Diversity and taxonomy of Chaetomium and chaetomium-like fungi from indoor environments

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Abstract: During a study of indoor fungi, 145 isolates belonging to Chaetomniaceae were cultured from air, swab and dust samples from 19 countries. Based on the phylogenetic analyses of DNA-directed RNA polymerase II second largest subunit (rpb2), β-tubulin (tub2), ITS and 28S large subunit (LSU) nrDNA sequences, together with morphological comparisons with related genera and species, 30 indoor taxa are recognised, of which 22 represent known species, seven are described as new, and one remains to be identified at species level. In our collection, 69 % of the indoor isolates with six species cluster with members of the Chaetomium globosum species complex, representing Chaetomium sensu stricto. The other indoor species fall into nine lineages that are separated from each other with several known chaetomniacean genera occurring among them. No generic names are available for five of those lineages, and the following new genera are introduced here: Amesia with three indoor species, Arcopilus with one indoor species, Collariella with four indoor species, Dichotomopilus with seven indoor species and Ovatospora with two indoor species. The generic concept of Botryotrichum is expanded to include Emilmuelleria and the chaetomium-like species B. murorum (= Ch. murorum) in which two indoor species are included. The generic concept of Subramaniula is expanded to include several chaetomium-like taxa as well as one indoor species. Humicola is recognised as a distinct genus including two indoor taxa. According to this study, Ch. globosum is the most abundant Chaetomniaceae indoor species (74/145), followed by Ch. cochlioides (17/145), Ch. eutalum (6/145) and B. piluliferum (5/145). The morphological diversity of indoor Chaetomniaceae as well as the morphological characteristics of the new genera are described and illustrated. This taxonomic study redefines the generic concept of Chaetomium and provides new insight into the phylogenetic relationships among different genera within Chaetomniaceae.

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INTRODUCTION

Fungal contamination in damp or water-damaged buildings has become an increasing problem worldwide (Andersen et al. 2011). After water damage (e.g. leaking water pipes, flooding, faulty building constructions, or severe and prolonged condensation) many building materials become good substrates for certain fungi. These growing fungi can cause adverse effects not only on the buildings but also to their occupants (Samson et al. 1994, WHO 2009, Samson et al. 2010, Flannigan & Miller 2011, Andersen et al. 2011, Miller & McMullin 2014). Members of the genus Chaetomium are capable of colonising various substrates and are well-known for their ability to degrade cellulose and to produce a variety of bioactive metabolites. More than 400 species have been described in Chaetomium. Some of these species have been reported to be important inhalant allergens. They contribute to the development of the symptoms of both rhinitis and asthma due to the production of mycotoxins and microbial volatile organic compounds as well as the liberation of ascospores and hyphal fragments in the indoor environment (Gonianakis et al. 2005, Aepreti et al. 2009, Flannigan & Miller 2011, Andersen et al. 2011, Miller & McMullin 2014).
et al. 2009, Polizzi et al. 2009, Mason et al. 2010, Andersen et al. 2011, Miller & McMullin 2014). Chaetomium globosum is the most common species of the Chaetomiaceae in the indoor environment (Vesper et al. 2007, Ayanbimpe et al. 2010, Straus 2011, McMullin et al. 2013, Miller & McMullin 2014), and this species can already be present in new gypsym wallboard (Andersen et al. in press). Chaetomium globosum has been reported to produce a variety of toxic metabolites, such as chaetoglobosins, chaetomulgins, and chaetovindins (Andersen et al. 2011, McMullin et al. 2013, Miller & McMullin 2014), while both Ch. elatum and Ch. globosum were able to produce cochliodones in pure cultures as well as on naturally contaminated building materials (Dosen et al. in press). Little is known about the other indoor Chaetomium species and their potential hazard to humans and buildings. Furthermore, Ch. globosum and several other Chaetomium species are reported as causal agents of onychomycosis or superficial infections (Koch & Hanke 1965, Naidu et al. 1991, Aspíroz et al. 2007, Hubka et al. 2011, de Hoog et al. 2013), and some of them are capable of opportunistically causing deep or systemic infections (Hoppin et al. 1983, Barron et al. 2003, Guuppy et al. 1998, Ahmed et al. 2016).

The genus Chaetomium is commonly recognised by having ostiolate ascomata with a membranaceous perithelial wall covered by relatively well-developed hairs, producing fasciculate and evanescent asci and single-celled, smooth and pigmented ascospores with germ pores (Arens 1963, von Arx et al. 1986). Chaetomium globosum, the type species of the genus, was first described by Kunze (Kunze & Schmidt 1817). The taxonomy of Chaetomium has been studied by several authors (Corda 1840, Zopf 1881, Chivers 1915, Skolko & Groves 1948, 1953, Sörgel 1960, Arens 1963, Mazzucchetti 1965, Seth 1970, Dreyfuss 1976, Millner 1977, Millner et al. 1977, von Arx et al. 1984), von Arx et al. (1986) re-defined the taxonomic concept of Ch. globosum. They included species that produce globose to ovate or obovate ascomata with a wall consisting of textura intricata, covered by a diverse morphology of ascomatal hairs ranging from erect, flexuous to regularly coiled. The ascomata contain clavate (or slightly fusiform), evanescent ascii, and the ascospores are limoniform and bilaterally-flattened shaped, and have an apical germ pore. Following this concept 28 species were reduced to synonymy with Ch. globosum. The species concept of Ch. globosum sensu von Arx was not supported by a recent study (Asgari & Zare 2011). For example, von Arx et al. (1986) treated Ch. coarctatum as one of the synonyms of Ch. globosum. Based on three genomic loci (ITS region, partial LSU rDNA and partial β-tubulin gene sequences), the phylogenetic analysis of Asgari & Zare (2011) indicated a distant relationship between the authentic isolate of Ch. globosum (CBS 148.51) and the ex-type strain of Ch. coarctatum (CBS 162.62). On the basis of phylogenetic inference of six loci and morphological characters, Ch. globosum was again revised by Wang et al. (2016), and six species that were treated as synonyms of Ch. globosum by von Arx et al. (1986) were resurrected. Furthermore, the non-ostiolate genus Chaetomidiurn was also synonymised with Chaetomiurn (Wang et al. 2016).

The aim of the present study was to conduct a global investigation of the species diversity of indoor Chaetomiaceae in the context of advanced taxonomy and chemical analysis. The results would not only be a useful tool for the identification of indoor Chaetomiaceae and evaluation of their chemical potential, but also provide new insights into the phylogeny of the Chaetomiaceae.

**MATERIALS AND METHODS**

**Isolates**

This study is based on a collection of isolates from indoor environments of 19 countries which are housed in the working collection of the Department of Applied and Industrial Mycology (DTO), and of those which were assigned to species of Chaetomiaceae and housed in the public collection of the CBS-KNAW Fungal Biodiversity Centre, Utrecht, The Netherlands (CBS). The strains isolated from dust were collected and isolated as previously described (Amend et al. 2010). Briefly, sterilised dust stream collectors (Indoor Biotechnologies) were attached to domestic vacuum cleaners for collection. Samples were filtered through a 2-mm sieve and refrigerated at 4 °C until further processing. The samples were analysed by a modified dilution-to-extinction plating technique (Visagie et al. 2014). Air samples were collected approx 1 m above the ground with a viable impaction sampler (MAS 100 Merck) and indoor surfaces (i.e. walls, ceilings) were sampled with a swab (Greiner Bio-One, Alphen aan de Rijn, The Netherlands). The air and swab samples were analysed using standard microbiological techniques. Agar media used for the isolation of the Chaetomiaceae strains include malt extract agar (Oxoid Ltd, Hampshire, UK) and dichloran 18 % glycerol (DG18: Oxoid Ltd, Hampshire, UK) agar. Petri dishes were incubated at room temperature or 25 °C, and inspected regularly. Metabolite extraction was performed on a subset of the representative isolates comprising the major indoor species in Chaetomiaceae. All the isolates used in this study are listed in Table 1.

**DNA phylogeny**

Genomic DNA was extracted from 7- to 15-d-old cultures grown on oatmeal agar (OA) using the UltraClean™ Microbial DNA Isolation Kit (Mo Bio Laboratories, Inc., Solana Beach, CA, USA) following the manufacturer's instructions. The primers used for PCR amplification and sequencing included: RPB2AM-tbf & RPB2AM-7R (Miller & Huhndorf 2005) for the partial second subunit of DNA-directed RNA polymerase II (rpb2) gene region; ITS5 & ITS4 (White et al. 1990) for the internal transcribed spacer regions (ITS) and intervening 5.8S nrRNA gene region, NL1 & NL4 (O'Donnell 1993) for the D1/D2 domains of the 28S nrDNA (LSU); T1 (O'Donnell & Cigelnik 1997) and TUB4Rd (Groenewald et al. 2013) for the partial beta-tubulin (tub2) gene region. The PCR conditions were the same as those described by Wang et al. (2016). Each of the amplicons was sequenced with the ABI Prism® Big Dye™ Terminator v. 3.1 Cycle Sequencing Kit. Samples were analysed on an ABI PRISM 3710 xl Genetic Analyzer. Consensus sequences for each locus were assembled using the forward and reverse sequences with the programme MEGA v. 6 (Tamura et al. 2013). Novel sequences generated in this study were deposited in GenBank (http://www.ncbi.nlm.nih.gov, Table 1).

Besides the sequences generated in this study, additional sequences were retrieved from GenBank. The sequence datasets were aligned using MAFFT v. 7 (Katoh & Standley 2013), and manually optimised using BioEdit v. 5.0.9 (Hall 1999). Congruency between the four loci was tested using the 70 % reciprocal bootstrap criterion (Mason-Gamer & Kellogg 1996, Gueidan et al. 2007, Lombard et al. 2010).
| Genus and species | Culture accession number(s)1 | Previous name | Origin | GenBank accession numbers2 |
|------------------|-----------------------------|---------------|--------|--------------------------|
|                 |                             |               |        | ITS | LSU | rpb2 | tub2 |
| Achaetomium      |                             |               |        |     |     |      |      |
| **Ach. globosum**| CBS 332.67 T                | **Ch. atrobrunneum** | Mouldy mattress, Solomon Islands | JX280771 JX280666 KX976798 KX976916 |
|                 | CBS 619.68                  | **Ch. aureum** | Virginia, USA | KX976582 KX976707 KX976806 KX976924 |
|                 | CBS 544.83                  | **Ch. cupreum** | Dung of hyrax, East Africa | KX976583 KX976708 KX976807 KX976925 |
|                  | CBS 152.97 T               | **Ch. fusiforme** | Dung of mouse, Mietta Hot Springs, Canada | KX976584 KX976709 KX976808 KX976926 |
|                  | CBS 333.67 T               | **Ch. gelatinosum** | Soil, Qus, Egypt | KX976580 KX976705 KX976804 KX976922 |
|                  |                             | **Ch. flavigenum** | Soil, Johannesburg, South Africa | KX976587 KX976712 KX976811 KX976929 |
|                  |                             | **Ch. turgidopilosum** | Top of storage tent, USA | KX976588 KX976713 KX976812 KX976930 |
| Botryotrichum    |                             |               |        |     |     |      |      |
| **B. atrogriseum** | CBS 130.28 T | **Ch. atrobranches** | Dung of rabbit, The Netherlands | KX976589 KX976714 KX976813 KX976931 |
|                  | CBS 604.69                  | **Ch. murorum** | Great Smoky Mts., Tennessee, USA | KX976591 KX976716 KX976815 KX976933 |
|                  | CBS 163.52 T               | **Ch. spirotrichum** | Dung of donkey, Algeria | KX976602 KX976727 KX976826 KX976944 |
|                  |                             | **Emilmuelleria spirotricha** | Dung of deer, California, USA | KX976601 KX976726 KX976825 KX976943 |
|                  |                             |               |        |     |     |      |      |
| Chaetomium       |                             |               |        |     |     |      |      |
|                  |                             | **C. cervicicola** | Dust, Mexico | KX976603 KX976728 KX976827 KX976945 |
|                  |                             | **C. coarctatum** | Air, China | KX976604 KX976729 KX976828 KX976946 |
|                  |                             | **C. cochliodes** | Air, Maastricht, The Netherlands | KX976605 KX976789 KX976947 |
|                  |                             |               |        |     |     |      |      |

(continued on next page)
| Genus and species | Culture accession number(s)¹ | Previous name | Origin       | GenBank accession numbers² |
|-------------------|-----------------------------|--------------|--------------|---------------------------|
|                   |                             |              |              | ITS   | LSU   | rpb2 | tub2 |
| DTO 319-B5; DTO 319-B6 | Dust, South Africa        | KX976607    | KX976730    | KX976829 | KX976949 |
| DTO 318-I*; DTO 318-H2; DTO 318-H4; DTO 318-H5; DTO 318-H7; DTO 318-H8; DTO 318-I3; DTO 318-I5; DTO 318-I6; DTO 318-I8; DTO 319-A1; DTO 319-B5; DTO 319-B6; DTO 325-F7 | Dust, USA | KX976608    |               | KX976950 |
| DTO 318-H9*; DTO 318-G7 | Dust, USA        | KX976609    | KX976731    | KX976830 | KX976951 |
| DTO 319-B3* | Dust, Australia        | KX976610    | KX976732    | KX976831 | KX976952 |
| DTO 333-E5 | Dust, Denmark        | KX976611    |               | KX976953 |
| CBS 142034 neoT (≈ DTO 333-E9 = IBT 42179) | Cardboard, Denmark | KX976612    | KX976733    | KX976832 | KX976954 |
| DTO 333-F8 (≈ IBT 42329) | Gypsum, Denmark       | KX976613    |               | KX976955 |
| DTO 134-D9; DTO 134-E1; DTO 134-E2; DTO 134-E3; DTO 134-E4; DTO 134-E5 | Air, Algeria | KX976614    |               | KX976956 |
| DTO 318-G3; DTO 318-G4; DTO 318-G5 | Dust, Canada | KX976615    |               | KX976957 |
| DTO 324-D7; DTO 324-G8; DTO 324-H1; DTO 324-H4; DTO 324-H5; DTO 324-I1; DTO 324-I2; DTO 324-I3; DTO 324-I4; DTO 324-I5; DTO 324-I6; DTO 324-I7; DTO 324-I8; DTO 324-I9; DTO 325-A1; DTO 325-A2; DTO 325-A3; DTO 325-A4 | Air, China | KX976616    |               | KX976958 |
| CBS 666.82* | Chili powder, China | KX976617    | KX976734    | KX976833 | KX976959 |
| DTO 333-D7 (= IBT 42328); DTO 333-D8 (= IBT 42326); DTO 333-D9 (= IBT 42327); DTO 333-F4 (= IBT 42297); DTO 333-F5 (= IBT 42299); DTO 333-F6 (= IBT 42301); DTO 333-F7 (= IBT 42325); DTO 333-E1 (= IBT 41766); DTO 333-E2 (= IBT 41777) | Gypsum, Denmark | KX976618    |               | KX976960 |
| DTO 333-E9* (≈ IBT 41800) | Linoleum, Denmark | KX976620    | KX976735    | KX976834 | KX976962 |
| DTO 333-E14 (= IBT 41801) | Carpet, Denmark | KX976621    |               | KX976963 |
| DTO 333-E7 (= IBT 42176) | Oriented strand board, Denmark | KX976622    |               | KX976964 |
| CBS 112386; DTO 340-i2 | Indoor environment, Germany | KX976623    |               | KX976965 |
| DTO 012-F3 | Air, Hamburg, Germany | KX976624    |               | KX976966 |
| DTO 012-D2 | Air, Koln, Germany | KX976625    |               | KX976967 |
| DTO 237-D4 | Air, Indonesia | KX976626    |               | KX976968 |
| DTO 319-B2*; DTO 319-A3; DTO 319-A4; DTO 319-A5; DTO 319-A6; DTO 319-A7; DTO 319-A8; DTO 319-A9; DTO 319-B1 | Dust, Mexico | KX976627    | KX976736    | KX976835 | KX976969 |
| DTO 085-E8; DTO 085-F5; DTO 085-F6 | Air, Baarn, The Netherlands | KX976628    |               | KX976970 |
| DTO 122-H9 | Air, Gorinchem, The Netherlands | KX976629    |               | KX976971 |
| DTO 123-D4 | Air, Zutphen, The Netherlands | KX976630    |               | KX976972 |
| DTO 264-C1 | Wall in house, Wassenaar, The Netherlands | KX976631    |               | KX976973 |
Table 1. (Continued).

| Genus and species | Culture accession number(s) | Previous name | Origin | GenBank accession numbers |
|-------------------|-----------------------------|---------------|--------|--------------------------|
| **Collariella**    |                             |               |        |                          |
| Col. bostrychodes  | CBS 163.73                  | Ch. bostrychodes | Dung of antelope, East Africa | KX976641 KX976738 KX976837 KX976983 |
|                   | CBS 586.83                  |               | Soil, Germany                  | KX976642 KX976739 KX976838 KX976984 |
| DTO 319-C4        |                             |               | Dust, Indonesia                | KX976643 KX976985 |
| DTO 324-H3; DTO 324-H6* |                   |               | Air, China                    | KX976644 KX976740 KX976839 KX976986 |
| CBS 121706        |                             |               | Commercial honey, Spain        | KX976645 KX976987 |
| Col. causiiformis | CBS 792.83* T               | Ch. causiiform | Sweatband of helmet liner, Solomon Islands | KX976646 KX976741 KX976840 KX976988 |
| Col. carteri      | CBS 128.85* T               |               | Air, British Columbia, Canada  | KX976647 KX976742 KX976841 KX976989 |
| Col. gracilis     | CBS 146.60 T                | Ch. gracile    | Soil, Tsu, Mie, Japan          | KX976648 KX976743 KX976842 KX976990 |
| CBS 249.75*      |                             |               | Air, Uttar Pradesh, India      | KX976649 KX976744 KX976843 KX976991 |
| Col. quadrangulata| CBS 142.58                 | Ch. quadrangulatum | Soil, French Polynesia | KX976650 KX976745 KX976844 KX976992 |
|                   | CBS 152.59                  |               | Dung of rabbit, Derbyshire, Chatsworth Park, England | KX976651 KX976746 KX976845 KX976993 |
| Col. robusta      | CBS 551.83 T                | Ch. robustum   | Litter, Portland Parish, Jamaica | KX976652 KX976747 KX976846 KX976994 |
|                   | CBS 508.84                  |               | Woodlot soil, Ocho Rios, Jamaica | KX976653 KX976748 KX976847 KX976995 |
| Col. virescens    | CBS 148.68 T                | Ch. virescens  | Agricultural soil, Lahore, Pakistan | KX976654 KX976749 KX976848 KX976996 |
|                   | CBS 547.75                  |               | Wheat straw compost, Ludhiana, Punjab | KX976655 KX976750 KX976849 KX976997 |
| Corinascella     | CBS 337.72 T                |               | Soil, Piedmont, North Carolina, USA | KX976656 KX976751 KX976850 KX976998 |
|                   | CBS 379.74                  |               | Soil, Piedmont, North Carolina, USA | KX976657 KX976752 KX976851 KX976999 |
| Dichotomopilus   | CBS 162.48 T                | Ch. dolichotrichum | Great Smoky Mts., USA | HM449049 HM449063 KX976852 JF772462 |
| D. dolichotrichus | CMMCC 3.14189               |               | Discarded cloth, Longing, Jilin Province, China | HM449048 HM449062 KX976853 JF772455 |
| D. erectus       | CBS 140.56 T                | Ch. erectum    | Petroselium sativum, USA       | HM449044 HM449058 KX976854 JF772458 |
|                   | CMMCC 3.12900               |               | Soil, Anqiu, Shandong Province, China | K109760 K109760 KX976855 K109778 |
| D. funicola      | CBS 159.52 eT               | Ch. funicola   | Germany                         | GU563369 GU563354 KX976856 JF772461 |
|                   | CBS 136.38                  |               | Unknown                         | HM449046 HM449060 KX976857 JF772457 |
| DTO 333-F1*; DTO 333-F2* |                   |               | Dust, outdoors, Denmark        | KX976658 KX976753 KX976858 KX977000 |
| DTO 318-I2       |                             |               | Dust, USA                       | KX976659 KX977001 |
| D. fusus         | CBS 372.66 T                | Ch. fusum      | Leaf litter, Bataan, Costa Rica | KX976660 KX976754 KX976859 KX977002 |
|                   | CBS 114.83                  |               | Tectona grandis or calyx, Jamaica | KX976661 KX976755 KX976860 KX977003 |
| D. indicus       | CMMCC 3.14184 eT            | Ch. indicum    | Rhizosphere of Panax notoginseng, Yunnan, China | GU563367 GU563360 KX976861 JF772453 |

(continued on next page)
| Genus and species | Culture accession number(s) | Previous name | Origin | GenBank accession numbers  |
|-------------------|-----------------------------|---------------|--------|---------------------------|
|                  |                             |               |        | **ITS** | **LSU** | **rpb2** | **tub2** |
| CGMCC 3.14182    |                             |               |        | GU563366 | GU563358 | KX976862 | JF772451 |
| DTO 333-E2*      |                             |               |        | KX976662 | KX976756 | KX976863 | KX977004 |
| DTO 333-F3*      |                             |               |        | KX976663 | KX976757 | KX976864 | KX977005 |
| DTO 319-B8*      |                             |               |        | KX976664 | KX976758 | KX976865 | KX977006 |
| D. pratensis     | CBS 133396 T (= CGMCC 3.14181) | Ch. pratense | Soil, Huangnan, Qinghai Province | GU563372 | GU563357 | KX976866 | JF772450 |
|                  | CBS 804.83                  |               | Wood of celer, Switzerland | KX976665 | KX976759 | KX976867 | KX977007 |
|                  | CBS 860.68*                 | Ch. indicum   | Air, Germany | KX976666 | KX976760 | KX976868 | KX977008 |
| D. pseudoberecctus | CBS 252.75*                |               | Air, Uttar Pradesh, India | KX976667 | KX976761 | KX976869 | KX977009 |
| D. pseudofunicola | CBS 142033 T (= DTO 318-I7)* |             | Dust, USA | KX976668 | KX976762 | KX976870 | KX977010 |
| D. ramosissimus  | CGMCC 3.14183 T             | Ch. ramosissimum | Rhizosphere of Panax Notoginseng, Yunnan, China | GU563371 | GU563361 | KX976871 | JF772452 |
|                  | CGMCC 3.12930               |               | Soil, Huanggang, Hubei Province | HM449045 | HM449059 | KX976872 | JF772449 |
| D. reflexus      | CBS 157.49 T                | Ch. reflexum  | Germiinating seed, Toledo, Ohio, USA | HM449051 | HM449055 | KX976873 | JF772460 |
| D. subfunicola   | CBS 132892 T (= CGMCC 3.14181) | Ch. subfunicola | Soil, Shihezi, Xinjiang Autonomous Region | KX976669 | KX976763 | KX976874 | KX977011 |
|                  | CGMCC 3.9466                |               | Rhizosphere of Panax Notoginseng, Yunnan, China | GU563368 | GU563353 | KX976876 | JF772446 |
|                  | CBS 812.73*                 | Pistol belt, New Guinea | KX976670 | KX976764 | KX976877 | KX977012 |
| D. variostiolatus| CBS 794.83*                 | Paper, Switzerland | KX976671 | KX976765 | KX976878 | KX977013 |
| DTO 319-A2*      | CBS 179.84* T (= CGMCC 3.14181) | Ch. variostiolatum | Tarpaulin, New Guinea | KX976672 | KX976766 | KX976879 | KX977014 |
| DTO 319-B9*; DTO 319-C1 |               | Dust, USA | KX976673 | KX976767 | KX976880 | KX977015 |
|                 | CBS 818.73*                 | Pistol belt, New Guinea | KX976671 | KX976765 | KX976878 | KX977013 |
| Humicola         | CBC 118.14 T                |               | Soil, Norway | KX976675 | KX976769 | KX976882 | KX977017 |
| H. fuscoatra     | CBC 142031 T (= DTO 319-C7)* |              | Dust, USA | KX976676 | KX976770 | KX976883 | KX977018 |
| H. olivacea      | CBC 583.83 T                |               | Dust, Mexico | KX976677 | KX976771 | KX976884 | KX977019 |
| Humicola sp.     | CBC 111.69 T                |               | Dust, South Africa | KX976678 | KX976772 | KX976885 | KX977020 |
| Melanocarpus     | CBC 638.94 T                | Chicken nest straw, Nevada, USA | KX976679 | KX976773 | KX976886 | KX977021 |
| Me. albomyces    | CBC 747.70                  | Coal pit refuse, UK | KX976680 | KX976774 | KX976887 | KX977022 |
| Me. tardus       | CBC 541.76* T               | Cotton jacket, Switzerland | KX976681 | KX976775 | KX976888 | KX977023 |
| Mycroft phthora  | CBC 406.69 T                | Mushroom compost, Pennsylvania, USA | HQ871794 | KX976776 | HQ871815 | KX977024 |
| My. heterothalica| CBC 202.75                  | Garden soil, Giessen, Germany | HQ871771 | KM655354 | HQ871798 | KX977025 |
| My. lutea        | CBC 145.77 neoT             | Hay, Newmarket, UK | HQ871775 | KM655351 | HQ871816 | KX977026 |
| My. sepedonium   | CBC 111.69 T                | Soil, Allahabad, India | HQ871751 | KX976777 | HQ871827 | KX977027 |
| My. thermophila  | CBC 669.85                  | Cellulase, USA | HQ871767 | KX976778 | HQ871806 | KX977028 |
|                  | CBC 381.97                  | Homo sapiens, Unknown | HQ871766 | KX976779 | HQ871805 | KX977029 |
| Ovatospora       | CBC 130174                  | Ch. brasiliense | Soil, Colombia | KX976682 | KX976780 | KX976895 | KX977030 |
|                  | CBC 140.50*                 | Moist jute cloth, Calcutta, India | KX976683 | KX976781 | KX976896 | KX977031 |
| O. medusarum     | CBC 148.67 T                | Ch. medusarum  | Soil, Zaire | KX976684 | KX976782 | KX976897 | KX977032 |
| O. mollicella    | CBC 583.83 T                | Ch. mollicellum | Dung of spotted skunk, Washington, USA | KX976685 | KX976783 | KX976898 | KX977033 |
| O. pseudomollicella | CBC 251.75* T             | Air, Uttar Pradesh, India | KX976686 | KX976784 | KX976899 | KX977034 |
| O. senegalensis  | CBC 726.84 T                | Ch. senegalense | Plant remains, Senegal | KX976687 | KX976785 | KX976900 | KX977035 |
|                  | CBC 798.83                  | Dung of gazelle, Israel | KX976688 | KX976786 | KX976901 | KX977036 |
The ITS region was used to initially screen the collection of fungi from the indoor environments in order to select members of the Chaetomiaceae. The tub2 gene region was used to recognise the species diversity within the indoor Chaetomiaceae isolates. The phylogenetic placement of the indoor isolates was determined using four loci (ITS, partial LSU, tub2 and partial rpb2) on the basis of the evaluation in a previous study (Wang et al. 2016), and representatives of related species and genera in the Chaetomiaceae were included as references in the final phylogenetic analyses. Phylogenetic analyses were based on Bayesian inference (BI), Maximum Likelihood (ML) and Maximum Parsimony (MP) as described previously (Wang et al. 2016). For BI, the best evolutionary model for each locus was determined using MrModeltest v. 2.0 (Nylander 2004). Obtained trees were viewed in FigTree v. 1.1.2 (Rambaut 2009). The alignment and derived trees were deposited in TreeBASE (submission ID 20347; http://treebase.org/treebase-web/home.html).

Morphology

Colony morphology was determined by inoculating strains onto four different media (Samson et al. 2010): OA, potato carrot agar (PCA), malt extract agar (MEA, Oxoid), and Dichloran 18 % glycerol agar (DG18), incubated in the dark at 25 °C for 7 d. Microscopic observation was performed on 15-d-old cultures grown on PCA, MEA and potato dextrose agar (PDA) (Samson et al. 2010), sometimes on OA. For the observations of the asexual morphology, SNA (spezieller nachwachsstoffarmiger agar) was used (Samson et al. 2010).

Metabolite extraction of pure cultures

Metabolite profiling was performed on 15-d-old cultures grown on MEA and potato dextrose agar (PDA) (Samson et al. 2010), where three agar plugs (6 mm diam) were cut across one colony from each agar medium and pooled in a 2 mL Eppendorf tube. One mL extraction solvent (ethyl acetate-2-propanol (3:1; vol/vol) containing 1 % formic acid) was added to each vial and the plugs were extracted in a sonication bath for 60 min. The extract was then transferred to a clean 2 mL Eppendorf tube and evaporated to dryness in a stream of N2. The dried extract was subsequently re-dissolved in 400 μL methanol in a sonication bath for 30 min, centrifuged for 3 min at 15 000 g, and transferred to a clean auto sampler vial.

| Genus and species | Culture accession number(s) | Previous name | Origin | GenBank accession numbers |
|-------------------|-----------------------------|---------------|--------|--------------------------|
| O. unipora        | CBS 109.83 T                | Ch. uniporum  | Soil, Egypt | KX976688 KX976787 KX976902 KX977037 |
| S. anamorphosha   | CBS 137114 T                | Ch. anamorphosha | Peritotics of Homo sapiens, Kuwait | KP862598 KP970641 KP900667 KP9800704 |
| S. asteroides     | CBS 123294 T                | Keratitis of Homo sapiens, USA | H906667 JX280731 KP060066 KP9800703 |
| S. cristata       | CBS 156.52 T                | Ch. cristatum | Dung of rabbit, Virginia, USA | JX280843 JX280732 KP060056 KP9800695 |
| S. cuniculorum    | DTO 324-H8; DTO 324-H7      | Ch. cuniculorum | Soil, Spain | KX976691 KX976789 KX976904 KX977039 |
| S. fusispora      | CBS 199.84                  | Ch. fusisporum | Dung of marmot, Alberta, Canada | KP862601 KP970645 KP900653 KP900707 |
| S. flavipila      | CBS 446.66 T                | Ch. irregular | Dead leaves, Bulgaria | KP862600 KP970647 KP900669 KP9800706 |
| S. obscura        | CBS 227.82                  | Ch. obscura   | Dung, Spain | KP862599 KP970646 KP900668 KP9800705 |
| S. thieliavoides  | CBS 122.78 T                | Ch. thieliavoides | Tinea pedis of Homo sapiens, Kuwait | KP862597 KP970654 KP900670 KP900708 |
| T. appendiculata  | CBS 731.68                  | Ch. appendiculata | Dung of rabbit, Wales | KX976693 KX976791 KX976907 KX977042 |
| T. fragilis       | CBS 456.73 T                | Ch. fragilis  | Rhizosphere of Pennisetum typhoideum in garden soil, Tamil Nadu, India | KX976693 KX976791 KX976907 KX977042 |
| T. hircaniae      | CBS 353.62 T                | Ch. hircaniae | Soil, Iran | KM655329 KM655368 KX976908 KX977043 |
| T. kuwaitensis    | CBS 945.72 T                | Ch. kuwaitensis | Desert soil, Kuwait | KM655322 KM655371 KX976909 KX977044 |
| T. terricola      | CBS 165.88                  | Ch. terricola | Barren soil, North Carolina, USA | KX976694 KX976792 KX976910 KX977045 |
| Microascus        | CBS 218.31 T                | Microascus    | USA | LM652443 HG380436 DQ470908 LM652655 |

T. eT and neoT denote ex-type, ex-epitype and ex-neotype cultures respectively.

1 The isolates from the indoor environments are highlighted in bold.

2 The newly generated sequences in this study are shown in bold; where multiple culture numbers are listed in the row only the sequences from the first culture was deposited in GenBank.

3 The isolates that were analysed for their metabolite production.

4 Here only the sequences of the representatives of indoor Chaetomium sensu stricto species are provided. For the information of other Chaetomium species please see in our previous study (Wang et al. 2016).
UHPLC-DAD-QTOF-MS analyses

Samples (0.5 μL) were analysed using ultra-high performance liquid chromatography-diode array detection-quadrupole time of flight mass spectrometry (UHPLC-DAD-QTOF-MS) on an Agilent Infinity 1290 UHPLC system (Agilent Technologies, Santa Clara, California, USA) equipped with a DAD detector scanning 200–640 nm. Metabolites were separated on an Agilent Poroshell 120 phenyl-hexyl column (2.1 x 250 mm, 2.7 μm) using a linear gradient of solvents consisting of water (A) and acetonitrile (B) buffered with 20 mM formic acid. The gradient started at 10 % B and increased to 100 % in 15 min where it was held for 2 min (Kildgård et al. 2014). The flow rate was 0.35 mL/min and the column temperature was 60 °C. Mass spectrometry detection was performed in ESI+ mode on an Agilent 6545 QTOF MS equipped with Dual Jet Stream electrospray ion source, using hexakis-(2,2,3,3-tetrafluoropropoxy) phosphazene as the lock mass. Other MS parameters, including Auto-MS/HRMS, can be found in Kildgård et al. (2014).

Secondary metabolites were identified by aggressive dereplication of the full HRMS (high resolution mass spectrometry) data against a list of possible known compounds that have been described in the literature as well as comparison to 1 500 fungal secondary metabolites. All samples were further analysed for peaks not detected by the previous approach, and those were matched against Antibase2012 for a tentative identification. Metabolites that did not match were considered as novel compounds and their elemental composition was determined from the accurate mass (±2 ppm) and isotopic pattern (Kildgård et al. 2014, Dosen et al. in press). The peak areas of [M+H]⁺, [M+Na]⁺ or [M+H₂O]⁺ of all the compounds, including the tentatively identified and the novel compounds, were then integrated in the Agilent MassHunter Quant software using extracted ion chromatograms ±12 ppm and the peak areas for multivariate data analysis.

RESULTS

Isolates

A total of 145 indoor isolates (Table 1, in bold font) were identified as members of Chaetomiaceae after the ITS sequencing. A further selection of 45 representative indoor isolates was made based on the tub2 gene sequences, combined with an examination of the macro- and micromorphology. Similar isolates were excluded and strains that possibly represent different species were included in the detailed morphological examination and four-locus analyses. Thirty-eight representative isolates (Table 1, marked with *) were included in the metabolite analysis.

Phylogeny

The phylogenetic analysis of tub2 gene region placed the indoor isolates into 30 well-supported clades in 10 distinct monophyletic lineages (Tables 1, 2). The preliminary identification based on the tub2 locus was confirmed by the four-locus analysis on the basis of a dataset consisting of 45 representative indoor isolates and representative isolates of related genera and species. Only the concatenated phylogenetic tree was presented with the bootstrap proportions (≥ 50 %) from ML or MP analyses and posterior probabilities (≥ 0.95) from Bayesian analyses plotted on the phylogramme to show statistical support (Fig. 1).

The multigene analyses contained 183 strains, including Microascus trigonosporus (CBS 218.31) as outgroup taxon. No topological conflicts were found when comparing the 70 % bootstrap reciprocal tree topologies based on the rpb2 and tub2 datasets. The minor incongruences observed for the ITS and LSU sequence data set failed to resolve some of the species, especially those in the Ch. globosum species complex recovered by each of the two protein-coding gene regions used here. All four loci were combined following recommendations of Cunningham (1997). The concatenated alignment consisted of 2 790 characters (including alignment gaps): 525, 968, 724 and 573 characters used in the rpb2, tub2, ITS and LSU partitions, respectively. Of these, 1 122 characters were constant, 339 characters parsimony-uninformative and 1 265 characters parsimony-informative. For the Bayesian inference, a GTR+I+G model was selected for rpb2, ITS and LSU and a HKY+I+G model for tub2. These models were incorporated into the analysis. A total of 23 822 trees were generated during the Bayesian inference, of which 5 956 trees were discarded as the “burnin-phase” and posterior probabilities (PP) were calculated from the remaining 17 866 trees. The BI consensus tree and PP confirmed the tree topologies and bootstrap support (BS) values obtained with the ML and MP analyses. The MP analysis yielded 136 equally most parsimonious trees (TL = 11 252; CI = 0.299; RI = 0.822; RC = 0.245). The BI consensus tree is presented (Fig. 1) with the respective MP- and ML-BL values indicated at the nodes.

The concatenated phylogenetic analyses revealed the Ch. globosum species complex (Wang et al. 2016) (MP-BS = 86; ML-BS ≤ 50; PP = 0.95) and 13 other monophyletic clades (Fig. 1). Six known genera were supported: Achaetomium including the type species A. globosum (MP-BS = 100; ML-BS = 89; PP = 0.95), Corynascella represented by the type species Cor. humicola (MP-BS = 100; ML-BS = 100; PP = 1.0), Humicola represented by the type species H. fuscoatra (MP-BS = 92; ML-BS = 95; PP = 0.99), Melanocarpus represented by the type species M. albomyces (MP-BS = 93; ML-BS = 97; PP = 0.99), Myceliophthora including the type species My. lutea (MP-BS = 96; ML-BS = 99; PP = 0.97), and Thielavia including five species (MP-BS = 98; ML-BS = 98; PP = 0.99). Elimiumella and Ch. murorum clustered in the Botryotrichum clade (MP-BS = 100; ML-BS = 99; PP = 1.0), which is represented by the type species B. piluliferum and two other Botryotrichum species. Chaetomium cristatum, Ch. curvulatum, Ch. irregularae, Ch. anamorphosum and Ch. fusisporum clustered in the Subramaniula clade (MP-BS = 100; ML-BS = 100; PP = 1.0).

Fig. 1. Consensus phylogram (50 % majority rule) resulting from a Bayesian analysis of the concatenated rpb2, tub2, ITS and LSU gene region alignment, with the confidence values of bootstrap proportions from the MP analysis (before the backslash), the ML analysis (after the backslash) above branches, and the posterior probabilities from the Bayesian analysis below branches. The “-” means lacking statistical support (<50 % for bootstrap proportions from ML or MP analyses; <0.95 for posterior probabilities from Bayesian analyses). The branches with full statistical support (MP-BS = 100 %; ML-BS = 100 %; PP = 1.0) are highlighted by thickened branches. Generic novelties are indicated with "gen. nov." after the genus name and the genus names of the species are abbreviated to facilitate layout of the tree. Genus and species clades are discriminated with boxes of different colours. The 45 isolates from the indoor environment are indicated with a red star on the right side of the culture number; these isolates are representative of all the indoor species recognised in this study. The scale bar shows the expected number of changes per site. The tree is rooted with Microascus trigonosporus strain CBS 218.31 (see Table 1 for GenBank accession numbers).
Fig. 1. (Continued).
| Species names          | Algeria | Australia | Canada | China | Cuba | Denmark | Germany | India | Indonesia | Mexico | The Netherlands | New Guinea | Solomon Islands | South Africa | Spain | Switzerland | Thailand | Uruguay | USA | Per species | Per genus |
|------------------------|---------|-----------|--------|-------|------|---------|---------|-------|-----------|--------|----------------|------------|----------------|-------------|-------|-------------|----------|---------|-----|-------------|------------|
| **Amesia atrobrunnea** | 1       |           |        |       |      |         |         |       |           |        |                |            |                |             |       |             |          |         |     |            |            |
| **Am. cymbiformis**    |         |           |        |       |      |         |         |       |           |        |                |            |                |             |       |             |          |         |     |            |            |
| **Am. nigricolor**     | 1       |           |        |       |      |         |         |       |           |        |                |            |                |             |       |             |          |         |     |            |            |
| **Arcopilus turgidopilosus** | 1   | 1         |        |       |      |         |         |       |           |        |                |            |                |             |       |             |          |         |     |            |            |
| **Botryotrichum murorum** | 2   | 1         |        |       |      |         |         |       |           | 4     |                |            |                |             |       |             |          |         |     |            |            |
| **B. piluliferum**     |         |           |        |       |      |         |         |       |           | 5     |                |            |                |             |       |             |          |         |     |            |            |
| **B. peruvianum**      |         |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Chaetomium cervicicola** | 1   | 1         |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Ch. coarctatum**     | 1       |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Ch. cochliodes**     |         |           |        |       |      |         |         |       |           | 3     | 2               | 12         | 17             |             |       |             |          |         |     |            |            |
| **Ch. elatum**         | 1       |           | 3      |       |      |         |         |       | 1         | 9     | 11             | 1          | 1              | 6           | 74    |             |          |         |     |            |            |
| **Ch. globosum**       | 6       | 3         | 19     |       |      |         |         | 13    | 3         | 1     | 9              | 1          | 1              | 6           | 74    |             |          |         |     |            |            |
| **Ch. testiferni**     |         |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Collariella bostrychodes** | 2  | 1         | 4      |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Col. caesiiformis**  |         |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Col. carteri**       | 1       |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Col. gracilis**      |         |           | 1      |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Dichotomopilus funicola** | 2  | 1         | 3      |       |      |         |         |       |           | 3     | 1              |            |                |             |       |             |          |         |     |            |            |
| **D. indicus**         | 2       |           | 1      |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **D. pratensis**       | 1       |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **D. pseudoeoerectus** |         |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **D. pseudofunicola**  |         |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **D. subfunicola**     | 1       | 1         |        |       |      |         |         |       |           | 2     |                |            |                |             |       |             |          |         |     |            |            |
| **D. variostiolatus**  | 1       | 2         | 1      |       |      |         |         |       |           | 4     |                |            |                |             |       |             |          |         |     |            |            |
| **Humicola olivacea**  | 1       | 1         | 4      |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Humicola sp.**       | 2       | 1         |        |       |      |         |         |       |           |       |                |            |                |             |       |             |          |         |     |            |            |
| **Melanocarpus tardus** |         |           | 1      |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Ovatospora brasilienis** | 1  |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **O. pseudomollicella** |         |           |        |       |      |         |         |       |           | 1     |                |            |                |             |       |             |          |         |     |            |            |
| **Subramaniula cristata** | 2  |           | 2      |       |      |         |         |       |           | 2     |                |            |                |             |       |             |          |         |     |            |            |
| **Totals**             | 6       | 1         | 4      | 26    | 1     | 21      | 4       | 6     | 2         | 12    | 18             | 2          | 3              | 5           | 1     | 2            | 3        | 1      | 27 | 145         |            |
represented by the type species *S. thielavioides*. The *Botryotrichum* and *Subramaniula* clades formed sisters to each other (MP-BS = 54; ML-BS = 97; PP = 1), which clustered closely with the *Humicola* clade to another indoor isolate (DTO 319-C7) and clustered with other known species complex, but with no statistical support for their relationships. Four others included: the *Ch. atrobrunneum* clade (MP-BS = 100; ML-BS = 99; PP = 1.0), the *Ch. aureum* clade (MP-BS = 100; ML-BS = 100; PP = 1.0), the *Ch. brasiileiense* clade (MP-BS = 99; ML-BS = 99; PP = 0.98) and the *Ch. bostrychodes* clade (MP-BS = 100; ML-BS = 99; PP = 0.99). They were distant from the *Ch. globosum* species complex and separated by the *Achaetomium*, *Botryotrichum*, *Corynascus*, *Melanocarpus*, *Myceliophthora*, *Subramaniula* and *Thielavia* generic clades. The presented topology received little to no statistical support for most of these.

Four known species were originally isolated from indoor environments or from materials associated with human lives, namely *Ch. atrobrunneum* (ex-type CBS 379.66, from moudly mattress), *Ch. cauasilforme* (ex-type CBS 792.83, from sweatband of helmet liner), *Ch. turgidopilosum* (ex-type CBS 169.92, from top of a storage tent) and *Ch. variostiolatus* (ex-type CBS 792.83, from tarpaulin). Twenty-eight other representative indoor isolates clustered in 18 known species clades with high statistical support (MP-BS ≥ 93; ML-BS ≥ 93; PP = 1.0), which were represented by their ex-type cultures (seven species), ex-epitype cultures (three species), ex-neotype culture (*Ch. globosum*), or representative strains (seven species), respectively.

Two isolates (DTO 319-B7 and DTO 318-G9) formed a sister clade to another indoor isolate (DTO 319-C7) and clustered with *H. fuscoatra* (ex-type CBS 118.14), the type species of *Humicola*. The isolate CBS 541.76, which is deposited as *Thielavia minuta* in the CBS collection, formed a sister lineage to the type species of *Melanocarpus* (*M. albomyces*, ex-type CBS 638.94), which was distant from the core *Thielavia* clade. The isolate CBS 251.75 formed a sister lineage to the ex-type of *Ch. mollicellum* and the *Ch. brasiileiense* clade (MP-BS = 100; ML-BS = 100; PP = 1.0). Three other isolates (DTO 318-G8, DTO 318-I7 and CBS 252.75) clustered close to but separated from their closest relatives: *Ch. fimeti*, *Ch. funicola* or *Ch. ramosissimum*, respectively. These isolates represent possible novel phylogenetic species.

**Metabolite profiling**

A subset of isolates (Table 3) was extracted and analysed in order to compare their metabolite production. The species names used in this paragraph are based on the newly proposed taxonomy mentioned below. The analyses showed that more than 68 metabolites could be detected, and the structure of 31 compounds is unknown. The majority of the detected metabolites (known and uncharacterised) were produced by isolates belonging to *Chaetomium sensu stricto* and *Dichotomopus*. Table 3 shows the production of 35 known and six unknown metabolites at species level. In general there were no species specific metabolites produced by one species alone, with the exception of the production of chaetosemin A, chaetocardin A, l and K by *H. olivacea* (DTO 319-C7) and sterigmatocystin by *Humicola* sp. (DTO 319-B7). Other metabolites were produced by isolates belonging to various genera and species. For example, cochlidiolin A was produced by *C. globosum*, *D. pratensis*, *B. murorum*, *B. piluliferum*, *S. cristata*, *A. nigricolor*, *O. brasilensis* and *O. pseudomollidica*, and cochlidiolin B was produced by *C. cochlidioides*, *C. pseudofimbriata*, *D. subfunicata*, *D. varist园latus*, *D. fusicola*, *A. cymbiformis*, *Col. bostrychodes* and *Col. carteri*. There were metabolites that were genus specific, and as can be seen from Table 3. Some metabolites, like chaetocardin and chaetomin and chaetoviridin B/C were only produced by *C. coarcctatum* and *C. globosum* whereas chaetocardin A, chaetomin and chaetoviridin B/C were only found in *C. cochlidioides* and *C. pseudofimbriata*.

**TAXONOMY**

Being the type species, *Chaetomium globosum* is affiliated with the *Ch. globosum* species complex (Wang et al. 2016). This species complex was confirmed as a monophyletic lineage in this study, which represents *Chaetomium sensu stricto*. Thirty species found in indoor environments could be accommodated in 10 genera of the *Chaetomiaceae*. Five new genera are established and seven new species described. One *Humicola* species represented by three indoor isolates remains to be compared with other known *Humicola* species and this will be done in future phylogenetic and morphological studies. All the species obtained from indoor substrates, and each of the recognised novel genera in this study are described and illustrated below. The generic concepts of *Subramaniula* and *Botryotrichum* are also expanded.

**Amesia** X. Wei Wang, Samson & Crous, gen. nov. MycoBank MB818829. Fig. 2. **Etymology** Named after L.M. Marion Ames for his contribution to our knowledge of the taxonomy of the *Chaetomiaceae*.

**Type species**: *Amesia atrobrunnea* (Ames) X. Wei Wang & Samson (= *Ch. atrobrunneum*)

Ascomata superficial, ostiolate, spherical, ellipsoid or ovate with walls of texture angularis, intricata or epidemoides in surface view. Terminal hairs straight, flexuous, undulate or spirally coiled. Lateral hairs straight, flexuous, or similar to terminal hairs, but shorter. Asci fasciculate, clavate, broadly clavate or fusiform, stalked, with 8 biseriate or irregularly arranged ascospores, evanescent. Ascospores brown at maturity, usually fusiform, elongate ovate to ovate, with an apical or sub-apical germ pore. Asexual morph unknown.

Notes: Several species of *Amesia* were investigated. These species exhibit a high morphological diversity in both ascomatal hairs and ascospore morphology. An ITS/LSU analysis indicated it to be a monophyletic lineage (de Hoog et al. 2013). Our four-locus phylogeny confirmed the ITS/LSU phylogeny. More
Table 3. Metabolite production by representatives in each of the indoor genera.

| Metabolites              | Genus | Amesia | Arcopilus | Botryotrichum | Chaetomium | Collariella | Dichotomopilus | Humicola | Melanocarpus | Ovumospora | Subramaniula |
|--------------------------|-------|--------|-----------|---------------|------------|-------------|----------------|----------|--------------|------------|--------------|
| Chaetochalasin A         | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetocin A              | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetocin C              | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetocochin C           | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetoglobosins A and C  | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetocinindin           | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetomin                | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetomugilin D          | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetoquadrin E          | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetoquadrins A, I and K| -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetosomin A            | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetoviridin A          | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetoviridin B/C        | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chaetoviridin E          | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chetoseminudin A         | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chochlidiolin A          | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chochlidiolin B          | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Chochlodiones 1–3        | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Dihydroxychaetocin       | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Mollicellin C            | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Mollicellin E            | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Prenisatin               | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Prochaetoglobosins I–IV  | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Rotiorinol               | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |
| Sterigmatocystin         | -     | -      | -         | -             | -          | -           | -              | -        | -            | -          | -            |

(continued on next page)
Table 3. (Continued).

| Genus          | Species                  | Ascomata                     | Culture characteristics |
|----------------|--------------------------|------------------------------|-------------------------|
| Humicola sp.   |                         |                              |                         |
| H. ovacea      |                         |                              |                         |
| D. verticillatus |                         |                              |                         |
| D. suillinica  |                         |                              |                         |
| D. pseudodendroidea |                 |                              |                         |
| D. pseudospathia |                         |                              |                         |
| D. praetextus |                         |                              |                         |
| D. indigens    |                         |                              |                         |
| D. umbrosus    |                         |                              |                         |
| D. angularis   |                         |                              |                         |
| D. candidum    |                         |                              |                         |
| D. carinatum   |                         |                              |                         |
| D. confluens   |                         |                              |                         |
| D. globosum    |                         |                              |                         |
| D. cochliodes  |                         |                              |                         |
| D. cymatodes   |                         |                              |                         |
| D. aschmidii   |                         |                              |                         |
| D. gleboides   |                         |                              |                         |
| D. coeliotriches |                         |                              |                         |
| D. coelosporides |                       |                              |                         |
| D. coelocaudatum |                       |                              |                         |
| D. coelocordatum |                     |                              |                         |
| D. coelomassilis |                      |                              |                         |
| D. coeloceraunum |                     |                              |                         |

| Ascomata         | Metabolites         | Comments |
|------------------|---------------------|----------|
| S. cristata      |                     |          |
| O. pseudomelanospora |               |          |
| O. braasiliensis |                     |          |
| M. tardus        |                     |          |
| O. brasiliensis  |                     |          |
| O. pseudomollicella |              |          |
| S. cristata      |                     |          |
| D. variostiolatus |                     |          |
| D. pratensis     |                     |          |
| H. Ar. turgidopilosus |              |          |
| O. subfunicola   |                     |          |
| D. pseudoerectus |                     |          |
| D. indicus       |                     |          |
| M. nigricolor    |                     |          |
| D. pseudofunicola |                    |          |
| D. funicola      |                     |          |
| C16H23NO3        | ++                  |          |
| C18H28O6         | ++                  |          |
| C28H40O7         | ++                  |          |
| MW306            | ++                  |          |
| MW665            | ++                  |          |

Notes: Several isolates of this species have been reported to cause human systemic and deep infection (Abbott et al. 1995, de Hoog et al. 2013). Our previous temperature test (Li et al. 2012) demonstrated its potential as an invasive human pathogen: the optimum growth temperature is 30–34 °C, and maximum growth temperature 47 °C.

Amesia atrobrunnea (Ames) X. Wei Wang & Samson, comb. nov. MycoBank MB818832. Fig. 3.
Basionym: Chaetomium atrobrunneum Ames, Mycologia 41: 641. 1949.

Ascomata superficial, ostiolate, fuscous black to black in reflected light, subglobose or ovate, 80–160 μm high, 70–140 μm diam. Ascomatal wall brown, textura angularis in surface view. Terminal hairs flexuous, sometimes recurved, smooth, brown, 2–3.5 μm diam. near the base. Lateral hairs

Notes: Several isolates of this species have been reported to cause human systemic and deep infection (Abbott et al. 1995, de Hoog et al. 2013). Our previous temperature test (Li et al. 2012) demonstrated its potential as an invasive human pathogen: the optimum growth temperature is 30–34 °C, and maximum growth temperature 47 °C.

Amesia cymbiformis (Lodha) X. Wei Wang & Samson, comb. nov. MycoBank MB818833. Fig. 4.
Basionym: Chaetomium cymbiforme Lodha, J. Indian Bot. Soc. 43:127. 1963.
Synonym: Chaetomium cymbiforme Lodha, J. Indian Bot. Soc. 43:127. 1963.

Ascomata superficial, ostiolate, greyish sepias when young and olivaceous to dark olivaceous because of the ascospores mass in reflected light, subglobose or ovate, 95–180 μm high, 90–150 μm diam. Ascomata wall brown, textura angularis in surface view. Terminal hairs flexuous, sometimes recurved, smooth, brown, 2–3.5 μm diam. near the base. Lateral hairs
flexuous and shorter. *Asci* fasciculate, clavate or fusiform, spore-bearing part 16–26 × 10.5–13 μm, stalks 7–15 μm long, with 8 irregularly arranged ascospores, evanescent. *Ascospores* olivaceous brown when mature, ovate or ellipsoidal, with attenuated ends, (7–)8–9(–9.5) × (5.5–)6–6.5(–7) μm, with an apical or slightly subapical germ pore at the more attenuated end. *Asexual morph* unknown.

**Culture characteristics**: Colonies on OA with an entire edge, about 33–39 mm diam in 7 d at 25 °C, translucent when young, then greenish olivaceous to olivaceous owing to ascomata together with masses of ascospores, without aerial mycelium, with olivaceous buff to pale luteous exudates diffusing into the medium, reverse pale luteous to grey olivaceous. Colonies on PCA with an entire edge, about 31–37 mm diam in 7 d at 25 °C, translucent, with loose and pale smoke grey aerial hyphae, without coloured exudates; reverse uncoloured. Colonies on MEA white with an entire edge, about 34–40 mm diam in 7 d at 25 °C, non-sporing, with white and floccose aerial hyphae, without coloured exudates, reverse ochraceous. Colonies on DG18 white with an entire edge, about 11–17 mm diam in 7 d at 25 °C, non-sporing, with white and floccose aerial mycelium, without coloured exudates; reverse uncoloured.

Specimens examined: **Solomon Islands**, isolated from tent rope, deposited in the CBS collection by J.C. Krug, culture CBS 175.84 (ex-culture of *Chaetomium cymbiforme*). **USA**, Atlanta, isolated from case liner, deposited in the CBS collection by J.C. Krug, culture CBS 176.84.

**Notes**: *Amesia cymbiformis* is closely related to *Am. atrobrunnea* (Fig. 1), but can be easily distinguished from *Am. atrobrunnea* (Fig. 3) by the shape and size of its ascospores (Fig. 4). Isolate CBS 175.84 was originally studied by Ames and named as *C. serpentinum* without description. Carter (1983) validly published this name after the description of *Ch. cymbiforme* that was originally isolated from cow dung in India (Lodha 1964). After studying the type specimens of *Ch. cymbiforme* and the ex-culture of *Ch. serpentinum*, von Arx et al. (1986) synonymised *Ch. cymbiforme* with *Ch. cymbiforme*. Here we followed von Arx et al. (1986) to accept *Ch. cymbiforme* as the basionym of this species.

*Amesia nigricolor* (Ames) X. Wei Wang & Samson, **comb. nov.** MycoBank MB818834. **Fig. 5.**

**Basionym**: Chaetomium nigricolor Ames, Mycologia 42: 654. 1950.

**Synonym**: Chaetomium amberpetense Rao & Reddy, Mycopath. Mycol. Appl. 24: 114. 1964.

Ascomata superficial, ostiolate, olivaceous grey in reflected light due to ascomatal hairs, subglobose to ovate, 140–300 μm high, 100–255 μm diam. *Ascomatal wall brown*, textura intricata or epidermoidea in surface view. *Terminal hairs* undulate to loosely coiled with erect or flexuous lower part, conspicuously rough (granulate), greyish sepia to brown, septate, 3–4.5 μm diam in the undulate or coiled upper portion. *Lateral hairs* flexuous, undulate or apically circinate. *Asci* fasciculate, clavate to fusiform, spore-bearing part 13.5–21 × 7.5–10.5 μm, stalks 6–11.5 μm long, with 8 irregularly-arranged ascospores, evanescent. *Ascospores* olivaceous brown when mature, ovate, (5.5–)6–7(–7.5) × 4–5(–5.5) μm, with an apical germ pore at the attenuated end. *Asexual morph* unknown.

**Culture characteristics**: Colonies on OA with entire edge, about 42–48 mm diam in 7 d at 25 °C, with sparse white aerial hyphae, with ochraceous to fulvous exudates diffusing into the medium, reverse pale luteous to amber. Colonies on PCA with entire edge, about 35–41 mm diam in 7 d at 25 °C, with sparse white to pale buff aerial hyphae; reverse uncoloured. Colonies on MEA with entire edge, about 47–53 mm diam in 7 d at 25 °C, with white floccose aerial mycelium, reverse sienna with pale edge. Colony on DG18 with entire edge, about 17–23 mm diam in 7 d at 25 °C, buff with sparse white aerial hyphae, without coloured exudates; reverse uncoloured.

**Specimen examined**: India, Bihar, isolated from paper, culture CBS 291.83 (ex-type culture of *Ch. amberpetense*).

**Notes**: *Amesia nigricolor* is morphologically similar to members of the genus *Ovatopsis*, especially in ascospore morphology. This species differs in possessing ascospores attenuated at one end and slightly apiculate at the other end. In contrast, the ascospores of the *Ovatopsis* species are attenuated at one and typically round at the other end. A few isolates of *Am. nigricolor* were isolated from patients, both superficial and deep infections (de Hoog et al. 2013).

*Arcopilus* X. Wei Wang, Samson & Crous, **gen. nov.** MycoBank MB818835. **Fig. 6.**

**Etymology**: Name refers to the arcuate terminal ascomatal hairs in most of the species in this genus.

**Type species**: *Arcopilus aureus* (Chivers) X. Wei Wang & Samson (= *Ch. aureus*)

Colonies usually with yellow to orange or red to rust exudates. Ascomata superficial, ostiolate, subglobose or ovate with brown walls of textura angularis in surface view. *Terminal hairs* usually arcuate, with apices incurved, circinate to coiled. *Lateral hairs* flexuous or apically incurved. *Asci* fasciculate, clavate, with 8 biseriate or irregularly arranged ascospores, evanescent. *Ascospores* brown when mature, more or less inequilateral, fusiform, elongate fusiform, navicular, reniform, lunate or limoniform, sometimes bilaterally flattened, with one or two apical germ pores. *Asexual morph* unknown.

**Notes**: This genus usually has arcuate ascomatal hairs, and often exhibits a colourful colony due to its ascomata and exudates. Ascospores of the species in this genus are relatively diverse (Fig. 6). Only one indoor species was examined in detail in this study. More morphological research is required to delimit species within the genus.

*Arcopilus turgidopilosus* (Ames) X. Wei Wang & Samson, **comb. nov.** MycoBank MB818836. **Fig. 7.**

**Basionym**: Chaetomium turgidopilosum Ames, Mycologia 41: 639. 1949.

Ascomata superficial, ostiolate, citrine or greenish olivaceous in reflected light due to ascomatal hairs, then becoming greenish black due to ascospores aggregating on the top, subglobose or ovate, 95–155 μm high, 85–150 μm diam. *Ascomatal wall brown*, textura angularis, sometimes mixed with hypha-like or amorphous cells in surface view. *Terminal hairs* arcuate, apically incurved, circinate to coiled, warty, or brown, distinctly septate,
Fig. 2. Morphology of the genus *Amesia*. A. Ascoma: *A. atrobrunnea* (CBS 379.66T). B. *A. gelasinospora* (CBS 643.83). C. *A. cymbiformis* (CBS 176.84). D. *A. nigricolor* (CBS 291.83). Ascospores: E. *A. atrobrunnea* (CBS 379.66T). F. *A. gelasinospora* (CBS 643.83). G. *A. cymbiformis* (CBS 176.84). H. *A. nigricolor* (CBS 291.83). Scale bars: A–D = 100 μm; E–H = 10 μm.

Fig. 3. *Amesia atrobrunnea* (CBS 379.66). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Asci. K. Ascospores. Scale bars: E–G = 100 μm; H–K = 10 μm.
Fig. 5. *Amesia nigricolor* (CBS 291.83). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Asci. K. Ascospores. Scale bars: E–G = 100 μm; H–K = 10 μm.

Fig. 4. *Amesia cymbiformis* (CBS 176.84). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Asci. K. Ascospores. Scale bars: E–G = 100 μm; H–K = 10 μm.
Culture characteristics: Colonies on OA with entire edge, about 30–36 mm diam in 7 d at 25 °C, with floccose white aerial hyphae at the beginning, with amber to luteous exudates diffusing into the medium, reverse amber to luteous. Colonies on PCA with pale luteous to amber crested edge, about 25–31 mm diam in 7 d at 25 °C, pale amber with floccose buff aerial hyphae mixed with ascomata, with amber exudates diffusing into the medium; reverse amber. Colonies on MEA with entire edge, about 34–40 mm diam in 7 d at 25 °C, with floccose white aerial mycelium, with red to pale rust exudates diffusing into the medium, reverse rust. Colony growth on DG18 pale rosy buff with entire edge, about 7–13 mm diam in 7 d at 25 °C, without coloured exudates; reverse uncoloured.

Notes: The ascospores of Ar. turgidopilosus are sometimes asymmetrical, but less inequilateral than most of the other species known in this genus (Fig. 6). This species is distinct from the other species by its swollen ascomatal hairs (Fig. 71). Phylogenetic inference places this species in a basal position to the other known species in the genus.

Botryotrichum Sacc. & Marchal, Bull. Soc. R. Bot. Belg. 24(1): 66. 1885.
Synonym: Emilmuelleria Arx, Sydowia 38: 6. 1985.

Type species: Botryotrichum piluliferum Sacc. & Marchal

Notes: Botryotrichum piluliferum was first described as an asexual species based on an isolate from Belgium (Saccardo 1886). Daniels (1961) induced perithecia from soil-buried cellulose films with a culture of B. piluliferum, and named the induced organism as Ch. piluliferum, the sexual morph of B. piluliferum. Chaetomium piluliferum was noted to be closely related to Ch. mororum by ellipsoid ascospores and unbranched ascomatal hairs with circinate tips (Daniels 1961, von Arx et al. 1986). Our phylogenetic analyses strongly support a monophyletic lineage containing B. piluliferum, two other Botryotrichum species, Ch. mororum and E. spirotricha, the type species of the monotypic genus Emilmuelleria. This lineage is more closely related to the genus Subramanlua than to the other lineages in the Chaetomiaceae. Since their sister relationships received low bootstrap support (MP-BS = 54), we prefer to keep these two clades as two separate genera for now.

Three indoor species of Botryotrichum are described below. More research based on a higher number of strains and species is required to better delimit this genus.

Botryotrichum murorum (Corda) X. Wei Wang & Samson, comb. nov. MycoBank MB818387. Figs 8, 9.

Basionym: Chaetomium mororum Corda, Icon. Fung. 1: 24. 1837.

Ascomata superficial, ostiolate, grey olivaceous, olivaceous to brown vinaceous in reflected light due to ascomatal hairs, sub-globose or ovate, 160–320 μm high, 150–270 μm diam. Asco-matal wall brown, textura intricata or epidermoidea in surface view. Terminal hairs usually over four times longer than ascospore, flexuous or undulate, often circinate at the apex (DTO 324-G9, Fig. 8), or undulate, usually apically straight, occasionally recurved or circinate at the apex (DTO 333-E6, Fig. 9), olivaceous brown, smooth, 4.5–7.5 μm diam near the base, up to about 3 mm long. Lateral hairs seta-like, shorter. Asci fasciculate, fusiform, sometimes clavate, spore-bearing portion 27–45 × 12.5–19 μm, stalks 12–36 μm long, with 8 irregularly-arranged ascospores, evanescent. Ascospores olivaceous brown when mature, ellipsoid-fusiform, (12–)12.5–15(–16.5) × (7–) 7.5–8.5 μm, with an apical germ pore. Asexual morph unknown.

Culture characteristics: Colonies on OA with a lobate or crenated edge, about 32–39 mm diam in 7 d at 25 °C, with sparse smoke grey aerial hyphae mixed with pale olivaceous grey ascomata, with vinaceous buff to livid purple or livid violet exudates diffusing into the medium, reverse pale purplish grey to fuscous black. Colonies on PCA showing an entire or slightly crenated edge with aerial hyphae olivaceous buff (DTO 324-G9, Fig. 8), or showing an irregularly or radially striated with lobate edge without aerial hyphae (DTO 333-E6, Fig. 9), with a few concentric and lobate rings on it, about 24–34 μm diam in 7 d at 25 °C, without coloured exudates; reverse olivaceous buff to honey. Colonies on MEA with a slightly undulate or lobate edge, about 30–37 mm diam in 7 d at 25 °C, possessing white and floccose with radial furrows (DTO 324-G9, Fig. 8) or pale olivaceous grey to white and floccose mycelium with concentric and floral or irregular rings on it (DTO 333-E6, Fig. 9), non-sporulating, without coloured exudates; reverse uncoloured at the beginning, then ochraceous, umber to cinnamon. Colonies on DG18 with an irregularly crenated edge, about 9–17 mm diam in 7 d at 25 °C, pale buff to buff, wrinkled on the surface, without aerial hyphae, non-sporulating, without coloured exudates; reverse uncoloured to pale luteous.

Notes: Isolates DTO 324-G9 and DTO 333-E6 have different colony morphologies and ascomatal hairs. The ascospores of DTO 324-G9 are also slightly bigger than those of DTO 333-E6. However, the phylogenetic analysis did not show any sequence differences between them, suggesting that the differences mentioned above represent the morphological diversity within the species.
Fig. 6. Morphological diversity in the genus Arcopilus. Ascoma: A. Ar. cupreus (CBS 560.80). B. Ar. aureus (CBS 153.52). C. Ar. flavigenus (CBS 337.67). D. Ar. turgidopilosus (CBS 169.52). Ascospores: E. Ar. cupreus (CBS 560.80). F. Ar. aureus (CBS 153.52). G. Ar. fusiformis (CBS 484.85). H. Ar. flavigenus (CBS 337.67). I. Ar. turgidopilosus (CBS 169.52). Scale bars: A–D = 100 μm; E–I = 10 μm.
Fig. 7. *Arcopilus turgidopilosus* (CBS 169.52T). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. An terminal ascomatal hair fading and tapering towards the tips. I. An terminal ascomatal hair with the widest lower middle portion. J. Asci. K. Ascospores. Scale bars: D = 100 μm; E–F = 20 μm; G–K = 10 μm.
**Botryotrichum peruvianum** Matsush., Icon. Microfung. Mat.-sush. Lect. (Kobe): 17. 1975. Fig. 10.

Sexual morph unknown. Sterile setae often solitary, sometimes clustered with conidiophores, brown, verrucose, erect, flexuous or undulate, unbranched, 2.5–4.5 μm diam near the base, up to 2,200 μm long. *Conidiophores* discrete or clustered with a tuft of setae, hyaline, occasionally ocreaceous, 2–4.5 μm near the base, up to 60 μm long, usually sympodially branched to produce several conidiogenous cells. *Conidiogenous cells* terminal or intercalary, monoblastic or sympodially polyblastic, cylindrical to broadly conical, sometimes flattened, 0–14.5 × 2–3.5 μm, sometimes swollen beneath the conidium. Conidia single, occasionally two to three in chains, globose to subglobose, hyaline when young, then becoming pale luteous to ocreaceous, conspicuously roughened, (10–)12–16(–17.5) μm diam.

**Culture characteristics**: Colonies on OA with an entire edge, 36–41 mm diam in 7 d at 25 °C, with sparse white aerial hyphae, and then becoming ocreaceous to pale mouse grey because of the formation of groups of conidia and setae, without coloured exudates; reverse uncoloured. Colonies on PCA with an undulate to lobate edge, about 22–28 mm diam in 7 d at 25 °C, with sparse white aerial hyphae, pale luteous in the centre, without coloured exudates; reverse honey in the centre. Colonies on MEA with a slightly lobate edge, about 21–28 mm diam in 7 d at 25 °C, with floccose, buff to pale ocreaceous aerial hyphae, greyish sepa in the centre; without coloured exudates; reverse ocreaceous to umber. Colonies on DGO18 buff to honey, with a slightly crenated edge, about 9–15 mm diam in 7 d at 25 °C, slightly wrinkled without aerial hyphae; without coloured exudates; reverse buff.

Specimen examined: **Cuba**, isolated from air by R. Castañeda, culture CBS 421.93.

**Notes**: This species can be distinguished from *B. piluliferum* by its white to pale ochraceous aerial hyphae, easily distinguished not only from the brown to ochraceous aerial hyphae of *B. piluliferum*. The setae of *B. piluliferum* are usually shorter and less branched than those of *B. peruvianum*. The conidiogenous cells of *B. piluliferum* are usually shorter and less constricted than those of *B. peruvianum*. The conidia of *B. piluliferum* are usually shorter and less globose than those of *B. peruvianum*. The sexual morph of *B. piluliferum* is not known.

**Type species**: *Chaetomium globosum* Kunze.

**Notes**: Since Saccardo (1882) separated *Chaetomium* from *Chaetomium* as a distinct genus, *Chaetomium* had been defined to be a genus possessing typical ostiolate ascocarps for over 100 years. Robust phylogenetic evidence (Wang et al. 2016) indicated that three species of *Chaetomium*, including its type species *Ch. fimet*, clustered in the *Chaetomium globosum* species complex. The data generated in this study further proved that the traditional morphologically-defined *Chaetomium* (Ames 1963, von Arx et al. 1986) has been divided into several different lineages which are intermingled with several other genera in the *Chaetomiaceae*. On the other hand, the monophyly of the *Chaetomium globosum* species complex was confirmed by the phylogenetic analysis based on the expanded dataset in this study (Fig. 1), thus the genus *Chaetomium* is restricted to the *Chaetomium globosum* species complex.
Fig. 8. Botryotrichum murorum (DTO 324-G9). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Structure of ascomatal wall in surface view. G. Upper part of a terminal ascomatal hair. H. Asci. I. Ascospores. Scale bars: D–E = 100 μm; F–I = 10 μm.
Fig. 9. Botryotrichum murorum (DTO 333-E6). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Upper part of terminal ascomatal hairs. G. Structure of ascomatal wall in surface view. H. Asci. I. Ascospores. Scale bars: D–E = 100 μm; F–I = 10 μm.
Fig. 10. Botryotrichum peruvianum (CBS 421.93). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Conidia on conidiophores together with setae on SNA, top view. C–D. Conidia on conidiophores together with setae mounted in lactic acid. E–G. Conidiophores with conidia. Scale bars: C–D = 20 μm; E–G = 10 μm.
Fig. 11. Botryotrichum piluliferum (DTO 254-B8). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Conidia on conidiophores together with setae on SNA, top view; C. Conidia on conidiophores together with setae on SNA, side view. D–E. Conidia on conidiophores together with setae mounted in lactic acid. F–G. Conidiophores with conidia. H. Conidia. Scale bars: D–E = 20 μm; F–H = 10 μm.
Six indoor species were recognised in this genus.

**Chaetomium cervicicola** X. Wei Wang et al., Persoonia 36: 93. 2016.

Culture sterile.

Specimen examined: **Mexico**, isolated from dust, culture DTO 318-G6.

Notes: This isolate phylogenetically clustered in the *Ch. cervicicola* clade. The ex-type culture CBS 128492 was also sterile. See phylogenetic description in Wang et al. (2016).

**Chaetomium coarctatum** Sergejeva, Not. Syst. sect. Crypt. Inst. Bot. Acad. Sci. U.S.S.R. 14: 146. 1961. Fig. 12.

Ascomata superficial, ostiolate, greyish white to olivaceous buff in reflected light owing to ascomatal hairs, subglobose, 320–480 μm high, 250–390 μm diam. Ascomatal wall brown, *textura epidermoidea* or *intricata* in surface view. *Terminal hairs* conspicuously rough, brown, undulate, 3–4 μm near the base and tapering towards the tips. Lateral hairs erect or flexuous, tapering towards the tips. Asci fasciculate, fusiform or clavate, sporobearing part 31–43 × 14–21 μm, stalks 20–38 μm long, with 8 irregularly-arranged ascospores, evanescent. Ascospores olivaceous brown when mature, broad limoniform, textura intricata in surface view. Colony characteristics: Colonies on OA with an entire edge and spreading rapidly, over 70 mm diam in 7 d at 25 °C, with sparse white buff and floccose aerial hyphae, then without aerial hyphae when ascomata manure, with pale luteous or pale amber to citrine exudates diffusing into the medium, reverse pale amber to pale citrine. Colonies on MEA buff aerial hyphae, grey olivaceous to isabelline in reverse, with white to buff aerial hyphae, with citrine exudates diffusing into the medium, reverse honey to olivaceous buff. Colonies on MEA with an entire edge and spreading rapidly, over 70 mm diam in 7 d at 25 °C, with sparse white or greyish white and floccose aerial hyphae, with white margin of ascomata, with pale luteous or pale amber to pale citrine exudates diffusing into the medium; reverse honey to olivaceous buff. Colony growth on DG18 with a slightly undulate edge, about 19–25 mm diam in 7 d at 25 °C, buffish white and floccose with white edge, without coloured exudates; reverse uncoloured.

Specimens examined: **Netherlands**, Maastricht, isolated from air, culture DTO 013-C2; Eindhoven, isolated from air, culture DTO O09-E2. **South Africa**, isolated from dust, cultures DTO 319-B5 and DTO 319-B6. **USA**, isolated from dust, cultures DTO 318-H2, DTO 318-H4, DTO 318-H5, DTO 318-H7, DTO 318-H8, DTO 318-I1, DTO 318-I3, DTO 318-i5, DTO 318-i6, DTO 318-i8, DTO 318-i9 and DTO 319-A1. The description above is based on the isolate DTO 318-I1.

Notes: This is a common indoor species, especially in the USA. The indoor isolates showed consistent morphology, fitting with that of *Ch. cochliodes* (ex-epitype CBS 155.52, fig. 9 in Wang et al. 2016).

**Chaetomium elatum** Kunze, Deutsche Schwmämme 8: 3, No. 184. 1818. Figs 14, 15.

Ascomata superficial, ostiolate covered by sparse white or buff aerial hyphae, grey olivaceous to isabelline in reflected light, globose or obovate, 280–440 μm high, 255–380 μm diam. Ascomatal wall brown, *textura intricata* in surface view. Terminal hairs conspicuously rough, dark brown, erect in the lower part, 3.5–6 μm near the base, tapering and fading towards the tips, spirally coiled in the upper part, usually with coils regularly tapering in diameter towards the tips, occasionally with coiled branches. Lateral hairs brown, flexuous, undulate or loosely coiled, tapering and fading towards the tips. Asci fasciculate, fusiform or clavate, spore-bearing part 30–45 × 13.5–21 μm, stalks 28–56 μm long, with 8 biseriate ascospores, evanescent. Ascospores brown when mature, limoniform, usually biapiculate at both ends, bilaterally flattened, (8.5–9)–10.5–(11) × (7–) 7.5–9(–9.5) × 5.5–6.5 μm, with an apical germ pore. Asexual morph unknown.

Culture characteristics: Colonies on OA with an entire edge and spreading rapidly, over 70 mm diam in 7 d at 25 °C, usually with sparse buff and floccose aerial hyphae, then without aerial hyphae when ascomata manure, with pale luteous or pale amber to citrine exudates diffusing into the medium, reverse pale amber to pale citrine. Colonies on OA with a slightly undulate margin, about 19–25 mm diam in 7 d at 25 °C, buffish white and floccose with white edge, without coloured exudates; reverse uncoloured.

Specimen examined: **China**, Beijing, isolated from air by A.J. Chen, culture DTO 324-H2.

Note: The morphology of the indoor isolates studied here fits with that of the ex-type culture, CBS 162.62 (fig. 8 in Wang et al. 2016), indicating that this species has a relatively stable morphology.

**Chaetomium cochliodes** Palliser, North Amer. Flora 3:61. 1910. Fig. 13.

Ascomata superficial, ostiolate, greenish olivaceous to dark citrine in reflected light owing to ascomatal hairs, ellipsoid or subglobose, 200–440 μm high, 140–420 μm diam. Ascomatal wall brown, *textura intricata* in surface view. Terminal hairs conspicuously rough, dark brown, erect in the lower part, 3.5–6 μm near the base, tapering and fading towards the tips, spirally coiled in the upper part, usually with coils regularly tapering in diameter towards the tips, occasionally with coiled branches. Lateral hairs brown, flexuous, undulate or loosely coiled, tapering and fading towards the tips. Asci fasciculate, fusiform or clavate, spore-bearing part 30–45 × 13.5–21 μm, stalks 28–56 μm long, with 8 biseriate ascospores, evanescent. Ascospores brown when mature, limoniform, usually biapiculate at both ends, bilaterally flattened, (8.5–9)–10.5–(11) × (7–) 7.5–9(–9.5) × 5.5–6.5 μm, with an apical germ pore. Asexual morph unknown.

Culture characteristics: Colonies on OA with an entire edge and spreading rapidly, over 70 mm diam in 7 d at 25 °C, usually with sparse buff and floccose aerial hyphae, then without aerial hyphae when ascomata manure, with pale luteous or pale amber to citrine exudates diffusing into the medium, reverse pale amber to pale citrine. Colonies on OA with a slightly undulate margin, about 19–25 mm diam in 7 d at 25 °C, buffish white and floccose with white edge, without coloured exudates; reverse uncoloured.

Specimens examined: **Netherlands**, Maastricht, isolated from air, culture DTO 013-C2; Eindhoven, isolated from air, culture DTO O09-E2. **South Africa**, isolated from dust, cultures DTO 319-B5 and DTO 319-B6. **USA**, isolated from dust, cultures DTO 318-H2, DTO 318-H4, DTO 318-H5, DTO 318-H7, DTO 318-H8, DTO 318-I1, DTO 318-I3, DTO 318-i5, DTO 318-i6, DTO 318-i8, DTO 318-i9 and DTO 319-A1. The description above is based on the isolate DTO 318-I1.

Notes: This is a common indoor species, especially in the USA. The indoor isolates showed consistent morphology, fitting with that of *Ch. cochliodes* (ex-epitype CBS 155.52, fig. 9 in Wang et al. 2016).
fusiform, spore-bearing part 36–49 × 12.5–16.5 μm, stalks 24–55 μm long, with 8 biseriate ascospores, evanescent. Ascospores brown when mature, limoniform, biapiculate or umbonate, bilaterally flattened, (10–)11.5–13.5(–16) × (8–) 8.5–10(–11) × (6.5–)7–8 μm, with an apical germ pore.

Asexual morph acremonium-like. Conidiophores phialidic, formed laterally from aerial hyphae, simple, 6–24.5 μm long, 1.5–3.5 μm diam at the base. Conidia formed basipetally in

Fig. 12. Chaetomium coactatum (DTO 324-H2). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view; E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Basal parts of terminal ascomatal hairs. J. Upper parts of terminal ascomatal hairs. K. Asci. L. Ascospores. Scale bars: E–G = 100 μm; H–L = 10 μm.
chains, hyaline, aseptate, smooth, ovate, often with a truncated base and a rounded apex, (2–)2.5–4(–5.5) μm × 1.5–2(–2.5) μm.

Culture characteristics: Colonies on OA with entire edge and spreading rapidly, over 70 mm diam in 7 d at 25 °C, with sparse, honey to greenish olivaceous aerial hyphae (DTO 319-B3), or forming sparse or radially sectorial, white to buff and floccose aerial hyphae (DTO 318-H9), without coloured exudates when young, or with greyish yellow-green, olivaceous buff to honey exudates diffusing into the medium, reverse honey to greenish olivaceous. Colonies on PCA pale luteous to luteous, with irregularly deep lobate edge, about 52–61 mm diam in 7 d at 25 °C, aerial hyphae sparse and honey, with luteous exudates diffusing into the medium; reverse pale luteous to amber.

Notes: Chaetomium elatum was originally described based on an isolate collected from dead leaves in Germany. Our attempt to find the holotype of Ch. elatum housed in Botanischer Garten und Botanisches Museum Berlin-Dahlem, Zentralinrichtung der Freien Universität Berlin) was unsuccessful because the ascomycete collection was partly destroyed by a fire in 1943, in which the holotype of Ch. globosum might have been included. Therefore, a dried culture, CBS H-22851 from D.T.O. 933-E9, is designated here as neotype of Ch. elatum, which was collected in Denmark geographically close to the collection location of the holotype.

As in our previous study (Wang et al. 2016), the phylogenetically defined Ch. elatum showed a diverse morphology in terminal ascomatal hairs. For example, CBS 910.70 (ex-type culture of Ch. ramipilosum) exhibits relatively slender and flexible terminal hairs (2.5–4.5 μm diam near the base, fig. 10 in Wang et al. 2016), while DTO 319-B3, DTO 318-H9 and DTO 333-E9 exhibit relatively rigid terminal hairs which are more similar to Ch. rectangularae. Also DTO 319-B3 has erect to flexuosus terminal branches of the hairs (Fig. 14), while DTO 318-H9 and DTO 333-E9 have undulate terminal branches of the hairs (Fig. 15). However, Ch. rectangularae can be distinguished from Ch. elatum by smaller ascosporae (10–11 × 7–9 μm) and thicker terminal hairs (4.5–7 μm diam near the base (fig. 28 in Wang et al. 2016).

Chaetomium globosum
Kunze, Mycol. Hefte 1: 16. 1817. Figs 16–18.

Ascomata superficial, ostiolate, greenish olivaceous (DTO 319-B2), or slightly dark olivaceous buff to grey (DTO 333-E3), or dull green (CBS 666.82) in reflected light owing to ascomatal hairs which can possess sulphur yellow lower parts (DTO 319-B2) or appear sulphur yellow to yellow (CBS 666.82), subglobose, ovate or obovate, 140–270 μm high, 100–240 μm diam. Ascomatal wall brown, textura intricata in surface view. Terminal hairs finely warty, brown, erect (more often in CBS 666.82) or flexuous (more often in DTO 333-E3) or undulate to loosely coiled (most of the indoor isolates, see DTO 319-B2, Fig. 16) with erect or flexuous lower part, tapering and fading towards the tips, 2–5 μm diam near the base. Lateral hairs brown, flexuous, fading and tapering towards the tips. Ascii fasciculate, fusiform or clavate, spore-bearing part 19–38 × 12–17 μm, stalks 22–48 μm long (most of the indoor isolates, Figs 16, 17), or 10–19 μm long (CBS 666.82) with 8 irregularly-arranged ascosporae, evanescent. Ascosporae brown when mature, limoniform, usually biapiculate, bilaterally flattened, 8.5–11(–12) × 7–8.5(–9.5) μm, with an apical germ. Asexual morph absent.

Culture characteristics: Colonies on OA with an entire edge, spreading rapidly, over 70 mm diam in 7 d at 25 °C, with sparse white to olivaceous buff aerial hyphae when young, then without aerial hyphae and becoming citrine green, yellow, greenish olivaceous to grey olivaceous (most of the indoor isolates, Figs 16, 17) or dull green (CBS 666.82) owing to the aggregation of ascomata, with fulvous, apricot to sienna exudates (DTO 319-B2), or olivaceous to olive-grey exudates (DTO 333-E3) or ochraceous to greenish olivaceous exudates (CBS 666.82) diffusing into the medium; reverse apricot, orange or sienna (DTO 319-B2), grey olivaceous to olivaceous (DTO 333-E3) or umber to dark brick (CBS 666.82). Colonies on PCA translucent, usually with a more or less lobate edge, about 39–48 mm diam in 7 d at 25 °C, without or with very sparse and floccose, pale yellow aerial hyphae, without coloured exudates; reverse uncoloured. Colonies on MEA with an entire edge (DTO 319-B2 and CBS 666.82) or a fimbriate to rhizoid (DTO 333-E3) edge, spreading rapidly, over 70 mm diam in 7 d at 25 °C, honey to olivaceous buff (DTO 319-B2 and DTO 333-E3), or malachite green to dull green (CBS 666.82) owing to the aggregation of ascomata mixed with floccose aerial hyphae, reverse fulvous, orange to sienna (DTO 319-B2 and DTO 333-E3) or scarlet to rust (CBS 666.82) owing to exudates diffusing into the medium. Colonies on DG18 with a lobate or slightly crenated edge, about 10–17 mm diam in 7 d at 25 °C, buff to pale luteous, with sparse white to greyish white aerial hyphae; reverse orange, rust to bay (DTO 319-B2), ochraceous (DTO 333-E3) or scarlet (CBS 666.82) owing to exudates diffusing into the medium.

Specimens examined: Algeria, isolated from air, cultures DTO 134-D9; DTO 134-E1; DTO 134-E2; DTO 134-E3; DTO 134-E4; DTO 134-E9. Canada, isolated from dust, cultures DTO 318-G3; DTO 318-G4; DTO 318-G5. China, isolated from chili powder, culture CBS 666.82; isolated from air by A.J. Chen in Beijing, cultures DTO 324-D7; DTO 324-G8; DTO 324-H1; DTO 324-H4; DTO 324-H5; DTO 324-I1; DTO 324-I2; DTO 324-I3; DTO 324-I4; DTO 324-I5; DTO 324-I6; DTO 324-I7; DTO 324-I8; DTO 325-A1; DTO 325-A2; DTO 325-A3;
**CHAETOMIUM**

**Fig. 14.** Chaetomium elatum (DTO 319-B3). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–F. Ascomate mounted in lactic acid. G. Ascomatal morph (Conidiophores and conidia); H. Structure of ascomatal wall in surface view; I–J. Upper part of terminal ascomatal hairs. K–L. Ascl. M. Ascosporae. Scale bars: E–F = 100 μm; G–M = 10 μm.

_DTO 325-A4. Denmark_. isolated from carpet by B. Andersen, culture DTO 333-E4 (= IBT 41800); from linoleum by B. Andersen, culture DTO 333-E3 (= IBT 41800); from gypsum by B. Andersen, cultures DTO 333-D7 (= IBT 42328); DTO 333-D8 (= IBT 42326); DTO 333-D9 (= IBT 42327); DTO 333-F4 (= IBT 42297); DTO 333-F5 (= IBT 42289); DTO 333-F6 (= IBT 42301); DTO 333-F7 (= IBT 42325); DTO 333-F9; from plywood by B. Andersen, cultures DTO 333-E1 (= IBT 41766); DTO 333-E8 (= IBT 42177); from oriented strand board by B. Andersen, cultures DTO 333-E7 (= IBT 42176). _Germany_. isolated from air, cultures CBS 112386; DTO 340-I2; DTO 012-F3; DTO 012-D2.

_Netherlands_. isolated from air, culture DTO 237-D4. _Mexico_. isolated from dust, cultures DTO 319-A3; DTO 319-A4; DTO 319-A5; DTO 319-A6; DTO 319-A7; DTO 319-A9; DTO 319-B1; DTO 319-B2. _Indonesia_. isolated from air, cultures DTO 085-E8; DTO 085-F5; DTO 085-F6; from indoor materials, cultures DTO 264-C1; DTO 272-C1; from swap, cultures DTO 086-D6; DTO 126-B6; from wall paper, cultures DTO 011-F7; DTO 012-F2. _South Africa_. isolated from dust, culture DTO 319-B4. _Thailand_. isolated from dust, culture DTO 319-C3. _Uruguay_. isolated from dust, culture DTO 319-C9. _USA_. isolated from dust, cultures DTO 318-H3; DTO 318-H5; DTO 318-I4; DTO 319-C5; DTO 319-C6; from stored cotton, culture CBS 148.51. The description above is based on the isolates DTO 319-B2 from dust in Mexico, DTO DTO 333-E3 from Linoleum in Denmark and CBS 666.82 from chili powder in China.

**Notes:** The general description and morphological diversity of _Ch. globosum_ has been discussed by Wang _et al_. (2016). The information presented here gave more insight into the morphological diversity of this species, especially its colony morphology.

**Ch. tectifimbri** X. Wei Wang & Samson, _gen. nov._ MycoBank MB818839. Figs 20, 21. _Etyymology:_ Name refers to a dark collar-like apex around the ostiolar pore of the ascomata in most of the species in this genus.

_Type species:_ *Collariella bostrychodes* (Zopf) X. Wei Wang & Samson (= _Ch. bostrychodes_)

This genus is divided into two subclades by both phylogenetic and morphological evidence. The two subclades are closely related to each other with high statistical support (Fig. 1), indicating that they share a recent common ancestor. We therefore decided to keep them in the same genus. Different descriptions are provided here for each subclade.

**Subclade 1:** _Ascomata_ superficial, ostiolar, ovate, obovate, ampulliform or cylindrical with brown walls of _textura angularis_ in surface view. Apices of ascomata truncated, usually with a darkened collar around the ostiolar pore, and easy to rupture and to be dispersed together with ascomatal hairs as a whole. _Terminal hairs_ highly diverse, straight, flexuous, undulate or spirally coiled or presenting two different types. _Lateral hairs_ straight, flexuous. _Asci_ fasciculate, fusiform or clavate, stalked, with 8 biseriate or irregularly arranged ascospores, evanescent. _Ascospores_ olivaceous brown at maturity, broadly limoniform to quadrangular, bilaterally flattened, with an apical germ pore, usually less than 7.5 μm in length. _Asexual morph_ unknown.

**Subclade 2:** _Ascomata_ superficial, ostialate, subglobose or ovate, with brown walls of _textura angularis_ in surface view. _Terminal hairs_ straight, flexuous, undulate or arcuate. _Lateral hairs_ straight, flexuous. _Asci_ fasciculate, clavate, fusiform or obovate, spore-bearing portion 18–26 × 11–14.5 μm, stalks 7–13 μm long, with 8 irregularly-arranged ascospores, evanescent. _Ascospores_ brown when mature, ellipsoidal or fusiform, never bilaterally flattened, with one or two apical or sometimes slightly sub-apical germ pores, usually more than 9 μm in length. _Asexual morph_ unknown.

**Collariella** X. Wei Wang, Samson & Crous, _gen. nov._ MycoBank MB818839. Figs 20, 21. _Etyymology:_ Name refers to a dark collar-like apex around the ostiolar pore of the ascomata in most of the species in this genus.

_Type species:_ *Collariella bostrychodes* (Zopf) X. Wei Wang & Samson (= _Ch. bostrychodes_)

This genus is divided into two subclades by both phylogenetic and morphological evidence. The two subclades are closely related to each other with high statistical support (Fig. 1), indicating that they share a recent common ancestor. We therefore decided to keep them in the same genus. Different descriptions are provided here for each subclade.

**Subclade 1:** _Ascomata_ superficial, ostiolar, ovate, obovate, ampulliform or cylindrical with brown walls of _textura angularis_ in surface view. Apices of ascomata truncated, usually with a darkened collar around the ostiolar pore, and easy to rupture and to be dispersed together with ascomatal hairs as a whole. _Terminal hairs_ highly diverse, straight, flexuous, undulate or spirally coiled or presenting two different types. _Lateral hairs_ straight, flexuous. _Asci_ fasciculate, fusiform or clavate, stalked, with 8 biseriate or irregularly arranged ascospores, evanescent. _Ascospores_ olivaceous brown at maturity, broadly limoniform to quadrangular, bilaterally flattened, with an apical germ pore, usually less than 7.5 μm in length. _Asexual morph_ unknown.

**Subclade 2:** _Ascomata_ superficial, ostiolar, subglobose or ovate, with brown walls of _textura angularis_ in surface view. _Terminal hairs_ straight, flexuous, undulate or arcuate. _Lateral hairs_ straight, flexuous. _Asci_ fasciculate, clavate, fusiform or obovate, spore-bearing portion 18–26 × 11–14.5 μm, stalks 7–13 μm long, with 8 irregularly-arranged ascospores, evanescent. _Ascospores_ brown when mature, ellipsoidal or fusiform, never bilaterally flattened, with one or two apical or sometimes slightly sub-apical germ pores, usually more than 9 μm in length. _Asexual morph_ unknown.

**Notes:** Phylogenetic inference indicated that _Ch. tectifimbri_ clustered close to but separate from _Ch. fimeti_ (ex-epitule culture DSM 62108). This species can be distinguished by its smaller ascomata (210–340 μm diam) than those of _Ch. fimeti_ (320–500 μm diam), and broader ascospores (8.5–10 μm wide in front view) than those of _Ch. fimeti_ (7–8 μm wide in front view).
Collariella bostrychodes (Zopf) X. Wei Wang & Samson, comb. nov. MycoBank MB818862. Fig. 22.
Basionym: Chaetomium bostrychodes Zopf, Abh. Bot. Ver. Prov. Brandenburg 19:173. 1877.

Ascomata superficial, pale greenish grey or pale purplish grey in reflected light owing to ascomatal hairs, subglobose, ovate or obovate, ostiolate, 210–300 μm high (including the collar), 160–240 μm diam. Wide, apically black due to a darkened collar in 25–55 μm high and 75–170 μm wide around the ostiolar pore with the area near the apical collar often in paler colour than the lower part of the ascoma. Ascomatal wall brown, textura angularis in surface view. Terminal hairs arising from the apical collar, conspicuously rough, dark brown, septate, erect in the lower part, 4–7 μm near the base, spirally coiled in the upper part, often with coiled branches. Lateral hairs seta-like, tapering and fading towards the tips. Ascii fasciculate, fusiform or clavate, spore-bearing part 22–33 × 7–11 μm, stalks 9–20 μm long, with 8 irregularly-arranged ascospores, evanescent. Ascospores olivevaceous when mature, limoniform, usually biapiculate at both ends, bilaterally flattened, 6–7(–7.5) × (5–)5.5–6.5 × (4–)4.5–5.5 μm, with an apical germ pore. Asexual morph unknown.

Culture characteristics: Colonies on OA with entire edge, about 34–40 mm diam in 7 d at 25 °C, usually without or with sparse white aerial hyphae, without coloured exudates, reverse uncoloured. Colonies on PCA translucent, with entire edge, about 33–39 mm diam in 7 d at 25 °C, without aerial hyphae, without coloured exudates; reverse uncoloured. Colonies on MEA translucent and membranous, with entire edge, about 29–35 mm diam in 7 d at 25 °C, forming radiated and luteous or fulvous furrows, non-sporulating, often with sparse and concentric white aerial hyphae; reverse uncoloured. Colonies on DG18 with entire edge, about 14–20 mm diam in 7 d at 25 °C, with white floccose aerial hyphae Especially at the edge, non-sporulating, reverse uncoloured.

Specimens examined: Indonesia, isolated from dust, DTO 319-C3. China, Beijing, isolated from air by A.J. Chen, cultures DTO 324-H3; DTO 324-H6. The description above is based on the isolate DTO 324-H6.

Notes: This species was originally described with ellipsoid ascomata (Saccardo 1882), and later Ames (1963) described the species with subglobose to ovoid ascomata. von Arx et al. (1986) placed several species in synonymy with Col. bostrychodes (= Ch. bostrychodes), and their description covered a high morphological diversity in the shape of ascomata. Our description based on the indoor isolates fitted with that of Ames. Examination on more isolates of related species is required to delimit this species more accurately.

Collariella carteri X. Wei Wang, Houbraken & Samson, sp. nov. MycoBank MB818863. Fig. 23.
Etymology: Named after Dr Adrian Carter, who recognised this species as new in his PhD thesis.
Synonym: Chaetomium intricatum A. Carter, A Taxonomic Study of the Ascomycete genus Chaetomium Kunze, unpublished PhD thesis of the University of Toronto. 1982. nom. inval.

Ascomata superficial, often covered by sparse white aerial hyphae, easily falling down rather than erect when mature, dark brick to sepia in reflected light, globose or subglobose, ostiolate, occasionally pyriform owing to a short ostiolar beak, 175–320 μm high (including the collar), 110–220 μm diam, apically black due to a darkened collar in 20–60 μm high and 40–120 μm wide around the ostiolar pore. Ascomatal wall brown, textura intricata mixed with angularis or epidermoidea in surface view. Terminal hairs arising from the apical collar, seta-like or flexuous, 30–180 μm long, usually shorter than the height of an ascoma, smooth, dark brown, distinctly septate, 4–8.5 μm near the base, tapering and fading towards the nearly hyaline tips. Lateral hairs similar but quite sparse. Asci fasciculate, clavate or slightly fusiform, spore-bearing part 17–26 × 8.5–11.5 μm, stalks 10–18 μm long, with 8 biseriate or irregularly arranged ascospores, evanescent. Ascosporae ollivaceous when mature, limoniform, usually biapiculate at both ends, bilaterally flattened, (6–)6.5–7.5(–8.5) × (4.5–)5–6(–7.5) × 4–5.5 μm, with an apical germ pore. Asexual morph unknown.

Culture characteristics: Colonies on OA with entire edge, about 24–30 mm diam in 7 d at 25 °C, with white aerial hyphae and citrine green or greenish yellow to citrine exudates diffusing into the medium, reverse greenish yellow to greenish olivaceous. Colonies on PCA translucent, with entire edge, about 28–34 mm diam in 7 d at 25 °C, without aerial hyphae, without coloured exudates; reverse uncoloured. Colonies on MEA translucent and membranous, with entire edge, about 29–33 mm diam in 7 d at 25 °C, forming radiated and luteous or ochraceous furrows; non-sporulating, reverse uncoloured. Colony growth on DG18 very limited, less 3 mm diam after 7 d, without coloured exudates; reverse uncoloured.

Specimen examined: Canada. Vancouver, isolated from air of Bacteriology Lab in the University of British Columbia by R.J. Bandoni on 14 Feb. 1966 (holotype CBS H-22845, culture ex-type CBS 128.85).

Notes: Collariella carteri is easily recognised by its short and seta-like terminal ascomatal hairs. Carter (1982) noted that the ascomatal wall of this species consists of textura intricata in surface view. Our observation showed that the wall structure of CBS 128.85 consisted of textura intricata, angularis and epidermoidea (Fig. 23E–I). This species formed a sister lineage to Col. bostrychodes.

Collariella causiformis (Ames) X. Wei Wang & Samson, comb. nov. MycoBank MB818864. Fig. 24.
Basionym: Chaetomium causiforme Mycologia 41: 644. 1949.

Ascomata superficial, usually forming a layer on the surface of OA medium owing to adjacent long ascomatal hairs intermingling with each other, hazel to olivaceous in reflected light due to ascomatal hairs, globose or subglobose, ostiolate, 70–140 μm high (including the darkened collar), 60–120 μm diam, apically black due to a darkened collar in 10–24 μm high and 32–65 μm wide around the ostiolar pore. Ascomatal wall translucent, ochraceous, textura angularis in surface view. Terminal hairs arising from the apical collar, a few type I: up to 2600 μm long, undulate,
Fig. 16. Chaetomium globosum (DTO 319-B2). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Ascii. K. Ascospores. Scale bars: E–G = 100 μm; H–K = 10 μm.
Fig. 17. *Chaetomium globosum* (DTO 333-E3). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Basal parts of terminal ascomatal hairs. I. Upper parts of terminal ascomatal hairs. J. Asci. K. Ascospores. Scale bars: E–F = 100 μm; G–K = 10 μm.
Fig. 18. Chaetomium globosum (CBS 666.82). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view. C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Ascii. K. Ascospores. Scale bars: E–G = 100 μm; H–K = 10 μm.
Fig. 19. *Chaetomium testifinum* (CBS 142032 = DTO 318-G8, ex-type culture). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Inner and external layers of ascomatal wall in surface view. G. Structure of external layer of ascomatal wall in surface view. H. Part of a terminal ascomatal hair, longer type. I. Terminal ascomatal hairs, shorter type J. Asci. K. Ascospores. Scale bars: D–E = 100 μm; F–K = 10 μm.
Fig. 20. Morphological diversity of ascomata in the genus Collariella. A. Col. bostrychodes (DTO 326-H6). B. Col. robusta (CBS 551.83T). C. Col. quandrangulata (CBS 152.59). D. Col. causiformis (CBS 792.83T). E. Col. intricata (CBS 129.83T). F. Col. virescens (CBS 148.89T). G. Col. gracilis (CBS 249.75). Scale bars: A–G = 100 μm.
Asci fasciculate, fusiform, sometimes clavate, spore-bearing portion 15–22 × 8–13 μm, stalks 6–13 μm long, with 8 irregularly-arranged ascospores, evanescent. Ascospores olivaceous when mature, broad limoniform or ovate, bilaterally flattened, (5–)5.5–6.5 × (4.5–)5.5–6) × (3.5–)4–5 μm, with an apical germ pore. Asexual morph unknown.

**Collariella gracilis** (Udagawa) X. Wei Wang & Samson, comb. nov. MycoBank MB818865. Fig. 25. Basionym: Chaetomium gracile Udagawa, J. Gen. Appl. Microbiol. 6: 235. 1960.

Ascomata superficial, often covered by white aerial hyphae, ostiolate, olivaceous in reflected light due to ascomatal hairs and with black ascospores aggregating on the top, subglobose or ovate, 120–200 μm high, 100–180 μm diam, often with truncated and darkened apices, but not easy to rupture and to be dispersed. Ascomatal wall brown, textura angularis. Terminal hairs numerous, arcuate, partly apically flexuous, incurved or circinate, fine rough, brown, septate, 3.5–5.5 μm diam near the base. Lateral hairs relatively sparse, seta-like or flexuous. Asci fasciculate, clavate, fusiform or obovate, spore-bearing portion 18–26 × 11–14.5 μm, stalks 7–13 μm long, with 8 irregularly-arranged ascospores, evanescent. Ascospores brown when mature, ellipsoid or broadly fusiform, (9.5–)10–12.5(–13) × 6–7.5(–8) μm, with an apical or sometimes slightly sub-apical germ pore. Asexual morph unknown.

**Culture characteristics:** Colonies on OA translucent at the beginning, with entire edge, 27–33 mm diam in 7 d at 25 °C, without aerial hyphae, without coloured exudates; reverse uncoloured. Colonies on MEA with entire edge and without aerial hyphae, without coloured exudates, reverse uncoloured. No visible growth of colonies on DG18 after 7 d at 25 °C.

**Specimen examined:** **India**, Uttar Pradesh, isolated from air by Kamal, culture CBS 249.75.

**Notes:** von Arx et al. (1986) suggested that this species was closely related to Col. virescens. Our phylogenetic analysis confirmed their close relationship. The two species differ in ascomata and ascospores (Figs 20, 21).

**Dichotomopilus** X. Wei Wang, Samson & Crous, gen. nov. MycoBank MB818840. Figs 26, 27. Etymology: Name refers to the shape of terminal ascomatal hairs which are usually dichotomously branched.

Ascomata superficial, ostiolate, spherical, ellipsoid or ovate with walls of textura intricata or epidermoidea in surface view, or of textura angularis in a few species. Terminal hairs seta-like and the beginning, then the majority developing into dichotomously or irregularly branched to form a net structure to hold ascospores, sometimes branched and seta-like together, occasional staying seta-like, usually punctulate or verrucose, with the exception of those of **D. dolichotrichum** (= Ch. dolichotrichum) presenting smooth. Lateral hairs unbranched, seta-like, tapering towards tips. Asci fasciculate, clavate, broadly clavate or ovate, stalked, with 8 biseriate or irregularly arranged ascospores, evanescent quickly. Ascospores brown at maturity, narrowly ovate, ovate or broad ovate, bilaterally flattened, attenuate at one or both ends, with an apical or slightly sub-apical germ pore at the most attenuated end, the opposite end more or less apiculate if not attenuate, usually less than 7.5 μm long, with the exception of **D. fusum** (= Ch. fusum) possessing cylindrical ascospores without visible germ pores. Asexual morph unknown.

**Type species:** **Dichotomopilus indicus** (Corda) X. Wei Wang & Samson (= Ch. indicum)

**Notes:** Skolko & Groves (1948) provided the first overview of this group of fungi. Based on the presence or absence of unbranched terminal hairs and the characteristics of the branched hairs, they circumscribed and accepted six species. Their classification was followed by Ames (1963), Mazzucchetti (1965) and Seth (1970). However, von Arx et al. (1986) only accepted two species: **Ch. indicum** and **Ch. funicola**. Chaetomium indicum was described to show typical dichotomously branched terminal ascomatal hairs, while **Ch. funicola** was described to produce both unbranched seta-like and dichotomously branched terminal hairs. Based on these definitions, **Ch. dolichotrichum** was treated as a synonym of **Ch. funicola**, and the rest of the species accepted by Skolko & Groves (1948) were questioned. Wang et al. (2014) re-assessed all these species based on a five-locus phylogenetic analysis. The results indicated that all these species clustered in a monophyletic clade. Five of the six species of Skolko & Groves (1948) were recognised with the exception of **Ch. cancroideum**, which clustered in the **Ch. funicola** clade. At the same time, three more species: **Ch. subfunicola**, **Ch. ramosissimum** and **Ch. pratense** were discovered,
Fig. 21. Morphological diversity of ascospores and asci in genus Collariella. Ascospores: A. Col. bostrychodes (DTO 326-H6). B. Col. robusta (CBS 551.83\textsuperscript{T}). C. Col. quadrangulata (CBS 152.59). D. Col. causiiformis (CBS 792.83\textsuperscript{T}). E. Col. intricata (CBS 128.85\textsuperscript{T}). F. Col. virescens (CBS 148.68\textsuperscript{T}). G. Col. gracilis (CBS 249.75). Asci: H. Col. bostrychodes (DTO 326-H6). I. Col. quadrangulata (CBS 152.59). J. Col. causiiformis (CBS 792.83\textsuperscript{T}). K. Col. gracilis (CBS 249.75). Scale bars: A–K = 10 μm.

Fig. 22. Collariella bostrychodes (DTO 324-H6). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of upper part of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Asci. K. Ascospores. Scale bars: E–G = 100 μm; H–K = 10 μm.
Fig. 23. Collariella carteri (CBS 128.85, ex-type culture). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H–I. Structure of ascomatal wall in surface view. J. Terminal ascomatal hairs. K. Asci. L. Ascospores. Scale bars: E–G = 20 μm; H–L = 10 μm.
which were phylogenetically close to but separated from Ch. funicola, Ch. erectum and Ch. indicum, respectively (Wang et al. 2014).

In the present study, a new genus Dichotomopilus is proposed to accommodate this monophyletic lineage. Within the genus, two more species D. pseudofunicola and D. pseudoerectus were described as new. Two other species, D. variostiolatus (= Ch. variostiolatum) and D. fusus (Ch. fusum), also clustered in this genus. The former was originally described to possess unbranched seta-like terminal hairs (Fig. 26A), and the latter produces dichotomously-branched terminal hairs (Fig. 26L), and quite distinct ascospores (Fig. 27L).

Seven indoor species were recognised in Dichotomopilus. A high morphological diversity in ascomatal hairs, asci and ascospores was observed within indoor isolates of D. funicola, D. indicus, D. subfunicola and D. variostiolatus. Our morphological examination indicated extremely high intra- and inter-species diversity and also overlap occurs between the indoor isolates of the four species. In contrast, the species D. pratensis (Figs 26G, 27G), D. dolichotrichus (Figs 26J, 27J), D. reflexus (Figs 26K, 27K) and D. fusus (Figs 26L, 27L) from different substrates and different locations are morphologically stable, and easy to be recognised on the basis of morphology. It is a challenge to identify D. funicola, D. indicus, D. subfunicola and D. variostiolatus only based on morphology. We highly recommend the use of sequence data to further understand these species in the genus Dichotomopilus.

Dichotomopilus fusicola ( Cooke) X. Wei Wang & Samson, comb. nov. MycoBank MB818841. Fig. 28.
Basionym: Chaetomium fusicola Cooke, Grevillea 1: 176. 1873. Synonym: Chaetomium cancroideum Tschudy, Am. J. Bot. 24: 478. 1937.

Ascomata superficial, ostiolate, greenish oliveaceous to grey oliveaceous in reflected light, subglobose to ellipsoid or ovate, 195–255 μm high, 180–240 μm diam. Ascomatal wall composed of brown, irregular or elongate cells (textura intricata or epidermoidea). Terminal hairs composed of two types: (1) wider, dark brown and erect, 4–5.5 μm diam near the base, tapering and fading towards tips, dichotomously branched at acute to wide angles starting from the upper half part, punctulate; (2) thinner, luteous to brown, 2–3.5 μm diam near the base, dichotomously branched at wide to acute angles starting from the upper half part, punctulate; Asc fasciculate, with 8 irregularly-arranged ascospores visible, clavate, narrowly clavate, fusiform to pyriform, spore-bearing portion 11–25.5 × 6.5–13.5 μm, stalks 6–15 μm long, evanescent quickly. Ascospores oliveaceous when mature, ovate to slightly elongate ovate, bilaterally flattened, 5.5–6.5 × 3.5–4.5 × 2.5–3 μm (DTO 333-F3), or 5.5–6.5 × 4.5–5 × 3–4 μm (DTO 319-B3), or (6–) 6.5–7.5(–8) × 4.5–5.5 × 3.5–4.5 μm (DTO 333-E2), with an apical germ pore at the more attenuated end. Asexual morph unknown.

Culture characteristics: Colonies on OA with entire edge, spreading rapidly, over 70 mm diam in 7 d at 25 °C, with pale yellow, sparse and floccose aerial hyphae, producing greenish oliveaceous to citrine exudates diffusing into the medium; reverse oliveaceous to cinnamon. Colonies on PCA oliveaceous buff to greenish oliveaceous because of the sparse aerial hyphae and ascomata, with irregularly crenated edge, spreading rapidly, over 70 mm diam in 7 d at 25 °C, without coloured exudates; reverse oliveaceous buff to greenish oliveaceous. Colonies on MEA with entire edge, about 57–63 mm diam in 7 d at 25 °C, forming profuse and pale yellow mycelium and then greenish oliveaceous because of the formation of ascomata, without coloured exudates, reverse oliveaceous. Colonies on DG18 buff with slightly lobate or crenated edge, about 10–16 mm diam in 7 d at 25 °C, without aerial hyphae, without coloured exudates; reverse pale buff.

Specimens examined: Denmark, isolated from dust by B. Andersen, cultures DTO 333-F1 (= IBT 42276); DTO 333-F2 (= IBT 42277). USA, isolated from dust, culture DTO 318-I2.

Notes: The terminal hairs of the indoor isolate examined above look like intermediates between the ex-epitype culture of D. fusicola (fig. 3i–o in Wang et al. 2014) and the authentic culture of Ch. cancroideum (Fig. 26E in this study), especially in the terminal branches. This implied intra-species variation within this species, and encouraged us to synonymise Ch. cancroideum into D. fusicola. This treatment is consistent with the phylogenetic data (Fig. 1).

Dichotomopilus indicus (Corda) X. Wei Wang & Samson, comb. nov. MycoBank MB818842. Figs 29–31.
Basionym: Chaetomium indicum Corda, Icon. Fung. 4: 38. 1840.

Ascomata superficial, ostiolate, greenish oliveaceous to grey oliveaceous in reflected light, subglobose or ovate, 160–310 μm high, 140–275 μm diam. Ascomatal wall composed of brown, irregular or elongate cells (textura intricata or epidermoidea). Terminal hairs composed of two types: (1) wider, dark brown and erect, 4–5 μm diam near the base, tapering and fading towards tips, dichotomously branched at acute angles starting from the upper half part, punctulate; (2) thinner, luteous to brown, 2–3.5 μm diam near the base, dichotomously branched at wide to acute angles starting near the base (DTO 333-F3), or only composed of one type: dark brown and erect, 3–5.5 μm diam near the base, dichotomously branched at acute to wide angles starting from the upper half part, verrucose, tapering and fading towards tips (DTO 319-B3) or partly shorter and dichotomously branched 1–4 times at acute angles starting from the upper half part, partly longer, unbranched and seta-like (DTO 333-E2). Lateral hairs unbranched, seta-like, tapering and fading towards tips. Asc fasciculate, with 8 irregularly-arranged ascospores visible, clavate, broadly clavate, fusiform to pyriform, spore-bearing portion 11–25.5 × 6.5–13.5 μm, stalks 6–15 μm long, evanescent quickly. Ascospores oliveaceous when mature, ovate to slightly elongate ovate, bilaterally flattened, 5.5–6.5 × 3.5–4.5 × 2.5–3 μm (DTO 333-F3), or 5.5–6.5 × 4.5–5 × 3–4 μm (DTO 319-B3), or (6–) 6.5–7.5(–8) × 4.5–5.5 × 3.5–4.5 μm (DTO 333-E2), with an apical germ pore at the more attenuated end. Asexual morph unknown.

Culture characteristics: Colonies on OA with entire edge, about 20–48 mm diam in 7 d at 25 °C, with sparse buff, pale yellow to pale primrose aerial hyphae, without coloured exudates at the beginning, and then producing pale luteous, amber, oliveaceous to cinnamon exudates diffusing into the medium, reverse buff, pale luteous, luteous, oliveaceous to cinnamon. Colonies on PCA usually with entire, slightly undulate, or irregularly crenated edge, about 25–54 mm diam in 7 d at 25 °C, oliveaceous buff, pale yellow to greenish oliveaceous because of the sparse aerial
hyphae together with ascomata and ascospores, without coloured exudates; reverse olivaceous buff, pale yellow to greenish olivaceous. Colonies on MEA with entire or slightly lobate edge, about 36–53 mm diam in 7 d at 25 °C, forming thick yellowish white to pale yellow mycelium, sometimes with radiating furrows, reverse pale luteous to ochraceous. Isolate DTO 333E2 showed distinct colony morphology: white and a little bit wrinkled with entire edge, about 12–18 mm diam in 7 d at 25 °C, forming a relatively thin layer of aerial hyphae, reverse pale luteous. Colonies on DG18 white with entire to crenated edge, about 8–15 mm diam in 7 d at 25 °C, with sparse white aerial hyphae, reverse pale yellow, pale luteous or rust. DTO 333E2 showed distinct colony morphology: buff and wrinkled with crenated edge, about 3–9 mm diam in 7 d at 25 °C, without aerial hyphae, reverse buff.

Specimens examined: **Denmark**, isolated from feather by B. Andersen, cultures DTO 333-F3 (IBT 42278); DTO 333-E2 (IBT 41796). **South Africa**, isolated from dust, culture DTO 319B8.

Notes: Three isolates phylogenetically recognised as *D. indicus* were examined critically. Each of them showed distinct morphology. Isolate DTO 319B8 presented relatively sparse terminal hairs with the branched part not significantly thinner than the basal part of the hairs (Fig. 29). DTO 333E2 showed seta-like terminal hairs, and only parts of them were branched near the top (Fig. 30). DTO 333-F3 presented relatively numerous terminal hairs dichotomously branched in two different types, the thicker ones with the branched part conspicuously thinner than the basal parts (Fig. 31). The examined isolates also showed difference to some extent in ascospores. DTO 333E2 produced the largest ascospores (6.5–7.5 × 4.5–5.5 × 3.5–4.5 μm) compared to those of the two other isolates, while DTO 333-F3 produced narrower ascospores (5.5–6.5 × 3.5–4.5 × 2.5–3 μm) than DTO 319B8 (5.5–6.5 × 4–5 × 3–4 μm).

**Dichotomopilus pratensis** (X.W. Wang & L. Cai) X. Wei Wang & Samson, sp. nov. MycoBank MB818843. Fig. 31. **Basionym:** Chaetomium pratense X.W. Wang & L. Cai, Mycol. Prog. 13: 723. 2014.

Ascomata superficial, ostiolate, greenish olivaceous to olivaceous grey in reflected light, subglobose or ovate, 135–220 μm high, 120–200 μm diam. Ascomatal wall composed of brown, irregular or elongate cells (textura intricata or epidermoidea). Terminal hairs dark brown and often attached by yellow but soluble crystals which would soon dissolve in the mounting solution, 3–4.5 μm diam near the base, dichotomously branched at wide to acute angles starting near the bases, verrucose. Lateral hairs similar to the terminal ones but shorter, or seta-like. Asci fasciculate, with 8 irregularly-arranged ascospores visible, clavate, broadly clavate, pyriform to ovate, spore-bearing portion 10–15 × 7.5–10.5 μm, stalks 4.5–10.5 μm long, evanescent quickly. Ascospores olivaceous when mature, ovate to broad ovate, bilaterally flattened, 5.5–6.5(–7) × 5–5.5 × 3.5–4 μm, with an apical germ pore at the more attenuated end. Asexual morph unknown.

Culture characteristics: Colonies on OA pale luteous to amber with entire or slightly undulate edge, about 34–40 mm diam in 7 d at 25 °C, with sparse aerial hyphae, with amber exudates diffusing into the medium, reverse amber to luteous. Colonies on PCA translucent with entire edge, about 43–49 mm diam in 7 d at 25 °C, pale luteous to greenish olivaceous because of the formation of ascomata, without aerial hyphae, without coloured exudates; reverse buff to pale luteous under the clusters of ascomata. Colonies on MEA amber, with irregularly lobate edge, about 29–35 mm diam in 7 d at 25 °C, with sparse yellow aerial hyphae, reverse luteous to ochraceous. Colonies on DG18 with entire edge, about 28–34 mm diam in 7 d at 25 °C, with yellow to amber aerial hyphae, reverse amber to luteous.

Specimen examined: **Germany**, Kiel-Klizenberg, isolated from air by K.H. Domsch, culture CBS 860.68.

Notes: Comparing several isolates of *D. pratensis* indicated a stable morphology. This species can be easily distinguished by its yellow to amber colony, broad ovate to nearly globose ascospores and the terminal hairs usually branched at wide (straight to right) angle. Previously, a mistake in sequencing gave a wrong identification for the indoor isolate CBS 860.68 (was wrongly identified as *Ch. indicum* in Wang et al. 2014). We corrected this mistake in the present study.

**Dichotomopilus pseudoerectus** X. Wei Wang & Samson, sp. nov. MycoBank MB818844. Fig. 33. **Etymology:** Name refers to its similarity to *D. erectus (= Ch. erectum)*.

Ascomata superficial, ostiolate, greenish olivaceous to olivaceous grey in reflected light, subglobose or ovate, 135–220 μm high, 125–195 μm diam. Ascomatal wall composed of brown, angular or elongate hypha-like cells (textura angularis mixed with textura intricata). Terminal hairs dark brown, irregular in length and often attached by amber but soluble crystals which would soon dissolve in the mounting solution, 3–4.5 μm diam near the base, dichotomously branched at wide to acute angles starting near the bases, verrucose. Lateral hairs similar to the terminal ones but shorter, or seta-like. Asci fasciculate, with 8 irregularly-arranged ascospores visible, clavate, broadly clavate, pyriform to ovate, spore-bearing portion 10–15 × 7.5–10.5 μm, stalks 4.5–10.5 μm long, evanescent quickly. Ascospores olivaceous when mature, ovate to broad ovate, bilaterally flattened, 5.5–6.5(–7) × 5–5.5 × 3.5–4 μm, with an apical germ pore at the more attenuated end. Asexual morph unknown.

Culture characteristics: Colonies on OA with entire edge and spreading rapidly, over 70 mm diam in 7 d at 25 °C, with luteous to ochraceous and floccose aerial hyphae, with amber to ochraceous exudates diffusing into the medium, reverse ochraceous. Colonies on PCA olivaceous with entire edge, about 45–51 mm diam in 7 d at 25 °C, with pale yellow to pale luteous, sparse and floccose aerial hyphae, without coloured exudates; reverse honey. Colonies on MEA white to pale yellow, with irregularly fimbriate edge, wrinkled with irregularly radiating furrows, about 22–26 mm diam in 7 d at 25 °C, with sparse aerial
Collariella gracilis (CBS 249.75). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–G. Ascomata mounted in lactic acid. H. Structure of ascomatal wall in surface view. I. Terminal ascomatal hairs. J. Asci. K. Ascospores. Scale bars: E–G = 20 μm; H–K = 10 μm.
Fig. 26. Morphological diversity of ascomata in the genus Dichotomopilus. A. D. variostiolatus (CBS 179.84T). B. D. variostiolatus (DTO 319-A2). C. D. subfunicola (CBS 812.73). D. D. pseudofunicola (DTO 318-17). E. D. funicola (CBS 136.38 = C. cancroideum). F. D. indicus (DTO 319-B8). G. D. pratensis (CBS 860.68). H. D. erectus (CGMCC 3.12900). I. D. ramosissimus (CGMCC 3.14183T). J. D. dolichotrichus (CBS 162.48T). K. D. reflexus (CBS 157.49T). L. D. fusus (CBS 114.83). Scale bars: A–L = 100 μm.
hyphae, reverse luteous to fulvous. Colonies on DG18 pale ochraceous with entire edge, about 7–13 mm diam in 7 d at 25 °C, without aerial hyphae, reverse pale luteous.

Specimen examined: India, Uttar Pradesh, isolated from air by Kamal (holotype CBS H-22846, culture ex-type CBS 252.75).

Notes: the ex-type culture CBS 252.75 is deposited in the CBS collection as Ch. erectum. This species is indeed morphologically similar to D. erectus (= Ch. erectum). However, the phylogenetic analysis (Fig. 1) indicated that it is closer to D. ramosissimus than to D. erectus. Dichotomophilus pseudoe erectus can be differentiated from D. ramosissimus by relatively sparse terminal ascomatal hairs which are often different in length.

Dichotomophilus pseudofunicola X. Wei Wang & Samson, sp. nov. MycoBank MB818845. Fig. 34.

Etymology: Name refers to its similarity to D. funicola.

Ascomata superficial, ostiolate, grey olivaceous to dark grey olivaceous in reflected light, subglobose or ovate, 140–260 μm high, 130–235 μm diam. Ascomatal wall composed of brown, hypha-like or irregular cells (textura intricata). Terminal hairs olivaceous brown, 4–7 μm diam near the base, punctulate, partly longer and erect, seta-like, unbranched or dichotomously branched 1–3 times at wide to acute angles usually only at the top part; partly shorter, dichotomously branched profusely starting near the base and forming a globose net to enfold ascomata. Lateral hairs unbranched, seta-like, tapering and fading towards tips. Ascii fasciculate, clavate, broadly clavate to pyriform or ovate, with 8 irregularly-arranged ascospores, spor e-bearing portion 12–18 × 7–10.5 μm, stalks 6–11 μm long, evanescent quickly. Ascospores olivaceous when mature, ovate to limoniform, bia piculate, bilaterally flattened, 5.5–6(–6.5) × 4–5 × 3.5–4 μm, with an apical germ pore at the more attenuated end. Asexual morph unknown.

Culture characteristics: Colonies on OA with an entire edge, about 46–54 mm diam in 7 d at 25 °C, with pale yellow, floccose aerial hyphae, producing pale luteous, pale citrine, citrine green to greenish olivaceous exudates diffusing into the medium; reverse pale luteous, citrine, greyish-yellow to green. Colonies on PCA pale yellow to greenish olivaceous because of the sparse aerial hyphae and ascomata, with entire or slightly lobate edge, about 55–62 mm diam in 7 d at 25 °C, without coloured exudates; reverse uncoloured. Colonies on MEA with lobate edge, about 41–47 mm diam in 7 d at 25 °C, forming profuse and pale yellow mycelium, greenish olivaceous because of the formation of ascomata (CBS 812.73), or with white to pale yellow aerial hyphae forming a few crenated concentric circles near the edge (CBS 794.83), without coloured exudates, reverse pale luteous to ochraceous. Colonies on DG18 pale luteous, with slightly lobate or crenated edge, about 7–16 mm diam in 7 d at 25 °C, with white aerial hyphae, without coloured exudates; reverse pale luteous.

Specimen examined: New Guinea, isolated from pistol belt by E.T. Reese, culture CBS 812.73. Switzerland, Engadin, isolated from paper by M. Dreyfuss, culture CBS 794.83. Notes: Dichotomophilus subfunicola is another species close to D. funicola. There is phylogenetic variation within the species, but no strong evidence allowed us to segregate it into two different species. This species also showed high morphological intra-species variation, especially in terminal ascomatal hairs.

Fig. 27. Morphological diversity of ascospores in the genus Dichotomophilus. A. D. variostiolatus (CBS 179.84). B. D. variostiolatus (DTO 319-A2). C. D. subfunicola (CBS 812.73). D. D. funicola (DTO 333-F1). E. E. indicus (DTO 319-B8). F. D. indicus (DTO 333-F3). G. D. pratensis (CBS 880.68). H. D. erectus (CGMCC 3.12900). I. D. ramosissimus (CGMCC 3.14183). J. D. dolichotrichus (CBS 162.48). K. D. reflexus (CBS 157.49). L. D. fusus (CBS 114.83). Scale bars: A–L = 10 μm.
Fig. 28. *Dichotomopilus funicola* (DTO 333-F1). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper part of a terminal ascomatal hair. I–J. Asci. K. Ascospores. Scale bars: D–F = 100 μm; G–K = 10 μm.

Fig. 29. *Dichotomopilus indicus* (DTO 319-B8). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper part of a terminal ascomatal hair. I–J. Asci. K. Ascospores. Scale bars: D–F = 100 μm; G–K = 10 μm.
Fig. 30. Dichotomopilus indicus (DTO 333-E2). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper part of a terminal ascomatal hair. I–J. Asci. K. Ascospores. Scale bars: E–F = 100 μm; G–K = 10 μm.
Fig. 31. *Dichotomus indicus* (DTO 333-F3). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper parts of terminal ascomatal hairs. I. Basal parts of terminal ascomatal hairs. J–K. Asci. L. Ascospores. Scale bars: D–F = 100 μm; G–L = 10 μm.
**Fig. 32.** *Dichotomopilus pratensis* (CBS 860.68). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper parts of terminal ascomatal hairs. I–J. Asci. K. Ascospores. Scale bars: D–F = 100 μm; G–K = 10 μm.
**Dichotomopsis pseudoerectus** (CBS 252.75, ex-type culture). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Textura angularis structure of ascomatal wall in surface view. G. Textura intricata structure of ascomatal wall in surface view. H. Terminal ascomatal hairs. I–J. Asci. K. Ascospores. Scale bars: D–E = 100 μm; F–K = 10 μm.
Fig. 34. *Dichotomopilus pseudofunicola* (CBS 142033 = DTO 318-I7, ex-type culture). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Terminal ascomatal hairs. I. Asci. J. Ascospores. Scale bars: D–F = 100 μm; G–J = 10 μm.
Isolates of the species often form two types of ascomatal hairs, but some isolates produce only one type (CBS 794.83, Fig. 36). Wang et al. (2014) differentiated D. subfunicola from D. funicola by broader (ovate) asci. Examination of more isolates showed a morphological diversity in the shape of the asci, and this indicates that this character is not suitable for differentiation between those two species.

**Dichotomopilus variostiolatus** (Carter) X. Wei Wang & Samson, comb. nov. MycoBank MB818847. Figs 37–39. Basionym: Chaetomium variostiolatum Carter, Canad. J. Bot. 61: 2603. 1983.

Ascomata superficial, or covered by white to pale yellow aerial hyphae, ostiolate, olivaceous grey dark brick to brown vinaceous in reflected light due to ascomatal hairs, globose or subglobose, 150–250 μm diam. Ascomatal wall brown, textura intricata or epidermoidea in surface view. Ascomatal hairs seta-like or flexuous, smooth to finely verrucose, brown, 4–6.5 μm diam near the base, fading and tapering towards the tips (CBS 179.84), or olivaceous to brown, 2–3.5 μm diam near the base, dichotomously branched profusely at wide angles starting near the base and forming a nearly globose net to enfold ascospores, and often with several longer hairs out of the net (DTO 319-A2), or composed of both types: (1) thinner, olivaceous to brown, 1.6–3.5 μm diam near the base, dichotomously branched profusely at acute to wide angles starting near the base, often constricted at septa, verrucose; (2) wider, dark brown and erect, 3–5 μm diam near the base, tapering and fading towards tips, seta-like or branched near the top, the branches often constricted at septa, verrucose (DTO 319-B9). Lateral hairs simply branched or seta-like, tapering and fading towards tips, sometimes covered by pale yellow soluble crystals. Asci fascicate, clavate, fusiform, pyriform or obovate, with 8 irregularly arranged ascospores, spore-bearing part 11–24 × 7–12.5 μm, stalks 7–20 μm long, evanescent quickly. Ascospores brown when mature, ovate, (5–)5.5–6.5(–7) × (3.5–)4–4.5(–5) × 3–4 μm, with an apical germ pore at the attenuated end. Asexual morph unknown.

**Culture characteristics:** Colonies on OA with lobate edge, about 34–46 mm diam (CBS 179.84 and DTO 319-B9) or spreading rapidly, over 70 mm diam (DTO 319-A2) in 7 d at 25 °C, with a relatively thick layer of white mycelium varying usually in thickness (CBS 179.84), or white to pale yellow at the beginning because of the aerial hyphae, gradually olivaceous grey because of the formation of ascomata (DTO 319-A2), or with sparse pale yellow aerial hyphae (DTO 319-B9), producing luteous, amber, citrine green to citrine exudates diffusing into the medium; reverse pale luteous, greyish olivaceous or greyish yellow-green. Colonies on PCA translucent, with an entire or crenated edge, about 29–47 mm diam (CBS 179.84 and DTO 319-B9) or over 70 mm diam (DTO 319-A2) in 7 d at 25 °C, with sparse and floccose aerial hyphae, without coloured exudates; reverse uncoloured. Colonies on MEA with an entire or lobate to irregularly crenated edge, about 34–40 mm diam(CBS 179.84 and DTO 319-B8), or about 54–60 mm diam (DTO 319-A2) in 7 d at 25 °C, with floccose and white aerial hyphae together with several radiated furrows and a dark ring around the central point because of the formation of ascomata (CBS 179.84 and DTO 319-B9), or white to greyish yellow-green because of the profuse aerial hyphae and ascomata below (DTO 319-A2) without coloured exudates; reverse luteous to ochraceous. Colonies on DG18 white to buff with an entire, a slightly crenated or lobate to edge, about 9–18 mm diam in 7 d at 25 °C, with a white floccose ring composed of aerial hyphae near the edge (CBS 179.84), or without aerial hyphae (DTO 319-A2 and DTO 319-B9), without coloured exudates, reverse uncoloured.

Specimens examined: New Guinea, collected from tarpaulin by E.T. Reese, ex-type culture CBS 179.84. Thailand, isolated from dust, cultures DTO 319-B9; DTO 319-C1. USA, isolated from dust, culture DTO 319-A2.

**Notes:** Dichotomopilus variostiolatus was originally described to possess unbranched seta-like terminal hairs on the basis of the ex-type culture CBS 179.84 (Carter 1983). This study confirmed the examination of Carter (Fig. 37), proving a stable morphology of the ex-type culture. At the same time, several indoor isolates were found to cluster with the ex-type. These isolates produce either dichotomously branched (Fig. 38) or together with seta-like (Fig. 39) terminal hairs, indicating a broad range of the species population.

**Humicola** Traaen, Nytt Mag. Natur. 52: 33. 1914.

**Type species:** *Humicola fuscoatra* Traaen

Two indoor taxa of this genus were recognised in this study. They are clustered closely with the type species of *Humicola*, *H. fuscoatra* (ex-type CBS 118.14) in a strongly supported monophyletic lineage (Fig. 1).

**Humicola olivacea** X. Wei Wang & Samson, sp. nov. MycoBank MB818848. Fig. 40.

**Etymology:** Name refers to the colony colour of this fungus.

**Somatic hyphae** hyaline to honey, 1–2.5 μm wide. **Aleurioconidia** usually produced singly or in chains on 2–8 μm long or very reduced lateral hyphae, olivaceous brown, subglobose to broad obovate, attenuated at the base, (7.5–)8–9.5(–11) × (7–) 7.5–9(–10) μm. Description of the micromorphology was based on the culture on SNA.

**Culture characteristics:** Colonies on OA with an entire edge, about 49–55 mm diam in 7 d at 25 °C, greenish olivaceous because of the formation of a large number of conidia, with a thin layer of aerial hyphae; reverse black. Colonies on PCA greenish olivaceous to grey olivaceous, with an entire edge, about 37–43 mm diam in 7 d at 25 °C, with sparse white to grey aerial hyphae; reverse black with grey edge. Colonies on MEA white, with an entire edge, 47–53 mm diam in 7 d at 25 °C, forming radiating furrows, with white and relatively sparse floccose aerial hyphae; reverse olivaceous buff to greenish olivaceous. Colonies on DG18 olivaceous with an entire and buff edge, about 13–19 mm diam in 7 d at 25 °C, with olivaceous aerial hyphae; reverse hazel with buff edge. Colonies on SNA with an entire edge, about 41–47 mm diam in 7 d at 25 °C, translucent, without aerial hyphae, grey olivaceous in the centre; reverse olivaceous in the centre.

Specimens examined: USA, isolated from dust by K. Seifert (holotype CBS H-22848, culture ex-type CBS 142031 = DTO 319-C7).

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Notes: This species is morphologically similar to *H. glauca*, *H. lutea* and *H. repens* (Bertoldi 1976), especially in shape and size of aleurioconidia, but can be distinguished by the colour of aleurioconidia, the colony morphology and the formation of aleurioconidia easily in chains. The ITS sequence data also supported the differences between this species and the three morphologically similar species (data not shown here).

**Humicola** sp. Fig. 41.

Somatic hyphae hyaline to subhyaline, 1–3 μm wide. *Aleurioconidia* produced terminally or laterally singly or two in chains on hyaline to pale brown hyphae which are very reduced till up to 16 μm long, smooth, globose, obovoid, pyriform to clavate, pale brown to brown, (7.5–)8.5–11.5(–13.5) × (5.5–)7.5–9(–11) μm.

**Culture characteristics**: Colonies on OA with an entire or irregularly undulate edge, about 52–58 mm diam in 7 d at 25 °C, partially with thick white and floccose aerial hyphae, immersed hyphae grey to black; reverse black. Colonies on PCA white to honey, with an entire edge, about 48–54 mm diam in 7 d at 25 °C, translucent, with thick white aerial hyphae in the centre; reverse white to smoke grey, black in the centre. Colonies on MEA with an entire edge, 51–57 mm diam in 7 d at 25 °C, with thick, white to honey floccose aerial hyphae; reverse black. Colonies on DG18 white, with an entire edge, about 18–24 mm diam in 7 d at 25 °C, with relatively thin white aerial hyphae; reverse pale luteous, black in the centre. Colonies on SNA white, with an entire edge, about 56–62 mm diam in 7 d at 25 °C, translucent with sparse and uneven white aerial hyphae; reverse partially black.

Specimens examined: Mexico, isolated from dust, cultures DTO 318-G9; DTO 318-H1. South Africa, isolated from dust, culture DTO 319-B7.

Notes: These isolates are morphologically similar to *H. piniformis* especially in the shape of their aleurioconidia. However, it differs in having larger aleurioconidia than *H. piniformis* (7.0–7.5 μm diam). The ITS sequences of *H. auraea*, *H. glauca*, *H. lutea*, *H. piniformis* and *H. repens* are identical and our indoor isolates differ only by one base pair. ITS sequences seemed not to be informative enough to distinguish the aleurioconidial fungi. For example, the ITS sequences of *H. grisea* and *Trichocladium asperum* were identical (data not shown here), but the morphology of these two species are distinct (Hambleton et al. 2005). Cultures of all the related species and more research are needed to re-evaluate these related species, and then to make an identification decision for this taxon.

**Humicola** is a well-known hyphomycetous genus possessing smooth-walled and usually aseptate aleurioconidia forming attached to lateral or terminal conidiogenous cells (Bertoldi 1976, Hambleton et al. 2005). Further study is strongly encouraged to clarify the relationships of the *Humicola* species included in this study to the other *Humicola* species as well as the members of *Farrowia* (Hawskworth 1975) and some traditional species of *Chaetomium* such as *C. homopilatum* which have humicola-like asexual morphs.

**Melanocarpus** Arx, Stud. Mycol. 8:17. 1975.

**Type species**: *Melanocarpus albomyces* (Cooney & R. Emers.) Arx

**Melanocarpus tardus** X. Wei Wang & Samson, sp. nov. MycoBank MB818849. Fig. 42.

Etymology: Name refers to the restricted growth of this fungus on the agar media.

**Ascomata** superficial, or embedded in white aerial mycelium, often aggregated, non-ostiolate, black in reflected light, glabrous or with a few hypha-like and hyaline hairs, globose, 50–170 μm diam. **Ascomatal wall** brown, ochraceous or fuscous when young, dark brown to black when mature, *textura epidermoidea* or *intricata* in surface view. **Asci** fasciculate, ovate to broadly ovate, spore-bearing portion 11–16.5 × 9–13.5 μm, stalks 4–9.5 μm long, with 8 irregularly-arranged ascospores, evanescent quickly before the ascospores mature. Ascospores brown when mature, ovate to broadly ovate, bilaterally flattened, 7–8(–8.5) × (6–) 6.5–7.5 × 5–6 μm, with an apical germ pore at the attenuated end. **Asexual morph** unknown.

**Culture characteristics**: Colonies on OA growing slowly, about 2–7 mm diam in 7 d at 25 °C, with an entire edge, with white, floccose and compact aerial mycelium, without coloured exudates, or producing honey to greenish olivaceous exudates diffusing into the medium when becoming old; reverse uncoloured. Colonies on PCA with an entire edge, about 2–8 mm diam in 7 d at 25 °C, buff, slightly floccose, without coloured exudates; reverse uncoloured. Colonies on MEA with a lobate edge, about 3–8 mm diam in 7 d at 25 °C, with white and floccose mycelium, without coloured exudates; reverse uncoloured. The growth of colonies on DG18 was restricted, less than 2 mm after 7 d at 25 °C, without coloured exudates; reverse uncoloured.

Specimen examined: Switzerland, St. Gallen, isolated from cotton jacket by E. Müller in Sep. 1976 (holotype CBS H-22849, culture ex-type CBS 541.76).

Notes: The ex-type culture CBS 541.76 is deposited in the CBS collection as *T. minuta*. *Thielavia minuta* was originally described to have rapidly spreading colonies. Furthermore, the ascocaratae are covered by a dense layer of curved brown and curved hairs, and the ascospores are ovate shaped, measuring 6.5–8 × 5–5.5 μm (Cain 1961). CBS 541.76 exhibits very restricted growth on agar media, and the ascocaratae are glabrous or nearly so, and contain conspicuously bilaterally flattened ascospores. This combination of characteristics does not fit with that of *T. minuta* and therefore a new species was introduced for this isolate.

Although *Melanocarpus tardus* and the type species of the genus *Melanocarpus*, *M. albomyces* are on two very long branches in the phylogenetic tree (Fig. 1), they clustered together with high statistic support. We prefer to keep this species as a member of *Melanocarpus* rather than introducing a novel monotypic genus to accommodate it.
The genus *Melanocarpus* was considered to possess non-ostiolate ascomata, and differs from *Thielavia* in having spreading colonies; obovate, spherical or oblate ascospores and chrysorilla-like asexual morph (von Arx et al. 1988). The isolate CBS 541.76 does not produce spreading colonies and chrysorilla-like asexual morph. The addition of this species into *Melanocarpus* prompts the re-evaluation of this genus.

**Ovatospora** X. Wei Wang, Samson & Crous, gen. nov. Myco-Bank MB818850. Figs 43, 44.

*Type species*: *Ovatospora brasiliensis* (Batista & Pontual) (= Ch. brasiliense).

Ascomata superficial, ostiolate, subglobose or ovate with brown walls of textura angularis in surface view. Terminal hairs usually coiled, sometimes with coiled branches. *Lateral hairs* flexuous. *Asci* fasciculate, cylindrical with 8 uniseriate ascospores, or clavate with 8 biseriate or irregularly arranged ascospores, evanescent. Ascospores brown when mature, broadly ovate, bilaterally flattened, rounded at one end, with an apical germ pore at another attenuate or apiculate end. *Asexual morph* unknown.

**Ovatospora brasiliensis** (Batista & Pontual) X. Wei Wang & Samson, comb. nov. MycoBank MB818851. Fig. 45. *Basionym*: Chaetomium brasiliense Batista & Pontual, Bol. Agr. Com. Pernambuco 15: 70. 1948.

Ascomata superficial, pale olivaceous grey to mouse grey in reflected light due to ascomatal hairs, globose or subglobose, ostiolate, 85–135 μm high, 75–110 μm diam. *Ascomatal wall* brown, *textura angularis*, sometimes mixed with *textura intricata* in surface view. *Terminal hairs* undulate to loosely coiled with erect or flexuous lower part, conspicuously rough (granulate), greyish sepia to brown, septate, 2–3.5 μm diam in the undulate or coiled upper portion. *Lateral hairs* flexuous, tapering and fading towards the tips. *Asci* fasciculate, cylindrical, spore-bearing part 35–45 × 5–7.5 μm, stalks 8–18 μm long, with 8 uniseriate ascospores, evanescent before ascospores become mature. Ascospores olivaceous brown when mature, ovate, bilaterally flattened, (6.5–7–7.5(–8) × (5.5–)6–6.5(–7) × (4.5–)5–5.5(–6) μm, with an apical germ pore at the attenuated end. *Asexual morph* unknown.

*Culture characteristics*: Colonies on OA with entire edge, about 43–49 mm diam in 7 d at 25 °C, with a floccose, white to pale grey mycelium, often with one or a few irregular concentric rings, with pigmented hyphae immersed in medium, and with mouse grey to black exudates diffusing into the medium, reverse black. Colonies on PCA with entire edge, about 33–39 mm diam in 7 d at 25 °C, with a floccose and white to olivaceous buff aerial hyphae mixed with ascomata, without coloured exudates; reverse hazel to olivaceous. Colonies on MEA with slightly undulate edge, about 41–37 mm diam in 7 d at 25 °C, with floccose, white and irregularly petaloid rather than concentric aerial mycelium, with pigmented hyphae immersed in medium, without coloured exudates, reverse black with pale edge. Colony growth on DG18 with entire edge, about 16–22 mm diam in 7 d at 25 °C, with white aerial mycelium appearing irregularly petaloid texture, without coloured exudates; reverse uncoloured.

*Specimen examined*: India, Uttar Pradesh, isolated from air by Kamal (holotype CBS H-22850, culture ex-type CBS 251.75).

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Fig. 36. *Dichomomopus subfunicola* (CBS 794.83): A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view; D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper parts of terminal ascomatal hairs. I. Asci. J. Ascospores. Scale bars: D–F = 100 μm; G–J = 10 μm.
Fig. 37. *Dichotomopilus variostiolatus* (CBS 179.84T). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Structure of ascomatal wall in surface view. G–J. Terminal ascomatal hairs from basal to upper parts. K. Asci. L. Ascospores. Scale bars: D–E = 100 μm; F–L = 10 μm.
**Fig. 38.** *Dichotomopilus variostiolatus* (DTO 319-A2). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view. C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Structure of ascomatal wall in surface view. G. Upper part of a terminal ascomatal hair. H. Net structure formed by terminal ascomatal hairs. I. Asci. J. Ascospores. Scale bars: D–E = 100 μm; H= 20 μm; F–G, I–J = 10 μm.
**Fig. 39.** Dichotomopilus variostilatus (DTO 319-B9). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–D. Mature ascomata on OA, side view. E–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Terminal ascomatal hair. I. Upper part of a branched terminal ascomatal hair. J–K. Asci. L. Ascospores. Scale bars: E–F = 100 μm; G–L = 10 μm.
Notes: Phylogenetic inference indicated that *O. pseudomollicella* clustered close to but separated from *O. mollicella* (CBS 583.83). This species can be distinguished by the size of its ascospores (7.5–8.5 × 6–7.5 × 5–6 μm), which are larger than those of *O. brasiliensis* (7–7.5 × 6–6.5 × 5–5.5 μm), and smaller than those of the ex-type of *O. mollicella* (8–9.5 × 7–8 × 6–7 μm; von Arx et al. 1986).

The previous study (Carter 1982) indicated that the species of this genus, together with the members of *Arcopilus* and *Farrowa* (Hawksworth 1975), had long stipitate ascogonial coils, while...
most of the other species in the Chaetomiaceae had irregular ascogonial coils. This might be worth noticing when observing the formation of young ascomata.

**Subramaniula** Arx, Proc. Indian Acad. Sci., Plant Sci. 94: 344. 1985.

Type species: *Subramaniula thieliavioides* (Arx, Mukerji & N. Singh) Arx

Synonym: *Achaetomium thieliavioides* Arx, Mukerji & N. Singh, Persoonia 10: 144. 1978.

Notes: The genus *Subramaniula* was originally proposed to accommodate species with urniform and nearly glabrous ascomata with a translucent wall and a wide ostiole surrounded by a hyaline collar (von Arx 1985b). A recent study (Ahmed et al. 2016) indicated the close relationships between *S. thieliavioides* and several chaetomium-like species. The phylogenetic analyses in this study confirmed their results. These data greatly expanded the number of species in this genus. *Subramaniula* remains to be redescribed, and the description of one species from the indoor environment is given below.

**Subramaniula cristata** (Ames) X. Wei Wang & Samson, comb. nov. MycoBank MB818853. Fig. 47.

*Basionym:* *Chaetomium cristatum* Ames, Mycologia 41: 639. 1949.

Ascomata superficial, ostiolate, pale olivaceous grey or pale mouse grey to mouse grey in reflected light owing to ascomatal hairs, subglobose or ovate, 240–390 μm high, 200–300 μm diam. Ascomatal wall brown, *textura angularis* in surface view. Terminal hairs erect, finely warty, dark brown, 4.5–5.5 μm diam near the base, apically irregularly-curved and branched repeatedly, forming a network consisting of thinner (1.5–2.3 μm diam), olivaceous or fawn, flexuous or undulate branches. Lateral hairs brown, seta-like, fading and tapering towards the tips. Asci fasciculate, fusiform or clavate, spore-bearing part 23–40 × 9–12 μm, stalks 12–30 μm long, with 8 irregularly-arranged ascospores, evanescent. Ascospores olivaceous brown when mature,
Fig. 42. Melanocarpus tardus (CBS 541.76, ex-type culture). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B–C. Mature ascomata on OA, top view; D–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Asci. I. Ascospores. Scale bars: D–F = 20 μm; G–I = 10 μm.
Fig. 43. Morphological diversity of Ascomata in the genus Ovatospora. A. O. brasiliensis (CBS 140.50). B. O. pseudomollicella (CBS 251.75T). C. O. medusarum (CBS 148.67T, young ascoma). D. O. medusarum (CBS 148.67T, mature ascoma). E. O. senegalensis (CBS 728.84T). F. O. unipora (CBS 109.83T). Scale bars: A–F = 100 μm.
ellipsoidal-fusiform, (9–)9.5–10.5(–11) × (5–)5.5–6.5(–7) μm, with a subapical germ pore. Asexual morph absent.

Culture characteristics: Colonies on OA with an entire edge, about 34–40 mm diam in 7 d at 25 °C, without aerial hyphae, with smoke grey to olivaceous grey exudates diffusing into the medium, reverse pale olivaceous grey to olivaceous. Colonies on PCA translucent, with numerous vinaceous buff ascomata in the central area and a slightly lobate edge, about 33–39 mm diam in 7 d at 25 °C, without aerial hyphae, without coloured exudates or pruinose colonies.
exudates; reverse uncoloured. Colonies on MEA pale vina-
ceous with brick perisphere, about 18–24 mm diam in 7 d at
25 °C, non-sporulating, reverse vinaceous with salmon edge.
Colonies on DG18 with an entire or slightly undulate edge,
about 3–9 mm diam in 7 d at 25 °C, buff and slightly floccose,
non-sporulating, without coloured exudates; reverse uncoloured.

Specimens examined. China, Beijing, isolated from air by A.J. Chen, cultures
DTO 324-H7 and DTO 324-H8.

Notes: Subramaniula cristata morphologically fits with
S. cuniculorum (Ch. cuniculorum). Ames (1963) synonymised
this species to Ch. cuniculorum. This decision was followed by
von Arx et al. (1986). The phylogenetic analysis indicated that
our indoor isolates clustered with the ex-type of S. cristata. They
were close to but separated from the reference isolate of
S. cuniculorum. Subramaniula cuniculorum was originally
collected from Germany in 1869. No ex-type culture of
S. cuniculorum were available now. The reference isolate CBS
800.83 was from Spain. Typification of S. cuniculorum and
distinguishing this species from S. cristata await comparison with
the holotype of S. cuniculorum.

Additional new combinations from non-indoor environments:

Amesia gelatinospora (Aue & Müller) X. Wei Wang & Samson,
comb. nov. MycoBank MB818854. 
Basionym: Chaetomium gelatinosporum Aue & Müller, Ber
Schweiz. Bot. Ges. 77:193. 1967.

Arcopilus aureus (Chivers) X. Wei Wang & Samson, comb.
nov. MycoBank MB818855.
Basionym: Chaetomium aureum Chivers, Proc. Am. Acad. Arts
Sci. 48: 87. 1912

Arcopilus cupreus (Ames) X. Wei Wang & Samson, comb.
nov. MycoBank MB818856.
Basionym: Chaetomium cupreum Ames, Mycologia 41: 642. 1949.

Arcopilus fusiformis (Chivers) X. Wei Wang & Samson, comb.
nov. MycoBank MB818857.
Basionym: Chaetomium fusiforme Chivers, Proc. Am. Acad. Arts
Sci. 48: 87. 1912.

Arcopilus flavigenus (van Warmelo) X. Wei Wang & Samson,
comb. nov. MycoBank MB818858.
Basionym: Chaetomium flavigenum van Warmelo, Mycologia 58:
847. 1966.

Botryotrichum spirotrichum (R.K. Benjamin) X. Wei Wang &
Samson, comb. nov. MycoBank MB818860.
Basionym: Magnusia spirotricha R.K. Benjamin, Aliso 3: 199. 1955.
Synonyms: Kernia spirotricha (R.K. Benjamin) Aliso 3: 344. 1956
Chaetomidium spirotricha (R.K. Benjamin) Malloch & Cain,
Canad. J. Bot. 49: 867. 1971.
Thielavia spirotricha (R.K. Benjamin) Malloch & Cain, Mycologia
65: 1069. 1973.
Emlimuellera spirotricha (R.K. Benjamin) Arx, Sydowia 38: 6. 1985.

Collariella quadrangulata (Chivers) X. Wei Wang & Samson,
comb. nov. MycoBank MB818861.
Basionym: Chaetomium quadrangulatum Chivers, Proc. Am.
Acad. Arts Sci. 48: 85. 1912.

Collariella robusta (Ames) X. Wei Wang & Samson, comb.
nov. MycoBank MB818872.
Basionym: Chaetomium robustum Ames, Monograph of the
Chaetomiaceae: 35. 1963.

Collariella virescens (Arx) X. Wei Wang & Samson, comb.
nov. MycoBank MB819488.
Basionym: Achaetomiella virescens Arx, Genera of Fungi: 247.
1970.
Synonym: Chaetomium virescens (Arx) Udagawa, Trans. Mycol.
Soc. Japan 21: 34. 1980.

Dichotomopilus dolichotrichus (Ames) X. Wei Wang &
Samson, comb. nov. MycoBank MB818866.
Basionym: Chaetomium dolichotrichum Ames, Mycologia 37:
145. 1945.

Dichotomopilus ercius (Skolko & J.W. Groves) X. Wei Wang
& Samson, comb. nov. MycoBank MB818867.
Basionym: Chaetomium ercius Skolko & J.W. Groves, Canad.
J. Res., Section C 26: 277. 1948.

Dichotomopilus fusus (Ames) X. Wei Wang & Samson, comb.
nov. MycoBank MB818868.
Basionym: Chaetomium fusum Ames, Monograph of the Chae-
tomiaceae: 25. 1963.

Dichotomopilus ramosissimus (X.W. Wang & L. Cai) X. Wei
Wang & Samson, comb. nov. MycoBank MB818869.
Basionym: Chaetomium subfunicola X.W. Wang & L. Cai, Mycol.
Prog. 13: 725. 2014.

Dichotomopilus reflexus (Skolko & J.W. Groves) X. Wei Wang
& Samson, comb. nov. MycoBank MB818870.
Basionym: Chaetomium reflexus Skolko & J.W. Groves, Canad.
J. Res., Section C 26: 279. 1948.

Ovatospora medusarum (Meyer & Lanneau) X. Wei Wang
& Samson, comb. nov. MycoBank MB818871.
Basionym: Chaetomium medusarum Meyer & Lanneau, Bull.
Soc. Mycol. Fr. 83: 318. 1967.

Ovatospora mollicella (Ames) X. Wei Wang & Samson, comb.
nov. MycoBank MB818873.
Basionym: Chaetomium mollicellum Ames, Monograph of the
Chaetomiaceae: 30. 1963.

Ovatospora senegalensis (Ames) X. Wei Wang & Samson,
comb. nov. MycoBank MB818874.
Basionym: Chaetomium senegalense Ames, Monograph of the
Chaetomiaceae: 36. 1963.

Ovatospora unipora (Aue & Müller) X. Wei Wang & Samson,
comb. nov. MycoBank MB818875.

Fig. 45. Ovatospora brasiliensis (CBS 140.50). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C. Mature ascomata on OA, side view. D–E. Ascomata mounted in lactic acid. F. Structure of ascomatal wall in surface view. G. Upper part of a terminal ascomatal hair. H. Basal part of
terminal ascomatal hairs. I. Asci. J. Ascospores. Scale bars: D–E = 100 μm; F–J = 10 μm.
**Fig. 46.** Ovatospora pseudomollicella (CBS 251.75, ex-type culture). A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B–C. Mature ascomata on OA, top view; D. Mature ascomata on OA, side view; E–F. Ascomata mounted in lactic acid. G. Structure of ascomatal wall in surface view. H. Upper parts of terminal ascomatal hairs. I. Asci. J. Ascospores. Scale bars: E–F = 100 μm; G–J = 10 μm.
Fig. 47. Subramaniula cristata [DTO 324-H8]. A. Colonies from left to right on OA, PCA, MEA and DG18 after 7 d incubation. B. Mature ascomata on OA, top view; C–E. Mature ascomata on OA, side view. F–H. Ascomata mounted in lactic acid. I. Structure of ascomatal wall in surface view. J. Upper part of a terminal ascomatal hair. K. Asci. L. Ascospores. Scale bars: F–H = 100 μm; I–L = 10 μm.
Subramaniula anamorphosa (S.A. Ahmed, et al.) X. Wei Wang & Samson, **comb. nov.** MycoBank MB818876. *Basionym:* Subramaniula anamorphosa S.A. Ahmed, et al., Fungal Diversity 76: 18. 2016.

**Subramaniula cuniculorum** (Fuckel) X. Wei Wang & Samson, **comb. nov.** MycoBank MB818877. *Basionym:* Subramaniula cuniculorum Fuckel, Symb. Mycol.: 89. 1869.

Subramaniula flavipila X. Wei Wang & Samson, **nom. nov.** MycoBank MB818878. *Basionym:* Chaetomium flavipile Sörgel, Nova Hedwigia 12: 386. 1966. *Etymology:* Name refers to the yellow to luteous ascomatal hairs of this fungus.

**Notes:** Non Subramaniula irregularis P. Cannon & D. Hawksworth, Trans. Br. Mycol. Soc. 87: 56. 1986. The name *S. irregularis* already exists, therefore the new name is proposed.

**Subramaniula fusispora** (G. Smith) X. Wei Wang & Samson, **comb. nov.** MycoBank MB818879. *Basionym:* Chaetomium fusisporum G. Smith, Trans. Br. Mycol. Soc. 44: 46. 1961.

**KEY TO THE MOST COMMON CHAETO MIACEAE SPECIES (OR SPECIES COMPLEX) FROM THE INDOOR ENVIRONMENTS**

1. **Asexual morph present** ................................................................................................................................................................................... 2
2. **Asexual morph absent** ................................................................................................................................................................................ 3
3. Terminal ascomata numerous, terminal ascomatal hairs repeatedly dichotomously branched, usually less than 5 μm diam near the base; Ascospores limoniform, bilaterally flattened, 11.5–14 × 8.5–10 × 7–8 μm, with an apical germ pore assexual morphs acremonium-like ................................................................................................................................................................................... 4
4. Terminal ascomata hairs not repeatedly dichotomously branched or seta-like, often composed of two types of hairs different in length; ascospores ovate to elongate ovate, bilaterally flattened, usually less than 5 μm diam near the base; **Botryotrichum piluliferum** (D. funicola species complex (including D. funicola, D. pseudofunicola, D. subfunicola and D. variostilatula)) ........................................................................................................................................................................... 4
5. Ascomata subglobose to obovate with a dark collar-like apex around the ostiolar pore; terminal hairs spirally coiled, ascospores limoniform, bilaterally flattened, 6–7 × 5.5–6.5 × 4.5–5.5 μm, with an apical germ pore .......... **Collariella bostrychodes** 5
6. Terminal hairs flexuous, undulate to slightly coiled .............................................................................................................................................................. 5
7. Terminal hairs spirally coiled, usually with coils regularly tapering in diameter ........................................................................................................................... 6
8. **DISCUSSION**

*Chaetomium* spp., together with several other genera such as *Stachybotrys, Aspergillus* and *Penicillium*, are of concern because of their ability to grow in the indoor environment and their association with production of bioactive metabolites (*Brasel et al. 2005, Samson et al. 2010, Andersen et al. in press, Dosen et al. in press*). Depending on the type of water damaged building material, *Chaetomium sensu lato* are found in 16–66 % of environmental samples (*Flannigan & Miller 2011, Andersen et al. in press*). Our survey shows a high species diversity of *Chaetomiaceae* in the indoor environments worldwide and based on phylogenetic analysis and morphological examination 30 indoor species lineages were recognised. These species were scattered throughout the *Chaetomiaceae* and this finding prompted us to re-evaluate the phylogeny of *Chaetomium* and related genera.

Traditionally, *Chaetomium* was defined to possess superficial and typically ostiolate ascomata covered by more or less developed hairs or setae and connected to the substrate by rhizoidal hyphae. The asci develop in basal fascicles, are stalked and have a thin and evanescent wall devoid of apical structures. The majority of species produce asci containing eight ascospores, which are single-celled, smooth and pigmented with germ pores and without sheaths (*von Arx et al. 1986*). This generic concept covers quite a high diversity of morphology. For example, ascomatal hairs can be straight (seta-like), flexuous, arcuate, undulate, cirinate, spirally coiled or variously branched, the asci obovate, clavate, fusiform to cylindrical, and the ascospores oblate, ovate, limoniform, fusiform, lunate, triangular to irregular, laterally flattened or not, with one, two or more germ pores which can be apically, sub-apically or even laterally formed on ascospores. Most species do not produce an asexual morph, while some species have a humicola-like, botryotrichum-like, or acremonium-like asexual state. Contrary to the genus *Chaeto-*
 Wide ostiole surrounded by a hyaline collar (von Arx 1985b, von Arx et al. 1989). The ascospores of Myceliophthora (= Corynascus, with asexual morph) and Corynascella (asexual morph unknown) have more than one germ pore per ascospore, and other non-ostiolate genera usually produce ascospores with only one germ pore.

The concept of Chaetomium has been challenged in the study of the non-ostiolate genus Chaetomidium (Greif et al. 2009, Wang et al. 2016). Based on a six-locus analysis, three species of Chaetomidium, including its type C. fimeti, are closely related to the type species of Chaetomium, C. globosum. As these three Chaetomidium species are all within the C. globosum species complex, the genus Chaetomidium was rejected and the three non-ostiolate species were transferred into the genus Chaetomium (Wang et al. 2016).

The phylogenetic inference in this study clearly demonstrated that the traditionally defined Chaetomium as noted above was polyphyletic. The indoor members of Chaetomium were segregated into 10 monophyletic lineages by several other genera in the family (Fig. 1). Six indoor species fell into the C. globosum complex which was designated here as Chaetomium sensu stricto, including 36 species with limoniform to globose or irregular and bilaterally flattened ascospores as delimited in our previous study (Wang et al. 2016). Chaetomium murorum clustered with three asexual species of Botryotrichum and non-ostiolate Emliumellaria in a strongly-supported monophyletic clade, which was designated here as the expanded genus Botryotrichum. This result also refuted the presence or absence of ascomatal ostioles to be a criterion for distinguishing genera in the Chaetomiaceae. Species of the traditional genus Subramaniula grouped with several species previously classified in Chaetomium, for example S. cristata (= C. cristatum), S. cucurculorum (= C. cucurculorum), S. fusispora (C. fusisporum) and S. flavipila (= C. irregular). Based on these data, the genus Subramaniula was expanded to include species with typical chaetomium-like ascostoma and ascomatal hairs. More data are needed to determine the morphological delimitation of the genera Botryotrichum and Subramaniula supported by the molecular data in this study.

Two taxa obtained from the indoor environment produced humicola-like conidia. Based on a preliminary analysis of ITS sequences of asexual Humicola species, only a few species clustered together with H. fuscoatra, the type species of this genus. The other Humicola species available were placed in several different clades, indicating that the asexual genus Humicola is polyphyletic. More research is needed to clarify the relationship of Humicola sensu stricto to the other humicola-like species as well as those chaetomium-like species with humicola-like asexual morph. The indoor species Me. tardus was on a long branch within the highly supported Melanocarpus clade. Further research is required to determine the phylogenetic relationships of the species with in this genus.

Representatives of the genera Achaeotomum, Myceliophthora, Thielavia, and Corynascella were included in our phylogenetic study. These data contributed to the delimitation of genera in Chaetomiaceae and the introduction of five new genera. The genera Achaeotomum and Myceliophthora were strongly supported as monophyletic lineages in this study. Thielavia was known as the second largest genus in the family (von Arx et al. 1988, Kirk et al. 2008). Five species of Thielavia were included in our analysis to represent this genus. The phylogeny confirmed the monophyly of this Thielavia clade. Further research with a larger sampling is required to re-evaluate this genus in more detail. Corynascella was represented only by its type species. Further data are required to determine the phylogenetic relationships between the type species and the other species of Corynascella.

Our results provided an insight in the phylogeny of the family, and in the diversity of indoor Chaetomiaceae (Table 2). Of the 145 isolates obtained in this survey, 30 species were recognised in 10 different genera, presenting a much higher species diversity of indoor Chaetomiaceae than previous studies. Chaetomium globosum was the predominant species in the indoor environments as also noted in the previous studies (Vesper et al. 2007, Ayanbimpe et al. 2010, Straus 2011, McMullin et al. 2013, Miller & McMullin 2014). This species accounted for 51 % of the total obtained isolates (74/145). Chaetomium cochliodes is the second most common genus (17/145), mainly because of its abundance in the indoor environments in the USA. In addition, Ch. elatum (6/145) and B. piluliferum (5/145) were also frequently encountered in samples obtained from indoor environments. At the genus level, members of Chaetomium sensu stricto accounted for 69 % of the total isolates obtained (100 isolates in six species). Dictotomopilus was found to be the second most common genus (15 isolates, seven species), followed by Collariella (seven isolates, four species), Botryotrichum (eight isolates, three species), Amesia (five isolates, three species) and Humicola (four isolates, two species). Members of the four other genera were found to be rare in the indoor environments.

Secondary metabolites have been used as valuable additional taxonomic features in several fungal genera such as Penicillium, Aspergillus, Alternaria, Fusarium (Frisvad et al. 2008). It has been known that, in order to adapt to diverse environments, the species of Chaetomium sensu lato are capable of producing various secondary metabolites, which display a wide range of biological activities (Udagawa et al. 1979, Sekita et al. 1981, Ding et al. 2006, Ge et al. 2008, Momesso et al. 2008, Phonkerd et al. 2008, Kharwar et al. 2011, Yamada et al. 2012, Zhang et al. 2012, Lu et al. 2013, Awad et al. 2014, Yan et al. 2014). Some of them are mycotoxins and can cause health hazards (Polizzi et al. 2009, Mason et al. 2010, Andersen et al. 2011, Miller & McMullin 2014, Wang et al. 2015). In this study profiles of metabolites were analysed in the majority of indoor chaetomium-like species using advanced analytical chemical methods to ensure correct identity of the secondary metabolites. The resulting metabolite profiling shows that it is possible to distinguish Chaetomium sensu stricto and Dictotomopilus from each other and from other genera based on secondary metabolites. It is even possible to discriminate between C. globosum and other species based on the pattern of metabolites. Chaetomium globosum seems to be the only species that produces the combination of chaetoviridin A, chaetoglobosin A, rotorinol and cochliodones, however, chemical analyses of more isolates from the other closely related Chaetomium species are necessary to verify the result. Furthermore, chaetoviridin A, chaetoglobosin A and cochliodones are the major metabolites produced on building materials with Chaetomium growth (Dosen et al. in press). Likewise, analyses of more...
isolates of C. cochloides are needed to determine which metabolite pattern that is species specific in order to distinguish it from C. pseudofumigati. Production of sterigmatocystin, the precursor to aflatoxin, was only found in H. olivaceae in this study. Another study by Rank et al. (2011) did detect sterigmatocystin in B. piluliferum (NRRL 38180), but it was not detected in the B. piluliferum isolate (DTO 254-B8) used in this study. Also in this case an extended analysis of isolates is needed. As only a limited number of isolates and species in the Chaetomiaceae were analysed for their metabolite profile in general, more research is encouraged in order to understand the correlation between the studied taxa, their metabolite profiles and the effects of these products on human health.

In this study we also showed the morphological diversity that exists in some species. Taken together with the morphological data from our earlier studies (Wang et al. 2014, 2016), we show that Ch. globosum, Ch. elatum, B. murorum, the D. funicola species complex (including D. funicola, D. pseudofunicola, D. subfunicola and D. variostiolatus) and D. indicus all exhibited intra-species morphological variation. For the D. funicola species complex, almost each of the examined isolates presented different morphology in the terminal ascomatal hairs. A similar problem in morphological identification also occurs in D. indicus. The examined isolates of this species showed morphological differences not only in the terminal ascomatal hairs, but sometimes even in the shape and size of ascospores. These results implied an active differentiation of morphology within these species lineages. This makes it very complicated to identify these species only based on morphology. A molecular based identification will help to solve this problem. Several Chaetomiaceae species share ITS sequences, and for routine identification, β-tubulin (tub2) is recommended. On the other hand, it needs to be noted that not all species are represented with tub2 sequences in the public databases and future studies should aim to complete this omission.

It has been demonstrated that the presence of C. globosum in the indoor environment is one of the important contributors to the development of symptoms of rhinitis, asthma and other health problems (Vesper et al. 2007, Apetrei et al. 2009, Polizzi et al. 2009, Mason et al. 2010, Miller & McMullin 2014). This species is also the most common human pathogen mainly associated with onychomyocosis (Naidu et al. 1991, Stiller et al. 1992, Aspiroz et al. 2007, Lathe et al. 2010, Tullio et al. 2010, Hwang et al. 2012, Lagacé & Cellier 2012, Kim et al. 2013). In addition, some other indoor chaetomium-like species were also reported in clinical cases, such as D. funicola (= C. funicola, Koch & Haneke 1965), O. brasiliensis (= C. brasiliensis, Hubka et al. 2011) and Am. atrobrunnea (= C. atrobrunnea, Guppy et al. 1998, de Hoog et al. 2013). These species, which grow in our living and working environment, deserve more attention in future.

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