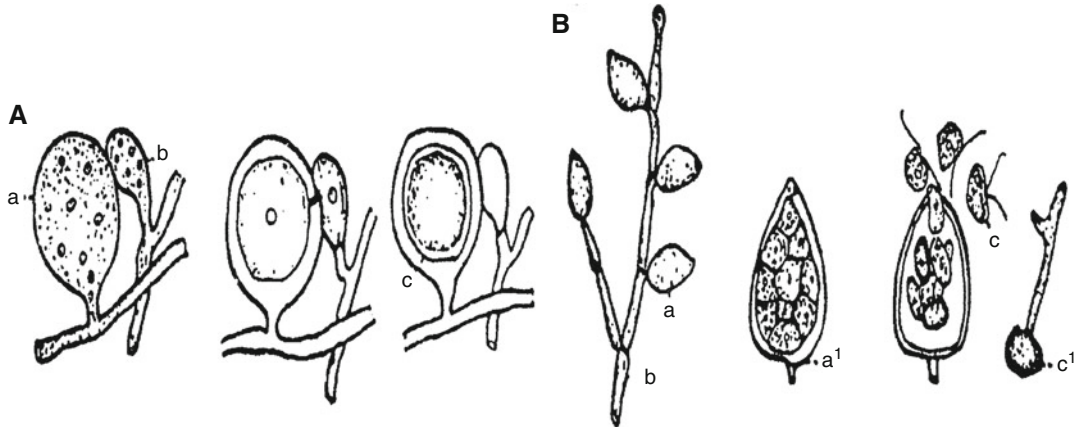

Fig. 1 Reproduction of an Oomycete (*Phytophthora*, order Peronosporales). **A** multinucleate oogonium (*a*) and male antheridium (*b*) in contact; fertilization tube formed between gametes after all nuclei except one has disintegrated; thick-walled oospore (*c*) formed inside oogonium. **B** asexual reproduction by sporangium (*a*) formed on sporangiophore (*b*); a^1 sporangium germinating by formation of ciliate zoospores; c^1 zoospores germinating with germ tube

Hyphochytriales has now been placed in the phylum Hyphochytriomycota which contains a single order, Hyphochytriales.

Saprolegniales

Marine forms, parasites of diatoms and algae, or in fresh water and soil, the water molds, with abundant mycelium; hyphae without constrictions; oogonium with several oospores.

Leptomitales

Water forms; hyphae constricted, with cellulin plugs; oogonium with a single oospore.

Lagenidiales

Primarily aquatic, mostly parasitic on algae and water molds; thallus simple; zoospores formed by cleavage within sporangium or partly or wholly in an evanescent external vesicle.

Peronosporales

Downy mildews and white rusts. Primarily terrestrial, living in soil or parasitic on vascular plants; in the latter case, zoosporangia function as conidia.

Albuginaceae The white rusts. Conidia (sporangia) in chains on club-shaped conidiophores borne in dense sori beneath epidermis of host, the sori forming white blisters; intercellular mycelium with globose haustoria.

Pythiaceae Conidiophores differing little from assimilative hyphae; mycelium saprophytic or parasitic, but if latter within cells and without haustoria. Two genera, *Phytophthora*, which includes the potato blight and other pathogens, and *Pythium*, causing damping-off, are especially important.

Peronosporaceae Downy mildews. Conidia are borne singly or in clusters at tips of usually branched, rarely clavate, conidiophores emerging through stomata; haustoria various.

Zygomycota

The thalli are vesicular, or more often represent a coenocytic, multinucleate mycelium (with aseptate hyphae). The gametangial cells conjugate and form a thick-walled, persistent resting spore, called a zygospore (see Fig. 2). Motile sex cells are absent, but sporangiospores and conidia are

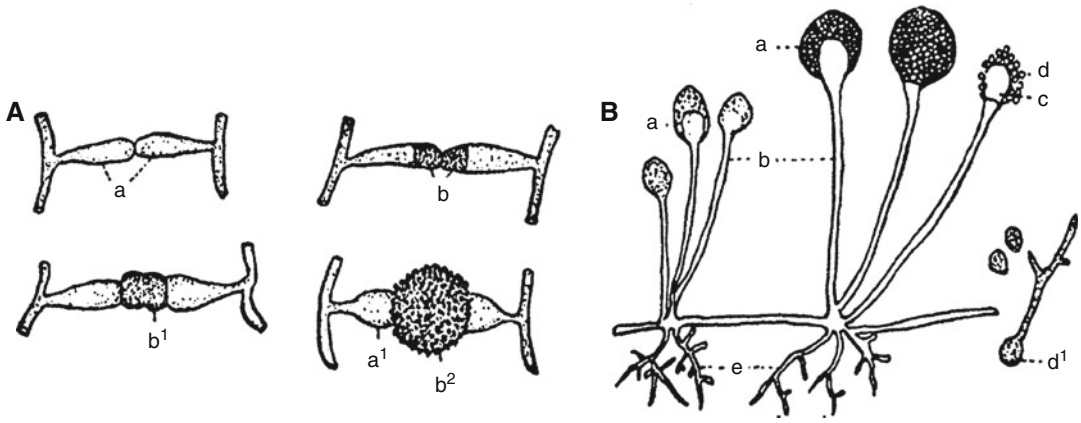

Fig. 2 Reproduction of a Zygomycete (*Rhyzopus*, order Mucorales). **A** suspensors (*a*) from different hyphae cut off gametes (*b*) ofequalsize which fuse (b^1) to form a spinyzygospore (b^2). **B** asexualsporangiospores (*d*) formed inside a sporangium (*a*) formed on a sporangiophore (*b*) around a columella (*c*). Hyphae are attached to substratum by rhizoids (*e*). Sporangiospore germinates by a germ tube (d^1)

usually formed and dispersed by air. There are two classes, the Zygomycetes, and the Trichomycetes (mainly parasitic on insects). These classes differ by morphological and chemical characteristics.

Zygomycetes

Mucorales

Profuse mycelium, much branched; asexual reproduction by sporangia or conidia; sexual reproduction by zygospores from union of two branches of the same mycelium or from different mycelia. Some species damage fruits and vegetables in storage. Only two families are of much interest to plant pathologists.

Mucoraceae Sporangiophores liberated by breaking up of thin sporangial wall; zygospores rough. *Mucor* and *Rhizopus* cause storage molds.

Choanephoraceae Both sporangia and conidia present, the latter borne on swollen tips; zygospores naked. *Choanephora* is a weak parasite causing blossom blight or blossom-end rot of young fruits.

Entomophthorales

Profuse mycelium, species frequently parasitic on insects or other animals, rarely on plants; anamorph spores modified sporangia functioning as conidia; zoospores free within a gametangial vesicle.

Ascomycota

The thalli may consist of aseptate yeast cells or septate hyphae. Following meiosis, endogenous spores (ascospores) form within a cell called an ascus. There are three groups: Archiascomycetes (members lack ascogenous hyphae and ascocarps, and asci sometimes homologized with sporangia), Saccharomycetales (Ascomycetes, Yeasts: contain no ascogeneous hyphae and ascocarps; asci thin walled and may release ascospores by deliquescing or breaking) and Filamentous Ascomycetes (with functional sex organs – possess ascogonium, ascogenous hyphae and crosiers that become enclosed in an ascocarp). The asci in Ascomycetes are aggregated in fructifications called ascomata (apothecia, cleistothecia, perithecia). The asexual states (anamorphs) of the Ascomycetes usually are classified in a separate class called Deuteromycetes.

Ascomycetes

The diagnostic characteristics of this class are a septate mycelium (hyphae with cross walls)

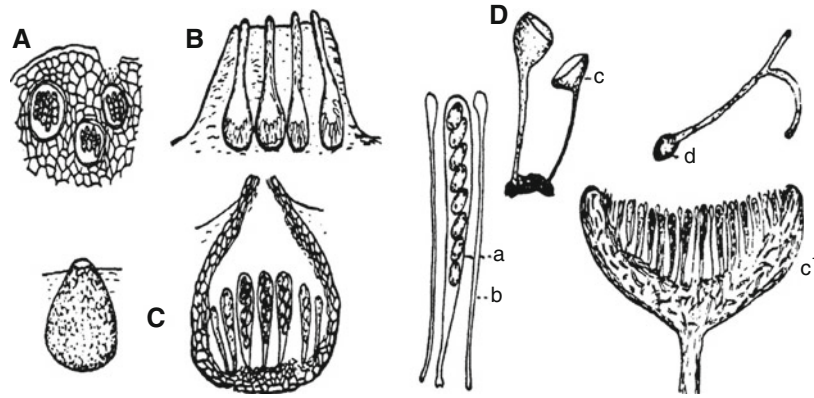

Fig. 3 Sexual reproduction in the Ascomycetes. **A** asci borne singly in locules in stroma (Myriangiales). **B** perithecia with long necks or beaks immersed in stroma (Sphaeriales). **C** papillate perithecium in host tissue, opening with a mouth or ostioles (Spaheriales). **D** Discomycetes (Heliotiales), ascus (*a*) and paraphyses (*a*) formed in a hymenial layer in a cuplike apothecium (*c*) and (c^1); ascospore (*d*) germinates by germ tube

and the ascus, a sac, typically club-shaped or cylindrical, bearing the sexual spores, ascospores, usually eight in number. Asci may be formed on or in hyphae or cells but are usually grouped in structures, ascocarps, either in locules in a stroma or lining a cup-shaped fruiting body called an apothecium or the walls of an enclosed round or flaska-shaped perithecium. The young ascus has two nuclei, which fuse and then undergo generally three divisions to give the eight spores. In many genera paraphyses, thin sterile clubs, are formed between the asci (see Fig. 3).

Many ascomycetes have both a parasitic and a saprophytic stage. In their parasitic stage they usually produce conidia or anamorph spores, sometimes on groups of conidiophores growing out of the mycelium, sometimes in a special pycnidium. Similar structures sometimes found are spermagonia containing spermatia, small sex cells.

Taphrinales

This order is now placed in the class Archiascomycetes. Hyphae bearing terminal chlamydospores or ascogenous cells, each of which produces a single ascus, usually forming a continuous hymenium-like layer on often modified tissues of hosts. Spore sac compound (a synascus) regarded as equivalent of numerous asci. Parasitic on vascular plants.

Protomycetaceae Chlamydospores thick-walled, germinating after a rest period, the exospore splitting and the endospore emerging to form a large multispored spore-sac. Parasitic on vascular plants.

Taphrinales Chlamydospores thin-walled; asci eight-spored but may become multispored by budding. Genera *Exoascus* and *Taphrina* cause leaf curl and leaf blisters and now *Exoascus* is usually considered a synonym of *Taphrina*.

Subclass **Euascomycetidae**. Asci borne in ascocarps.

Eurotiales

The order is characterized by (1) asci free on mycelium or within sessile or stipitate ascocarps; (2) sexual fusion, usually by trichogyne and undifferentiated hypha; (3) spherical-to-ovoid evanescent asci; (4) single-celled ascospores that are oblate, spherical, globosa, or smooth or with reticulations, spines, or thickened rings; sometimes with appendages; (5) dry usually phialidic conidia; and (6) being known from a variety of often starchy, oily, or cellulosic substrates.

Trichocomaceae Diversity of coverings are found over the asci: pseudoparenchymatous cleistothecia; stromata in which cleistothecia develop; stromata without cleistothecia; or wefty hyphal coverings over the asci.

Pseudeurotiaceae Species have coiled ascocarp initials, hyaline, to dark cleistothecia, and scattered globose asci that are evanescent.

Ouygenales

This order characterized by asci free on mycelium; fusion of gametangial hyphae variable without trichogyne but with ascogonium sometimes coiling; spherical to ovoid deliquescent asci; single-celled ascospores variously shaped.
Gymnoascaceae Cloistothecia around asci of loosely interwoven hyphae.
Onygenaceae Ascocarp stalked and capitate, small to medium; peridium tough, opening above; ascospores pitted.

Erysiphales (Perisporiales)

Parasites of higher plants; mycelium generally on surface of host; perithecia without true ostioles. The powdery mildews. White mycelium, with conidia in chains; perithecia rupturing with an apical tear or slit.

Meliolales

Dark or black mildews. Mycelium dark; stroma unilocular, resembling a perithecium. Mycelium dark; asci exposed by gelatinization of upper portion of ascocarp.

Myriangiales

Stroma well developed, often gelatinous; asci borne singly in locules. Nearly all are parasites on higher plants.
Piedraiaceae Tropical fungi invades cuticle of hair of primates, including humans.
Myriangiaceae Stroma pulvinate, often with lobes, nearly homogeneous.
Elsinoaceae Stroma effused, with gelatinous interior and crustose rind.

Dothideales

Mycelium immersed in substratum; stroma with hard, dark rind, soft and pale within; locules more or less spherical, resembling perithecial cavities.
Capnodiaceae Sooty molds. Often on living plants associated with insect secretions. Stroma massive, carbonaceous, often excessively branched; fruiting bodies borne singly at tips of branches, resembling perithecia. This family is now placed in the order Capnodiales.
Coryneliaceae Stroma lobed, each lobe with a single locule which is finally wide open. Martin places this in the Coryneliales.
Dothideaceae Stroma not markedly lobed, locules immersed in groups; at maturity stroma is erumpent and superficial.
Acrospermaceae Stroma typically uniloculate, clavate, erect; dehiscence by a fimbriate, often spreading, tip. Martin places this family in the Coryneliales and adds, under Dothideales, Pseudo-sphaeriaceae, with asci more or less separated by stromatic tissue.
Microthyriaceae (including Asterineae and Trichopelteae) Stromatic cover of radial or parallel hyphae; chiefly tropical species.

Microthyriales

Mycelium largely superficial; stroma flattened; dimidiate; opening by a pore or tear, simulating the upper half of a perithecium.
Polystomellaceae (including Stigmateae) Mycelium largely internal, forming a hypostroma; fruiting stroma subcuticular or superficial.
Trichothyriaceae Superficial mycelium irregular or lacking; base of stroma well developed; parasitic on other fungi.

Pleosporales

Ostiole an elongated slit on a usually flattened, elongate apothecium, bearing asci in a flat, basal layer.
Hysteriaceae Ascocarps superficial from the first; black, carbonaceous, round or elongate.
Micropeltaceae (Hemisphaeriaceae) Internal mycelium scanty; stromatic cover not of radially arranged hyphae; chiefly tropical species. This family now placed in order Pleosporales; formerly in Microthyriales.

Hypocreales

Perithecia, and stromata if present, bright colored, soft, and fleshy. Martin gives two families.
Nectriaceae Asci elliptical to cylindrical; inoperculate; ascospores various but never long-filiform.

Clavicipitaceae Asci long-cylindrical, with a thickened tip, ascospores long-filiform.

Sphaeriales (Pyrenomycetes)

Mycelium well developed; perithecia dark, more or less hard, carbonaceous, with an ostiole typically circular in section; with or without stromata; asci inoperculate (without a lid) but spores discharged with force; paraphyses and periphyses usually present.

Chaetomiaceae Perithecia superficial, hairy, walls membranous; asci deliquescent; ascospores dark; paraphyses wanting. Now placed in order Sordariales.

Sordariaceae (Fimetariaceae) Perithecia superficial, walls membranous, naked or sparsely setose; asci discharging spores forcibly. Now placed in order Sordariales.

Sphaeriaceae Perithecia superficial, walls carbonaceous, mouths papillate.

Ceratostomataceae Perithecia superficial, carbonaceous, with long, hairlike beaks.

Cucurbitariaceae Stroma present but perithecia completely emergent at maturity; formed in groups.

Amphisphaeriaceae Bases of perithecia persistently immersed in stroma; mouths circular.

Lophiostomataceae Bases of perithecia persistently immersed in stroma; mouths compressed, elongate.

Sphaerellaceae (Mycosphaerellaceae) Perithecia immersed in substratum; stroma lacking or poorly developed; asci not thickened at tips; mouths of perithecia papillate.

Gnomoniaceae Perithecia immersed in substratum; usually beaked; asci thickened at tips. This family has been eliminated: Gnomonia species are in the order Dothideales.

Clypeosphaeriaceae Stroma a shieldlike crust (clypeus) over perithecia, through which necks protrude.

Valsaceae Stroma composed of mixed host and fungal elements; perithecia immersed, with long necks; conidia borne in cavities in stroma.

Melanconidiaceae Like Valsaceae but conidia borne superficially on the stroma.

Diatrypaceae Stroma composed wholly of fungus elements; in some genera present only in conidial stage; perithecia develop under bark; ascospores small, allantoid, hyaline to yellow-brown. This family now placed in order Xylariales.

Melogrammataceae Conidia typically borne in hollow chambers in stroma composed of fungal elements; ascospores one-to many-celled, hyaline or brown.

Xylariaceae Conidia borne in superficial layer on surface of stroma; ascospores one-to two-celled, blackish brown.

Martin does not use the order Sphaeriales. He places some of the above families in separate orders. This family now placed in order Xylariales.

Laboulbeniales

Minute parasites on insects or spiders; mycelium represented by a small number of basal cells functioning as haustorium and stalk.

Phacidiales (=Rhytismatales)

Discomycetes in which the hymenium is covered by a membrane until ascospores are mature, then splitting stellately or irregularly.

Phacidiaceae Ascocarps leathery or carbonaceous, black, remaining embedded in host tissue or in stroma; hypothecium thin. Martin includes Tryblidiaceae, ascocarps leathery, immersed, hypothecium thick; but Ainsworth and Bisby place members of this family in the Helotiales.

Helotiales

Discomycetes without a membrane; asci inoperculate, opening with a definite pore. Cup fungi.

Geoglossaceae Ascocarps calvate or caplike, hymenium covering convex upper portion.

Ascocorticiaceae Fructification effused, indeterminate, without excipulum; paraphyses lacking.

Stictidiaceae Ascocarps first immersed in substratum, then erumpent; asci long-cylindrical with thickened apex; ascospores filiform, breaking up into segments at maturity.

Cyttariaceae Ascocarps compound, in form of subglobose stromata bearing numerous apothecial pits. Now placed in order Cyttariales; no family.

Patellariaceae Apothecia leathery, horny, cartilaginous, or gelatinous; tips of paraphyses united to form an epithecium; asci thick-walled. Now placed in order Patellariales; no family.
Mollisiaceae Apothecia waxy or fleshy; peridium of rounded or angular, mostly thin-walled, dark cells forming a pseudoparenchyma.
Helotiaceae Apothecia soft, fleshy, stalked; peridium of elongate, thin-walled, bright-colored hyphae, arranged in parallel strands.
Sclerotiniaceae Apothecia arising from a definite sclerotium or stromatized portion of the substratum; stalked, cup-shaped, funnel-form, or saucer-shaped; usually brown; asci inoperculate, usually eight-spored; spores ellipsoidal, often flattened on one side, usually hyaline; spermatia globose to slightly ovate; conidial forms lacking in many genera. These families are from Martin's 1954 *Key to Families*. His 1961 list puts Ostropaceae in the Ostropales and Patellariaceae in the Hysteriales. Ainsworth and Bisby list Geoglossaceae and put all other genera under "other Helotiales."

Pezizales

Asci operculate, opening by a lid; hymenium exposed before maturity of spores; apothecia often brightly colored; most forms saprophytic.
Pezizaceae Apothecia cup-shaped or discoid; sessile or stalked.
Helvellaceae Fruit bodies upright, columnar or with a stalk and cap; sometimes edible.

Tuberales

Ascocarp hypogeic, remaining closed; hymenium covered with a pseudo-tissue or hymenium lacking and asci filling cavities; mostly subterranean; includes edible truffles.
Tuberaceae Interior waxy at maturity; asci persistent. This family now placed in order Pezizales. The order Tuberales has been eliminated.
Elaphomycetaceae Interior powdery at maturity; asci disappearing early, leaving interior filled with spores. This family now placed in order Pezizales. The order Tuberales has been eliminated.

Basidiomycota

The thalli may contain budding cells which are formed successively by new inner layers which burst through the outer layers. After meiosis, the haploid cells are formed exogenously by budding and are called basidiospores or sporidia. Endogenous spores (sporangiospores or ascospores) are absent in Basidiomycota.

The structures on which haploid spores resulting from meiosis are formed are termed basidia and usually bear a constant number of spores, 2 or 4, occasionally more. The basidia are differentiated on dikaryotic hyphae usually in or on fruiting bodies called basidiomata. The basidia may also be formed on resting spores called teliospores (see Fig. 4). Dikaryotic resting spores may also germinate with a shorter or longer tube, which is termed promycelium. The three classes now distinguished are the Ustomycetes, the Urediniomycetes and the Basidiomycetes.

The Ustomycetes propagate mainly by budding cells; septate hyphae may be present, but are rare. After meiosis, resting spores form short, often septate promycelia, which produce budding cells laterally or terminally. Characteristic basidia or basidiospores are absent.

The Urediniomycetes form basidia, which after meiosis form uninucleate cells by transverse septation. Each cell forms a single, stalked basidiospore.

Nearly all Uredinomycetes are obligate parasites of vascular plants and are known as rust fungi.

The Basidiomycetes form basidia, which usually remain aseptate after meiosis; the basidiospores are arranged in an apical whorl and are sessile or stalked. The septa of the hypha have characteristic central pores termed dolipores, with thickened walls and caps. Dolipores are not present in the Ustomycetes and the Urediniomycetes.

Ustomycetes

Ustomycetes include about 500 species belonging to two orders; the plant parasitic Ustilaginales (smut fungi), and the Sporidiales (red yeasts).

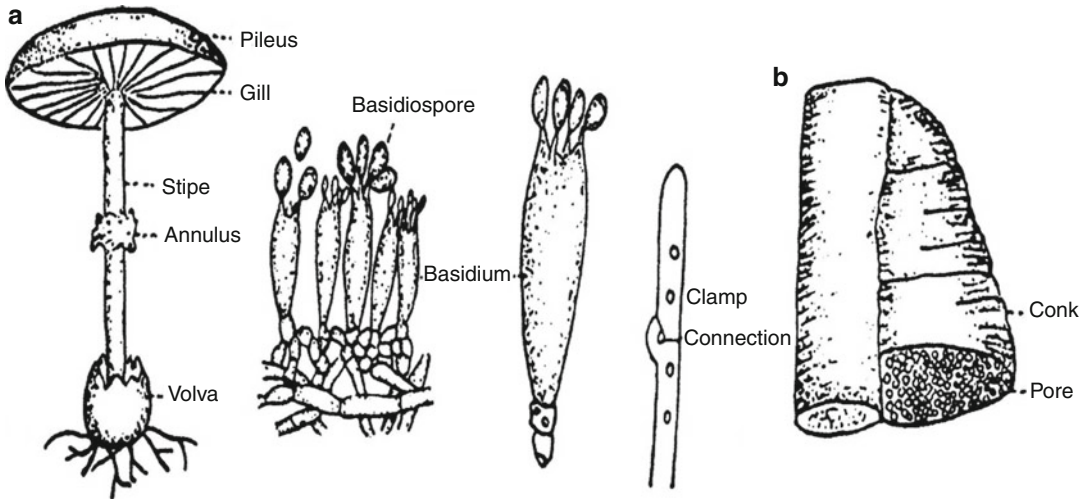

Fig. 4 Reproduction in Basidiomycetes. **a**, mushroom (Agaricaceae) with cap of pileus lined with gills bearing basidia germinating by basiodiospores. **b**, sporophore, or conk, in Polyporaceae where basidia line pores instead of gills. Mycelium in basidiomycetes sometimes have a structure around a septum called a clamp connection

Ustilaginales

The smuts. Spore masses are usually black; spores are heavy-walled chlamydospores, germinating by a promycelium (basidium) and four or more sporidia (basidiospores).

Ustilaginaceae Smuts. Basidiospores are produced on sides of a four-celled promycelium.

Tilletiaceae Smuts. Elongated basidiospores produced in a cluster at tip of a non-septate promycelium or basidium.

Urediniomycetes

Urediniomycetes – have cylindrical, often slightly curved, transversely septate basidia. Each cell forms a sterigma with a basidiospore, which is forcibly discharged when mature. Usually basidia develop on resting spores called teliospores. The Urediniomycetes contain two orders, the Uredinales (rust fungi, obligate parasites on vascular plants) and the Auriculariales.

Uredinales

The rusts. More than 5,000 species have been described in about 300 genera. Always parasitic in vascular plants; teliospores or probasidia germinate with a promycelium divided transversely into four cells, each producing a single basidiospore on a sterigma; spore masses are yellowish or orange, and there are several spore forms.

Melampsoraceae Teliospores sessile, in crusts, cushions, or cylindrical masses, or solitary, or in clusters, in mesophyll or epidermis of host. Now placed in the order Melanosporales.

Pucciniaceae Teliospores usually stalked, separate, or held together in gelatinous masses; sometimes several on common stalks; less frequently sessile, catenulate, breaking apart.

Auriculariaceae Basidia with transverse septa; typically gelatinous. The genus *Helicobasidium* causes violet root rot and the genus *Herpobasidium* causes blight of lilac. Now placed in the order Auriculariales.

Septobasidiaceae (Felt fungus) Arid, lichenoid, parasitic on scale insects; probasidia often with thickened walls. Now placed in the order Septobasidiales. There are six other families, of no particular interest from the standpoint of plant disease.

Basidiomycetes

Basidiomycetes – About 10,000 species have been described and includes the mushrooms and

the bracket fungi formed on trees. Most grow in the soil and many form mycorrhiza with roots of forest trees. The hyphae in general are septate and dikaryotic. The septa of the hyphae often have clamp connections, hyphal outgrowths formed during cell division and forming a connection between two cells. The basidia are formed in or on basidiomata on dikaryotic hyphae or on dikaryotic resting spores (teliospores). At maturity they are arranged either in a free, open layer termed hymenium or enclosed in fungal structures termed gleba. The basidiospores are sessile or more often develop on sterigmata. Young basidia are dikaryotic, until the nuclei fuse and meiosis follows. The two, four or more haploid nuclei migrate into the basidiospores, which usually are uni-, occasionally binucleate. Those orders containing plant parasitic species are included below.

Graphioliales

Graphiolaceae False smuts. Black, erumpent sori and spores in chains; on palms in warmer regions.

Tremellales

Trembling fungi Basidiocarp usually well developed, often gelatinous varying to waxy or leathery hornlike when dry; mostly saprophytic, sometimes parasitic on mosses, vascular plants, insects, or other fungi.

Agaricales

Hymenium (fruiting layer) present, exposed from beginning or before spores are matured.

Exobasidiaceae Hymenium on galls or hypertrophied tissues of hosts, which are vascular plants. Martin places this in a separate order, Exobasidiales.

Thelephoraceae Hymenium smooth or somewhat roughened or corrugated; basidiocarp weblike or membranous, leathery or woody; hymenium on lower side. Now placed in order Aphyllophorales.

Clavariaceae Hymenium smooth, pileus more or less clavate or club-shaped, erect, simple or branched, fleshy or rarely gelatinous; hymenium on all surfaces. Now placed in order Aphyllophorales.

Hydnaceae Hymenium covering downward-directed spines, warts, or teeth. Now placed in order Aphyllophorales.

Polyporaceae Hymenium lining pores (pits or tubes); hymenophore woody, tough or membranous, rarely subfleshy but never soft. Martin places this family and the preceding three in another order, Polyporales. Now placed in order Aphyllophorales.

Boletaceae Fruiting surface poroid or occasionally pitted; basidiocarp fleshy to tough or membranous.

Agaricaceae The mushrooms. Fruiting bodies usually fleshy, sometimes tough or membranous, often with a stipe and cap; hymenophore lamellate, with gills.

Hymenogastrales

Hymenium present in early stages, lining chambers of the gleba, closed fruiting body, which is fleshy or waxy, sometimes slimy and fetid at maturity.

Phallales

Gleba slimy and fetid; exposed at maturity on an elongated or enlarged receptacle.

Lycoperdales

The puffballs. Gleba powdery and dry at maturity; spores usually small, pale.

Sclerodermatales

Gleba powdery at maturity; chambers not separating from peridium or each other; spores usually large, dark.

Nidulariales

Bird's nest fungi. Gleba waxy; chamber with distinct walls forming peridioles (the eggs in the nest), which serve as propagules of dissemination.

Deuteromycetes: Fungi Imperfecti (Mycelia Sterilia)

Anamorph fungi are those for which a teleomorph state is not yet known or does not

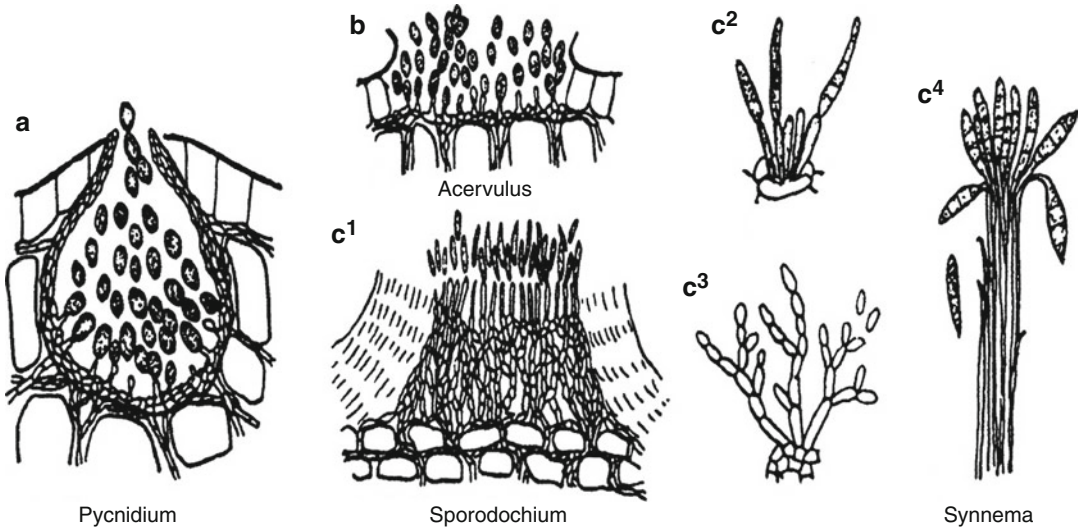

Fig. 5 Spore formation in the Deuteromycetes. **a** Sphaeropsidales, conidia in pycnidum. **b** Melanconiales, conidia in acervulus. **c** Moniliales – **c**[1] sporodochium of Tuberculariaceae; **c**[2] dard conidiophores and conidia of Dematiaceae; **c**[3] hyaline conidia in chains, Moniliaceae; **c**[4] conidiophores grouped into a synnema, Stilbaceae

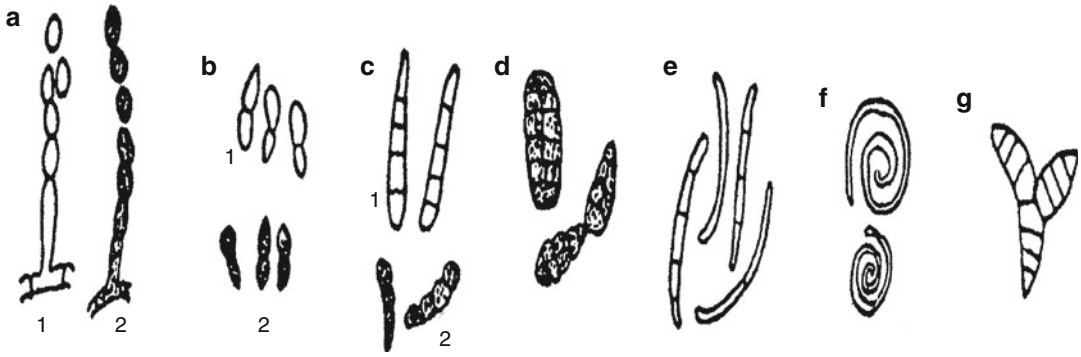

Fig. 6 Spore forms in the Deuteromycetes, commonly designated by letters and figures. **a** Amerosporae, one-celled; **a**[1] Hyalosporae, spores hyaline; **a**[2] Phaeosporae, spores dark. **b** Didymosporae, two-celled; **b**[1] Hyalodidymae, hyaline; **b**[2] Phaeodidymae, dark. **c** Phragmosporae, spores with two or more cross septa; **c**[1] Hyalophragmiae, hyaline or light; **c**[2] Phaeophragmiae, dark. **d** Dictyosporae, muriform spores. **e** Scolecosporae, filiform spores. **f** Helicosporae, spirally coiled spores. **g** Staurosporae, starlike spores

exist. Most of them are in the Ascomycetes. The groupings are based on conidia: hyaline or colored; with one, two, or several cells; formed in pycnidia, on acervuli (little cushions of hyphae breaking through the host epidermis), or free on the surface of the host (see Figs. 5 and 6).

Sphaeropsidales

Conidia borne in pycnidia or chambered cavities.

Sphaerioidaceae (Sphaeropsidaceae Phyllostictaceae) Pycnidia more or less globose, ostiolate or closed; walls dark, tough, leathery or carbona ceous.

Nectrioidaceae As above but walls or stroma bright-colored, fleshy or waxy.

Leptostromataceae Pycnidia dimidate (having the outer wall covering only the top half); usually radiate, sometimes long and cleft.

Excipulaceae Pycnidia discoid or cupulate.

Melanconiales

Conidia borne in definitely circumscribed acervuli; erumpent (breaking through the substratum).

Melanconiaceae Conidia are slime-spores; cause anthracnose diseases.

Moniliales

Conidiophores (specialized hyphae bearing conidia) superficial, entirely free or bound in tufts or in cushionlike masses (sporodochia).

Pseudosaccharomycetaceae (Cryptococcaceae) False yeasts. Hyphae scanty or nearly lacking; reproduction by budding but not germinating by repetition.

Sporobolomycetaceae False yeasts. Reproduction by budding and germination by repetition; probably anamorph species of the Tremellales, in the Basidiomycetes.

Moniliaceae Hyphae and spores hyaline or brightly colored; conidiophores not grouped together.

Dematiaceae Same as Moniliaceae but hyphae or conidia, or both, brownish to black.

Stilbaceae (Stilbellaceae) Conidiophores united into a coremium or synnema, an upright group of hyphae.

Tuberculariaceae Hyphae and conidiophores combined in a sporodochium, a tight, spore-bearing mass.