

A REVALUATION OF CHAETOMIUM AND THE CHAETOMIACEAE

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A revaluation is made of the genus *Chaetomium* which comprises about 300 species, and relatives classified in several genera of the Chaetomiaceae, Melanosporaceae and Microascaceae. The classification is based on the size, shape and symmetry of the ascospores, the number of the germ pores, the shape of the asci (clavate, obovate, fusiform or cylindrical) and the size, shape, structure and ornamentation of the ascomata.

In Ascomycetes with pigmented, 1-celled ascospores the presence or absence and the number of germ pores or germ slits are characters used to delimit not only genera, but also families. The Xylariaceae and the Coniochaetaceae contain exclusively Pyrenomycetes with ascospores with a germ slit. Amyloid apical rings are present in the asci of the former family, absent in the latter. All genera included in the Boliniaceae, Sordariaceae, Microascaceae, Melanosporaceae and Chaetomiaceae are characterized by ascospores with germ pores.

Most genera of the Sordariaceae include taxa with ascospores having a single germ pore and cellular or gelatinous sheaths or appendages. The species of the genera *Neurospora* and *Gelasinospora*, usually classified in the Sordariaceae, have unsheathed but ornamented ascospores, often with two or up to eight germ pores. They also include arthric anamorphs of the form genus *Chrysonilia* and therefore may be classified in a separate family (von Arx, 1981, 1982).

The Chaetomiaceae (including the Melanosporaceae and parts of the Microascaceae) at present contain the genera *Chaetomium* Kunze, *Chaetomidium* (Fuckel) Sacc., *Achaetomium* Rai & al., *Achaetomiella* v. Arx, *Boothiella* Lodhi & Mirza, *Farrowia* D. Hawksworth, *Melanospora* Corda, *Sphaerodes* Clem., *Petriella* Curzi, *Pseudallescheria* Negroni & Fischer, *Lophotrichus* R. K. Benjamin, *Thielavia* Zopf, *Corynascus* v. Arx and *Corynascella* v. Arx & Hodges. *Chaetomidium*, *Farrowia*, *Thielavia* and *Boothiella* contain species with ascospores with a single germ pore, while the species of *Melanospora*, *Sphaerodes*, *Achaetomiella*, *Petriella*, *Pseudallescheria*, *Corynascella* and *Corynascus*

have biporate ascospores (only those of *Corynascus heterothallicus* (v. Klopotek) v. Arx are uniporate). Most of the species classified in *Chaetomium* and *Achaetomium* have uniporate ascospores; in a small number they are biporate.

All the genera except *Chaetomium* contain less than 15 species, several are monotypic. They are characterized by ascomata which are either ostiolate or non-ostiolate, smooth, often translucent, sometimes covered with undifferentiated, non-erect hyphae. All genera however are characterized by evanescent, stalked, often fasciculate, clavate, obovate or narrow cylindrical asci and 1-celled, pigmented ascospores without appendages of sheaths, but usually with germ pores. In species with ostiolate ascomata the ascospores are not forcibly discharged, but become free in a cirrhous or as a slimy mass, which may become dry but not powdery.

The genus *Chaetomium* contains species with superficial, ostiolate ascomata covered with characteristic hairs or setae. All are saprophytic, often cellulolytic or coprophilous and some are rather common on plant debris, e.g. on straw or paper. They are easily isolated and show abundant fructification on adequate media. The identification of the species is often difficult and time consuming because the genus has long been favoured for taxonomic study, with about 300 taxa having been described. Several are known only by the type specimen.

Dreyfuss (1976) observed in monospore cultures of *Ch. murorum* saltants or mutants which differed both morphologically and physiologically from the original strain as well as from each other. Some of them were reidentified as *Ch. elongatum*, some others formed smooth or nearly smooth ascomata.

Chaetomium species form expanding colonies with superficial, spherical, ovate or ampulliform, ostiolate ascomata covered with characteristic hairs or setae, on which several apparently heterogeneous sections have been distinguished e.g. by Zopf (1881), Bainier (1910), Chivers (1915), Skolko & Groves (1948, 1957), Udagawa (1970), Ames (1963), Mazzucchetti (1965), Seth (1972) and Millner (1975). Sections or species groups with branched or unbranched terminal hairs have been delimited. The branching may be dichotomous, at right angles or irregular. The hairs may be straight, flexuous, arcuate, undulate, circinate, spirally coiled or contorted. Based on these characters up to ten species groups have been distinguished. Several hair types also may be mixed and a distinction is made between terminal and lateral hairs. Hawksworth & Wells (1973) introduced the ornamentation of the terminal hairs seen in SEM as a further character. The definite hair shape and ornamentation however depends on the age of the ascomata and also on culture conditions.

Whiteside (1957) introduced the structure of the ascomatal initials (ascogonia) as a further character for a subdivision of *Chaetomium*. He distinguished the 'globosum type' forming an undifferentiated cluster of hyphae and the 'brasiliense type' forming a coil surrounding an ascogonial cell at the end of a hypha. Dreyfuss (1976) however showed that the structure of the initials may be influenced by the incubation temperature.

Seth (1972) provided a key based on the shape of the ascospores. The shape of the asci (clavate, obovate, fusiform or cylindrical) usually has been neglected. It was indicated in the descriptions given by Ames (1963), but was not considered in the classification.

The shape of the asci and the structure of the ascospores have been introduced as characters to delimit apparently more homogeneous taxa by Sörgel (1960, 1961), Aue & Müller (1967) and Dreyfuss (1976). More attention has been paid to the germ pore of the ascospores, which may be small or distinct, flat or protuberant, apical, subapical or slightly lateral, and occasionally surrounded by a thickened and/or darkened wall. These aspects were studied by Millner & al. (1977), for a rather large number of taxa. These authors and Dreyfuss (1976) observed ascospores with two germ pores, one at each end, in a few species.

THE REVALUATION OF GENERA AND SPECIES GROUPS

The following subdivision of *Chaetomium* and the other genera of the Chaetomiaceae is based on characters of the ascospores and asci in particular. These details were derived from mostly personal observations, but data published by Dreyfuss (1976), Millner & al. (1977), von Arx (1977), Cannon & Hawksworth (1982) and others were employed without re-examination of the respective specimens.

I. Ascospores with one germ pore

A. Asci clavate, obovate or fusiform

a. Germ pore of the ascospores apical.

1. Ascospores $8-13 \times 7-10 \mu\text{m}$, often biapiculate, laterally flattened; ascomata spherical or ovate, ostiolate, $180-400 \mu\text{m}$, with a wall of textura intricata *Ch. globosum* Kunze.

Further species: *Ch. cochliodes* Palliser, *Ch. cruentum* Ames (an albino form of *Ch. globosum*), *Ch. elatum* Kunze (with branched ascomatal hairs, often heterothallic), *Ch. subaffine* Sergejeva (heterothallic), *Ch. umbonatum* Brever (with biumbonate ascospores), *Ch. madrasense* Natarajan (with ascospores with a lateral bulge).

2. Ascospores spherical or nearly so, $10-12 \mu\text{m}$; ascomata with a wall of angular cells, ostiolate
Ch. globosporum Rikhy & Mukerji.

3. Ascospores $7-11 \times 5-9 \mu\text{m}$, biumbonate or biapiculate, laterally flattened, brown; ascomata ampulliform or pyriform, with a wall of angular cells, covered with seta-like, apically often circinate or branched hairs; aleurioconidia (chlamydo-spores) mostly present *Ch. homopilatum* Omvik.

Further species: *Ch. longicolleum* Krzem. & Badura, *Ch. malaysensis* (D. Hawksworth) v. Arx, *Ch. seminudum* Ames. The following species differ by larger ascomata and the absence of chlamydo-spores: *Ch. ampullare* Chivers, *Ch. sphaerale* Chivers, *Ch. subspirale* Chivers.

4. Ascospores $6-9 \times 6-7 \mu\text{m}$, roundish, biapiculate or angular, dextrinoid when young, light bluish grey when mature, occasionally darkened near the poles; ascomata obovate, ampulliform or cylindrical, around the ostiolum with a darkened collar and with a wall of angular or elongate cells; terminal hairs in the upper part coiled *Ch. bostrychodes* Zopf.

Further species: *Ch. convolutum* Chivers, *Ch. caprinum* Bainier sensu Chivers, *Ch. quadrangulatum* Chivers.

5. Ascospores $5-8 \times 4-6 \mu\text{m}$, ovate, brown; ascomata $110-180 \mu\text{m}$, ostiolate, covered with dark, stiff setae and/or with dichotomously branched hairs *Ch. indicum* Corda.

Further species: *Ch. cancroideum* Tschudy, *Ch. erectum* Skolko & Groves, *Ch. funicola* Cooke, *Ch. spinosum* Chivers.

6. Ascospores 7–13 × 6–11 μm, ovate or pyriform; ascomata spherical or ovate, ostiolate, covered with undulate or spirally coiled hairs; aerial mycelium often abundant, white . . . *Ch. nigricolor* Ames.
Further species: *Ch. semen-citrulli* Sergejeva, *Ch. uniporum* Aue & Müller.

7. Ascospores 12–21 × 6–11 μm, ellipsoidal or broadly fusiform, with longitudinal bands; ascomata spherical or ovate, ostiolate, 90–330 μm, with a wall of textura epidermoidea or angularis; asci often obovate *Ch. murorum* Corda.

Further species: *Ch. depectivum* Malloch & Benny (with slightly longer ascospores), *Ch. piluliferum* Daniels (with a *Botryotrichum* anamorph), *Ch. subspirilliferum* Sergejeva (ascomata small, with undulate, delicate hairs), *Ch. succineum* Ames (ascomatal hairs coiled).

8. Ascospores 10–17 × 7–10 μm, limoniform or broadly fusiform; ascomata spherical, non-ostiolate, covered with thick hairs or setae and with a dark wall of angular cells

Chaetomidium fimeti (Fuckel) Sacc.

Further species: *Chaetomidium arxii* Benny, *Chaetomidium cephalothecoides* (Malloch & Benny) v. Arx, *Chaetomidium pilosum* (Booth & Shipton) v. Arx, *Chaetomidium trichorobustum* Seth, *Chaetomium irregulare* Sörgel ex Gams (with irregular ascospores and a translucent ascomatal wall).

9. Ascospores of different size and shape; ascomata spherical, non-ostiolate, with a translucent or a brown wall of textura epidermoidea, smooth or nearly so *Thielavia basicola* Zopf.

Further species: *T. australiensis* Tansey & Jack, *T. emodensis* Udagawa & Sugiyama, *T. hyalocarpa* v. Arx, *T. microspora* Mouchacca, *T. minuta* (Cain) Malloch & Cain, *T. peruviana* (Gochenaux) Malloch & Cain, *T. pseudomaritima* Davidson, *T. terrestris* (Apinis) Malloch & Cain, *T. terricola* (Gilman & Abbott) Emmons, *T. variospora* Cain (Malloch & Cain, 1973; von Arx, 1975).

10. Ascospores triangular in face view, 7–11 × 4–7 μm; ascomata pyriform, setose; catenate conidia often present *Ch. (Bommerella) trigonosporum* (Marchal) Chivers.

11. Ascospores 8–14 × 5–7 μm, navicular, reniform, ovate, clavate or fusiform, often dextrinoid when young; ascomata small, with a wall of textura angularis, covered with tapering seta or arcuate, occasionally circinate hairs: see II (taxa with biporate ascospores).

b. Ascospores often fusiform, with a subapical or lateral germ pore.

1. Ascomata ostiolate, with a wall of textura intricata, covered with partly dark, seta-like, partly light and much branched hairs *Ch. cuniculorum* Fuckel.

2. Ascomata ostiolate, with a wall of textura intricata, covered with at least partly circinate, undulate or coiled hairs *Ch. fuisporum* G. Smith.

Further species: *Ch. gangligerum* Ames, *Ch. gelasinosporum* Aue & Müller, *Ch. jodhpurensis* Lodha, *Ch. perlucidum* Sergejeva, *Ch. raii* Malhotra & Mukerji.

3. Ascomata urniform, with a wide apical opening, smooth, thin-walled; ascospores 20–27 × 13–16 μm *Achaetomium thielavioideum* v. Arx & al.

4. Ascomata spherical, non-ostiolate, smooth, hairy or setose, with a wall of textura epidermoidea
Thielavia hyrcaniae Nicot.

Further species: *T. appendiculata* Srivastava & al., *T. arenaria* Mouchacca, *T. subthermophila* Mouchacca (von Arx, 1975).

5. Ascomata small, ostiolate, with a wall of *textura angularis*, covered with setae or arcuate or undulate hairs see II (taxa with biporate ascospores).

B. Asci cylindrical; ascospores uniseriate, often ovate, attenuated towards the germ pore

1. Thermophilic; ascospores $7-12 \times 7-9 \mu\text{m}$, dark; ascomata spherical or ovate, usually ostiolate, covered with light, branched hairs *Ch. thermophile* LaTouche.

2. Ascospores $10-14 \times 7-9 \mu\text{m}$, biumbonate, brown; asci mostly 4-spored; ascomata ostiolate, $300-450 \mu\text{m}$, covered with branched hairs *Ch. tetrasporum* Hughes.

3. Ascospores $7-13(-17) \times 5-9(-12) \mu\text{m}$, ovate; ascomata ostiolate, covered with spirally coiled, contorted or undulate, often thick and/or branched hairs; asci 8-spored . . . *Ch. crispatum* Fuckel.

Further species: *Ch. brasiliense* Batista & Pontual; *Ch. medusarum* Meyer & Lanneau, *Ch. senegalense* Ames, *Ch. amygdalisporum* Udagawa & Muroi (with larger ascospores: $13-17 \times 9-12 \mu\text{m}$).

4. Ascospores spherical or nearly so, $14-20 \times 12-15 \mu\text{m}$, black, with a protuberant germ pore; asci 4-spored; ascomata non-ostiolate, with a translucent wall of angular cells

Thielavia (Boothiella) tetraspora (Lodhi & Mirza) v. Arx.

5. Ascospores spherical or nearly so, $10-15 \times 10-13 \mu\text{m}$, black; asci 8-spored; ascomata ostiolate, with a dark wall of *textura intricata*, covered with light hyphae

Achaetomium globosum Rai & Tewari.

Further species: *A. marinum* Chowdhery & Rai.

6. Ascospores fusiform or ellipsoidal, $8-25 \times 5-18 \mu\text{m}$, black or dark brown; asci 8-spored; ascomata ostiolate, with a dark wall of *textura intricata* covered with light, often yellow hyphae

Achaetomium strumarium Rai & al.

Further species: *A. brevisemum* Chowdhery & Rai, *A. cristalliferum* Faurel & Locquin-Linard, *A. luteum* Rai & Tewari and several other species (Chowdhery, 1981).

7. Ascomata spherical, non-ostiolate; ascospores $24-30 \times 11-15 \mu\text{m}$, fusiform

Thielavia tortuosa Udagawa & Sugijama.

II. Ascospores with two (occasionally one) germ pores asci clavate or obovate (not cylindrical)

1. Ascospores ovate, oblate, ellipsoidal or irregular, thick-walled, $10-19 \times 8-13 \mu\text{m}$; ascomata spherical or ovate, ostiolate, with a dark wall covered with septate hyphae . . . *Ch. megalocarpon* Bainier.

Further species: *Ch. nozdrenkoae* Sergejeva (heterothallic), *Ch. variosporum* Udagawa & Horie, *Achaetomium purpurascens* Udagawa & Sugiyama.

2. Ascospores fusiform, navicular or reniform, $8-16 \times 4-8 \mu\text{m}$, often dextrinoid when young; ascomata ostiolate, mostly small, covered with setae or with arcuate or circinate hairs; anamorphs absent; colonies often coloured by red, yellow or green exudates *Ch. aureum* Chivers.

Further species: *Ch. gracile* Udagawa, *Ch. flavigenum* van Warmelo, *Ch. fusiforme* Chivers, *Ch. mareoticum* Beseda & Yusef, *Ch. turgidopilosum* Ames, *Ch. virescens* (v. Arx) Udagawa.

The following species are similar, but have ascospores with a single, apical or subapical germ pore: *Ch. venezuelense* Ames, *Ch. atrobrunneum* Ames, *Ch. carinthiacum* Sörgel, *Ch. cupreum* Ames, *Ch. lentum* van Warmelo, *Ch. lucknowense* Rai & Tewari.

3. Ascospores ellipsoidal, $7-10 \times 5-8 \mu\text{m}$, dextrinoid when young, yellowish when ripe; ascomata ostiolate or non-ostiolate, with an apical tuft of long, thick-walled hairs; asci obovate; anamorphs absent *Lophotrichus ampullus* R. K. Benjamin.

Further, probably identical species: *L. bartelettii* (Masse & Salmon) Malloch & Cain (often non-ostiolate), *L. martinii* R. K. Benjamin.

4. Ascospores ellipsoidal, fusiform or reniform, $8-11 \times 4-7 \mu\text{m}$, dextrinoid when young, reddish brown when mature; ascomata ostiolate, mostly setose; asci obovate; *Graphium* or *Scedosporium* anamorphs forming 1-celled blastoconidia present *Petriella sordida* (Zukal) Barron & Gilman.

5. Ascospores ellipsoidal, $8-11 \times 4-7 \mu\text{m}$, dextrinoid when young, yellowish when mature; ascomata non-ostiolate; *Graphium* or *Scedosporium* anamorphs forming 1-celled blastoconidia present
Pseudallescheria (Petriellidium) boydii (Shear) McGinnis & al.
P. boydii is a human pathogen, some other species are soil borne (McGinnis & al., 1982).

6. Ascospores ellipsoidal, $10-28 \times 7-17 \mu\text{m}$, smooth, dark brown when mature; ascomata with a translucent wall of angular cells and with an elongate ostiolum of fused hairs or hyphae
Melanospora zamiae Corda.

Cannon & Hawksworth distinguished 12 species; all except *M. chionaea* (Fr.) Corda are close to each other.

7. Ascospores $18-30 \times 10-17 \mu\text{m}$, with a reticulate or striate wall and protuberant, thickened germ pores; ascomata ostiolate or non-ostiolate, with a translucent wall of angular cells

Sphaerodes episphaeria (Phill. & Plowr.) Clem.

Cannon & Hawksworth (1982) accepted 6 species, all except *S. fimicola* (Hanson) Cannon & D. Hawksworth have non-ostiolate ascomata and are close to each other. They classified two ostiolar species with finely reticulate ascospores in a separate genus *Perisciospora*.

8. Ascospores ellipsoidal, $10-14 \times 8-12 \mu\text{m}$, dark when mature; ascomata spherical, small, non-ostiolate, with a wall of irregular cells; *Myceliophthora* anamorphs forming 1-celled, hyaline, often ornamented and catenate blastoconidia present *Corynascus sepedonium* (Emmons) v. Arx.

Further species: *C. heterothallicus* (v. Klopotek) v. Arx (thermophilic, with uniporate ascospores), *C. novoguineensis* (Udagawa & Horie) v. Arx, *C. thermophilus* (Fergus & Sinden) v. Klopotek. The genus may be related to Onygenaceae (*Ctenomyces*, *Arthroderma*) with similar anamorphs.

9. Ascospores ellipsoidal, $12-20 \times 7-14 \mu\text{m}$, smooth, with a thickened wall around the germ pores; ascomata non-ostiolate, with a hyphal wall covered with short hyphae; anamorphs absent
Corynascella humicola v. Arx & Hodges.

Further species: *C. inaequalis* (Pidoplichko & al.) v. Arx, *C. inquinata* Udagawa & Ueda.

III. Ascospores without visible germ pores, but with a thinner wall at the attenuated ends

1. Ascospores fusiform, $22-27 \times 8-9 \mu\text{m}$; ascomata ostiolate or non-ostiolate, covered with unbranched hairs; *Botryotrichum* anamorphs with botryose, 1-celled, hyaline aleurioconidia present
Ch. megasporum Sörgel.

2. Ascospores cylindrical, with attenuated ends, $9-11 \times 2.5-3 \mu\text{m}$; ascomata ostiolate, covered with erect, apically branched hairs; anamorphs absent *Ch. fusum* Ames.

CONCLUSIONS

The genera of the Chaetomiaceae were formerly based on characters of the ascomata, that is ostiolate or non-ostiolate, translucent or with a dark wall, smooth or hairy, spher-

ical or elongate-ampulliform. The shape of the asci (clavate, obovate, fusiform or cylindrical), the size and shape of the ascospores, and the presence or absence, number and position of insertion of the germ pores were neglected. The latter characters, however, are more suited to the delimitation of homogeneous taxa. Therefore the above classification is based on characters of ascospores and asci. If this classification were accepted in the nomenclature, several new genera and numerous new combinations would have to be proposed. An alternative choice would be acceptance of a voluminous genus *Chaetomium*, for all member of the Chaetomiaceae. The genus would then also include taxa with non-ostiolate or with smooth or nearly smooth ascomata, often with a colourless, translucent wall.

Chaetomium globosum, the type species of the genus, is characterized by spherical, ostiolate ascomata with a wall composed of brown hyphae (textura intricata), covered with numerous, flexuous, undulate or coiled, verrucose hairs; by fasciculate, clavate, stalked, evanescent asci and by ascospores with a single apical germ pore. A rather large number of species have similar characters. Those that differ have, for example, an ascomata wall of angular, flattened cells (textura angularis), narrow cylindrical asci; biporate ascospores or a combination of these characters.

The genus *Chaetomidium*, introduced for non-ostiolate counterparts of *Chaetomium* has often not been accepted (e.g. by von Arx and Müller, 1954). Some of the species occasionally have been considered to be related with *Ch. globosum* and *Ch. murorum*. They however differ by the non-ostiolate ascomata, the peculiar structure of the ascomatal wall and the configuration of the ascomatal hairs.

Thielavia and *Boothiella* have been proposed for Chaetomiaceae or Sordariaceae with non-ostiolate ascomata and uniporate ascospores. The type species of the latter genus is characterized by ascomata with a translucent wall, cylindrical, 4-spored asci and ovate ascospores with a protuberant germ pore. It may be related to *Achaetomium globosum* with similar asci and ascospores but with ostiolate ascomata and 8-spored asci. *Chaetomium tetrasporum* is the only *Chaetomium* species with 4-spored, cylindrical asci.

Thielavia basicola, type of the genus *Thielavia*, also has ascomata with a translucent wall, but the asci are clavate and 8-spored and the ascospores fusiform, with a distinct, non-protuberant germ pore at one end (von Arx, 1975). Most of the other *Thielavia* species have a pigmented, non-translucent ascomata wall. Some have ascospores with a subapical germ pore and agree in this respect with *Chaetomium cuniculorum* or *Ch. fusi-sporum* and their relatives, but also with some *Podospora* species (Sordariaceae).

The genus *Farrowia* is also distinguished with difficulty from *Chaetomium*. Its type species is related to *Ch. homopilatum*; *Ch. seminudum* is an intermediate.

The genus *Achaetomium* differs from *Chaetomium* not only by the ascomata with a thick wall of textura intricata covered with light, spreading (not erect), undifferentiated hyphae, but also by cylindrical asci with uniseriate ascospores. It should be restricted to species with a hyphal, thick ascomatal wall and with uniporate, opaque ascospores. (*Achaetomium luteum* has been described as having biporate ascospores, but these in fact are uniporate.) The *Chaetomium* species with cylindrical asci belonging to the

Chaetomium crispatum species group, differ from *Achaetomium* by having thicker, coiled hairs and smaller, non-fusiform or nearly spherical, but ovate or pyriform, paler ascospores with a germ pore at the attenuated end.

The generic name *Bommerella* may be reintroduced for *Chaetomium trigonosporum*. This species differs from other *Chaetomium* species not only by the triangular ascospores, but also by ampulliform, setose ascomata and by the formation of a *Scopulariopsis*-like anamorph with catenate conidia with a truncate base. It is without doubt intermediate between *Chaetomium* and *Microascus*. The dextrinoid, triangular, uniporate ascospores and the similar anamorphs are common characters.

Malloch (1970) characterized the Microascaceae mainly by the ascospores, which are relatively small, dextrinoid when young, yellowish or reddish brown when mature and have one or two germ pores. In many *Chaetomium* species, however, young ascospores are also dextrinoid (e.g. in *Ch. cupreum*, *Ch. caprinum*, *Ch. fusiforme* or *Ch. bostrychodes*). This character and the pigmentation of mature ascospores do not suffice to distinguish the families. In our opinion the Microascaceae should be restricted to the genera *Microascus* and *Kernia* with small, roundish or ovate, often catenate asci and small ascospores with a single germ pore. Most of the species include a *Scopulariopsis* anamorph. The remaining genera of the Microascaceae sensu Malloch are therefore included above in the Chaetomiaceae with biporate ascospores.

The taxonomic position of *Chaetomium* species with biporate, mostly fusiform and often dextrinoid ascospores such as *Ch. aureum* or *Ch. fusiforme* is not clear. The respective species group is also characterized by small ascomata with a wall of angular cells, covered with unbranched, arcuate hairs. Von Arx (1970) introduced a separate genus, *Achaetomiella* for a similar fungus with biporate ascospores and ampulliform, nearly smooth or slightly setose ascomata. Its type *A. virescens* is now seen to be related to *Ch. gracile* which has similar ascospores, though spherical ascomata covered with arcuate hairs. If the genus *Achaetomiella* were to be maintained, it would have to include species with biporate and others with uniporate ascospores, classified in the *Chaetomium aureum* species group above.

There is little doubt that *Ch. aureum*, *Ch. virescens* and similar species with biporate ascospores are related to species with similar ascospores, classified in *Melanospora*, *Petriella*, *Lophotrichus*, *Neurospora* and other genera.

The ascospores of *Ch. megalocarpum*, *Ch. nozdrenkoae* and *Ch. variosporum* are also biporate. The three species are closely related, showing common characters such as ovate or irregularly spherical, thick-walled, brown, ascospores and rather large ascomata with a wall of hyphal cells and covered with undifferentiated, pigmented, often branched hyphae or hairs.

One of the few *Chaetomium* species with ascospores in which no germ pores could be observed is *Ch. megasporum*. It has small ascomata covered with hypha-like hairs and relatively large, fusiform ascospores. It also includes a *Botryotrichum* or *Staphylotrichum* like anamorph with botryose, 1-celled, spherical, hyaline conidia. Similar but not botryose but pigmented conidia are known in *Ch. homopilatum* and some related spe-

cies, keyed out by Hawksworth (1975), though these have smaller, limoniform, uniporate ascospores. *Botryotrichum* is rather similar to *Harzia*, *Olpitrichum* and *Myceliophthora*, which include anamorphs of some Onygenaceae and of *Corynascus* and *Melanospora*. Both these genera are characterized by biporate, broadly fusiform or ellipsoidal ascospores, similar in size and shape to those of *Ch. megasporum*. *Chaetomium fusum* also has ascospores without germ pores but is not closely related to *Ch. megasporum*.

In most of the larger species groups defined above, the delimitation of the species is either difficult or impossible and subjective. The *Chaetomium globosum* group, for example, now contains about 20 species and several varieties. Dreyfuss (1976) studied numerous, partly fresh isolates and tried to delimit some of the species and varieties, but the result is not satisfactory. Nearly every strain can be distinguished from any other in some respects, e.g. in the daily growth rate and pigmentation of the colonies or in the shape and size of the ascomatal hairs. The asci and ascospores are alike in shape, but often not in size. It would be much more convenient to reduce the whole group to a few species. *Ch. cochliodes* has been distinguished from *Ch. globosum* by a yellow green exudate and by the often spirally coiled ascomatal hairs. But some strains with this exudate have undulate or coiled hairs. *Ch. globosum* has been restricted to homothallic strains. The heterothallic *Ch. subaffine* can be distinguished also by the formation of phialoconidia (spermatia), by slightly larger ascospores and by thicker, flexuous, tapering ascomatal hairs (Sedlar & al., 1972, 1973; Müller & Sedlar, 1977). It often has been confused with *Ch. olivaceum* Cooke & Ellis.

Another difficulty is the fact that no types are available of most of the older and of many of the recently described species. The descriptions are often incomplete or misleading. Dried specimens often proved to be inadequate for study, because some of the structures has desintegrated and has shrunk. We urge that in future only cultures of Chaetomiaceae are described. Dried specimens should not be killed, because the ascospores remain viable for at least 25 years.

In the first and still the best monograph of *Chaetomium*, Zopf (1881) treated the most common species *Ch. globosum* (as *Ch. kunzeanum* Zopf), *Ch. elatum*, *Ch. murosorum*, *Ch. spirale*, *Ch. indicum*, *Ch. bostrychodes* and *Ch. cirspatum*. The descriptions and figures are adequate and can serve as type. The size and shape of the asci and ascospores are correctly given and the presence of germ pores is mentioned. These characters have been fully neglected by all later monographers. No type specimens are available of the species described by Bainier (1910) and the descriptions and figures partly are unclear. Some data given by Chivers (1915) are incorrect and the beautiful but unsatisfactory figures have often been copied by subsequent authors, e.g. by Ames (1963) without citation. The cover figure in Ames is reminiscent to a figure published by von Arx & Müller (1954). Most of the common *Chaetomium* species are easily recognized by means of the micrographs published by Matsushima (1971, 1975).

The Sordariaceae are closely related to the Chaetomiaceae but are distinguished having asci with apical rings or thickenings and ascospores with gelatinous sheaths or cellular or gelatinous appendages. The ascospores in *Neurospora*, *Gelasinospora* and related genera are not sheathed but ornamented. The cleistothecial genera *Thielavia* and

Boothiella, here classified in the Chaetomiaceae, can also be included in the Sordariaceae. Their position is questionable but their representatives have evanescent asci without apical rings and unsheathed ascospores. Some cleistothecial Sordariaceae classified in *Zopfiella* Winter (hardly distinguishable from *Podospora* Ces.) or *Echinopodospora* Robinson (hardly distinguishable from *Apiosordaria* v. Arx & Gams) also have evanescent asci and unsheathed, but inaequally 2-celled ascospores. Numerous Sordariaceae have ascospores with a subapical germ pore, as do several Chaetomiaceae.

The species of *Chaetomium*, *Achaetomium* and *Melanospora* in which the ascospores are extruded in a mucoid mass are highly adapted to spore dispersal by animals (insects, mites). In this respect they are similar to *Ophiostoma*, *Ceratocystis*, *Sphaeronemella* and *Microascus*. Sordariaceae with ostiolate ascomata and ascospore ejaculation may be the ancestors of *Chaetomium*. Species with ascospores with a subapical germ pore and with an ascomatal wall of *textura intricata* may be descendants of Sordariaceae with corresponding characters classified in *Podospora*. Some *Podospora* species have ascospores similar in shape, symmetry and pigmentation, and the ascospores appendages may be small and dissolving.

Neurospora-like Ascomycetes may be the ancestors of *Chaetomium* species with biporate ascospores and with a wall of *textura angularis*, e.g. *Ch. aureum* or *Ch. gracile*. *Chaetomium crispatum* with its ascospores with an apical germ pore and with cylindrical asci may have been derived from *Sordaria* species. The non-ostiolate Sordariaceae/Chaetomiaceae, e.g. species of *Thielavia* or *Chaetomidium*, may also have been derived from ostiolate relatives or vice versa.

The genus *Chaetomium* in its present delimitation without doubt is a biological, but not a phylogenetical entity of sordariaceous Ascomycetes.

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