How to Do Classical Taxonomic study of Fungi

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What is a Fungus?
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Fungi are either macroscopic or microscopic (most)
What is a Fungus?

Fungus = singular
Fungi = plural

A fungus is not a plant
A fungus is not an animal
A fungus is not a bacterium

Fungi belong in their own Kingdom
Kingdom Fungi
(true fungi)

Phyla

• Chytridiomycota
• Zygomycota
• Ascomycota (including yeasts)
• Basidiomycota
What is a Fungus?

Fungi are either:

- **Saprobes** – live on dead matter
- **Parasites** – live on living plants or animals
- **Symbionts** – mutually beneficial association
  e.g., lichens, mycorrhizae
What is a Fungus?

Fungi are:

- Eukaryotic (not Prokaryote, bacteria)
- Heterotrophic (not Autotrophic, plant)
- Absorptive organisms
- Usually develop a diffuse branched, tubular body
- Reproduce by spores
Hypha (pl. hyphae)
- Individual threads or filaments of a fungus
- May possess cross walls (septa) or be coenocytic (non-septate)

Mycelium (pl. Mycelia)
- thallus
- A mass of hyphae
Structure of a Fungus

Sclerotium (pl. sclerotia)

- A compact mass of hyphae with or without host tissue
- Usually with a darkened rind (skin)
- Capable of surviving adverse environmental conditions. Some sclerotia can survive in soil for up to 20 years
Sclerotia germinating
Stroma

A mass or matrix of vegetative hyphae, with or without tissue of the host or substrate, in or on which spores or fruit bodies bearing spores are produced.
Rhizomorph

A root-like aggregation of hyphae

Orchid: *Gastrodia elata* & *Armillaria mellea*

Symbiosis
Structure of a Fungus

Chlamydospore

A thick-walled, resistant, asexual spore

*Thermomyces lanoginosus*
Clamp Connections

Many basidiomycetes produce clamp connections on the mycelium, a device that ensures that each new cell receives one of each parent nucleus.
Numbers of Species in the World

Estimated 1.5 million fungal species
Fungi on plants

Rust on blackberry – biological control

Rust on cereals
Rust fungus infecting *Rubus*

Apple black spot

Taro leaf blight

Fungi on plants
Fungi on Insects

Vegetable caterpillar

Chalkbrood of honey bees
Ophiocordyceps sinensis
Qinghai-Tibet plateau, above 3500 m
蛹虫草

Cordyceps militaris
Fungi on Animals - Tinea or Ringworm

Tinea = Latin for grub, larva, worm
St Anthony's Fire - ergotism

Ergots of *Claviceps purpurea*
Mould on surfaces

Black moulds and *Penicillium* moulds on ceilings, walls, and leather
Dry Rot Fungus
Fungi on Stamps
Fungi on Stamps
Ranks of Fungi

- 界 (Kingdom)
- 门 (Phylum) - mycota
- 纲 (Class) - mycetes
- 目 (Order) - ales
- 科 (Family) - aceae
- 属 (Genus)
- 种 (Species)
Kingdom Fungi (true fungi)

Phyla

- Chytridiomycota
- Zygomycota
- Ascomycota (including yeasts)
- Basidiomycota
Phylum Chytridiomycota
Class Chytridiomycetes

- Motile reproductive spores
- Mycelium with few, if any cross walls (septa)

*Synchytrium* – potato wart, false leaf rust

*Olpidium* – in roots
Phylum Zygomycota

- Non-motile reproductive spores
- Mycelium with few, if any cross walls (septa) said to be coenocytic
- Most species are saprobes
- Class Zygomycetes
  Order Mucorales (mainly fruit rots)
  - *Mucor*
  - *Rhizopus*
Gametangia may arise from the same mycelium or from two different mycelia.

- Produce a thick-walled resting spore (zygospore)

- Asexual reproduction by sporangiospores
Rhizopus stolonifer 匍枝根霉
Rhizopus oryzae 米根霉
Rhizopus oryzae 米根霉
Phylum Ascomycota
(ascomycetes, sac fungi)

- Sexual propagation by means of ascospores, in sac-like structures (asci) within fruit-bodies (ascomata)

- Often accompanied by one or more asexual forms of sporulation, the anamorph
Ascomycetes

Ascomata (fruit-bodies)

Tuber (truffle)
Four types of Asci formed

A. naked asci
B. cleistothecium, -a
C. perithecium, -a
D. apothecium, -a
**Ophiocordyceps sinensis**
Clavicipitaceae
Ascomycetes

Asci (sing. ascus)

- **Unitunicate asci (one-layered),**
  ascospores liberated
  - by dehiscence of the undifferentiated ascus wall
  - through an operculum
  - through an apical pore (inoperculate asci)

- **Bitunicate asci (two-layered)**
  outer wall (exotunica) bursts at maturity and elastic inner wall (endotunica) expands
  ascospores liberated through an apical pore
Asci

A-D. unitunicate
E. bitunicate

A. no opening
B. ascal pore
C. operculum
D. split
E. dehiscence
Types of Asci
Ascomycetes

• **Ascospores**
  - Usually 8 ascospores in each ascus (sometimes 1 to over 1000)
  - Globose to fusiform or cylindrical
  - Hyaline or coloured (often brown or black)
  - Presence or absence of firm ornamentations (spines, ridges), or soft gelatinous sheaths or appendages is often characteristic
  - Non-septate to many septate
  - Euseptate (true septa) or distoseptate
  - In dark ascospores an apical germ pore, or a lateral germ slit may be seen
Ascospores
Phylum Basidiomycota
(basidiomycetes, club fungi)

- Septate, mostly dikaryotic mycelium
- Sexual propagation by means of basidiospores
- Basidiospores are formed on club-shaped structures (basidia)
- Basidia often within fruit-bodies (basidiomata = basidiocarps)
Basidiomycetes

Basidiomata (fruit-bodies)

- Most basidiomycetes form macroscopic fruit-bodies (mushrooms, puffballs, shelf or conks)
- Rusts and smut fungi produce microscopic basidiomata
Clamp Connections

Many basidiomycetes produce clamp connections on the mycelium, a device that ensures that each new cell receives one of each parent nucleus.
Development of basidia and basidiospores

[Alexopoulos et al., 1996]
Basidiomycetes

Basidia

- Clavate structures, basidiospores are formed
- Septate or non-septate
Types of basidia

(A) 典型的无隔担子；(B) 花耳属(Dacrymyces)的音叉状担子；(C) 胶膜菌属(Tulasnella)担子；(D) 银耳属(Tremella)担子；(E) 木耳属(Auricularia)担子；(F) 柄锈菌属(Puccinia)担子

[引自Alexopouloue et al., 1996]
Basidiomycetes

Basidiospores

- usually 4 basidiospores on each basidium (sometimes 2, in some smut fungi, over 100)
- globose, subglobose or ellipsoid
- hyaline or brown, black, pink, green, etc.
- non-septate, occasionally 1-septate
Anamorphic Fungi (fungi imperfecti, deuteromycetes)

- Reproduce asexually by conidia
- Mostly part of life cycle of ascomycetes, rarely of basidiomycetes
- A frequently isolated group of fungi
- Play major role:
  - in decay
  - in the mycota of air and soil
  - important as plant parasites
- Taxonomy is artificial, in order to facilitate identification and naming of the organisms
Anamorphic Fungi

Classification by place of conidium formation

(1) **Hyphomycetes** – on simple or aggregated hyphae

- conidiophores often single and naked on hyphae
- conidiophores aggregated in pustules (**sporodochia**)
- conidiophores aggregated in erect bundles (**synnemata**)
Anamorphic Fungi

(2) Coelomycetes – in fruit-bodies

- Acervuli – flattened fructifications in a host plant, usually covered by the cuticle or epidermis (Melanconiales)
- Pycnidia – closed fruit-bodies usually opening with an apical pore (Sphaeropsidales)
Fungal taxonomy stages

- Classical taxonomy period:
  Before 1990, Morphology, Physiology, Biochemistry (isozyme)

- Molecular taxonomy period:
  On and after 1990, triggered by polymerase chain reaction (PCR)
How to Do Classical Taxonomic study of Fungi

A case study

“Revision of the ascomycete genus Amphisphaeraia”
An estimation of 80 species may be accepted in 260 taxa;
Confused with other 2-celled, brown spores ascomycete genus

Why does this genus need to be revised?
Introduction and History

1. History of *Amphisphaeria* Ces. & De Not.
   a) Established by Cesati & De Notaris in 1863, 18 species introduced
   b) 260 taxa listed now
   c) Lectotype: *Amphisphaeria umbrina* (Fr.) De Not. 1923, 1988
Position of *Amphisphaeria*

Ascomycota
Hymenoascomycetes
Amphisphaeriales
Amphisphaeriaceae
*Amphisphaeria*
Introduction and History

2. Criteria to define an acceptable species
   a) Habitat: Previously, worldwide distribution; nowadays, temperate area, dicotyledonous
   b) Ascomata: peridium, paraphyses
   c) Asci: unitunicate, subapical ring J+ or J-
   d) Ascospores: 2-celled, brown, without striation or germ slits
Ascomata, peridium, paraphyses, asci, ascospores of *Amphisphaeria*
Amphisphaeria sp.

Asci: unitunicate, subapical ring J+, J-
Ascospores: 2-celled, brown, without striation or germ slits
Substrate
Substrate

1000 μm
Substrate
Substrate
Substrate
Materials and methods

1 Collecting original papers of all species

a) Saccardo’s Sylloge Fungorum (before 1920)
b) Index of Fungi (1920 or after 1920)
References

- CABI: Index Fungorum
  http://www.indexfungorum.org/names/names.Asp.
Materials and methods

2 Loaning materials from herbaria world wide
3 Examining the specimens

🌞 Mounted slide, Melzer reagent (I-KI) reaction, section
🌞 Photography
🌞 Description
🌞 Plate
Cryotome for section
Scissors for microfungi isolating
Microscopes
Results

- Of 170 type specimens, 12 accepted, the remaining species belonging in other genera, most of them having bitunicate asci
- 12 new combinations
- Keys to *Amphisphaeria*
Accepted Species of *Amphisphaeria*

- *A. bertiana*, *A. depressa*, *A. fallax*, *A. gaugae*, *A. lusitanica*, *A. multipunctata*, *A. paedida*, *A. pakistani*, *A. pseudoumbrina*, *A. seriata*, *A. umbrina*, *A. vibratis*
**Description**


Ascomata seated on a subiculum, erumpent, or becoming superficial, subglobose, coriaceous, apex papillate, 350-500 μm diam., solitary or gregarious (Fig. 1). Peridium 20-35 μm thick, dark brown. Paraphyses ca 1 μm wide, filamentous, septate. Asci 110-145 × 5-6 μm ( = 125 × 5.5 μm, n = 10), 8-spored, cylindrical, unitunicate, pedicellate, with a J- apical apparatus (Figs. 2-4). Ascospores 10.5-12.5 × 4-5 μm ( = 11 × 4.5 μm, n = 20), 1-seriate, ellipsoidal, 2-celled, brown, not or slightly constricted at the septum, smooth-walled (Figs. 5, 6).

**Material examined:** USA, New York, Lyndonville, in cavities at the end of a rotting log, October 1905, Chrods (CUP, holotype of *Amphisphaeria bertiana*).

**Remarks:** *Amphisphaeria bertiana* differs from other *Amphisphaeria* species since it has a J- apical apparatus, erumpent or superficial ascomata on a subiculum and smooth-walled ascospores.
3.2 Key to the accepted species of *Amphisphaeria*

1. Ascal ring J+ .................................................................2
1. Ascal ring J- ...............................................................10
2. Ascal ring wedge-shaped .................................................3
2. Ascal ring discoid ..........................................................4

3. Ascal ring 0.8-1.2 × 2.5-3 μm, ascospores 12.5-19 × 5.5-7.5 μm, not or slightly constricted at the septum .................................................................*A. gaubae*

3. Ascal ring 2-3 × 3-4 μm, ascospores 20-28 × 8-10 μm, strongly constricted at the septum .................................................................*A. lusitanica*

4. Ascospores finely rough-walled ...........................................5
4. Ascospores smooth-walled ..................................................6

5. Ascospores 15.5-20 × 6-8 μm, wall finely foveolate, with a mucilaginous sheath, ascomata globose .........................................................*A. seriata*

5. Ascospores 14-18 × 6-7.5 μm, wall rugose, ascomata oblate ..........*A. pseudoumbrina*
Plate 2, Figs. 1-5. *Amphisphaeria depressa* (from holotype). 1. Vertical section through ascoma. 2-5. Unitunicate asci, with a J+, discoid, subapical ring (arrowed), and ascospores. Bars: 1 = 100 µm; 2-5 = 10 µm.
Plate 18, Figs. 1-6. *Arecophila murioana* (from holotype of *Amphisphaeria murioana*).
1. Habit of ascomata on host surface. 2. Vertical section through ascoma. 3-6. Unitunicate asci, with a J+, wedge-shaped, subapical ring (arrowed), and ascospores with striations. Bars: 1 = 500 μm; 2 = 100 μm; 3-6 = 20 μm.
Plate 23, Figs. 1-7. Cainia passerinii (from holotype of Amphisphaeria passerinii). 1. Vertical section through ascoma. 2. Habit of ascomata on host surface. 3-7. Unitunicate asci, with a J+, complex, subapical ring (arrowed in 4) and ascospores with germ slits (arrowed in 6). Bars: 1 = 200 μm; 2 = 500 μm; 3-7 = 20 μm.
Plate 88, Figs. 1-9. Apiorhynchostoma trabicola (from holotype of Amphisphaeria trabicola). 1. Habit of ascomata on host surface. 2-4. Asci with J- apical ring. 5-7. Ascospores with a small cell at the base (arrowed in 6) and a germ pore at the other end (arrowed in 5). Bars: 1 = 500 μm; 2-7 = 10 μm.
Fungal Diversity Research
Fungi and Names
Fungi are the only Kingdom where single species are allowed to have more than one valid scientific name

- Holomorph = Teleomorph + Anamorph

*Gibberella fujikuroi* (Sawada) Wollenw., 1931

= *Fusarium moniliforme* J. Sheld, 1904

*Emericella nidulans* (Eid.) Vuill., 1927

= *Aspergillus nidulans* (Eid) Wint, 1884
Eupenicillium shearii Stolk & Scott, 1967
= Penicillium shearii Stolk & Scott, 1967

Neurospora crassa Shear & B.O. Dodge 1927
= Monilia crassa Shear & B.O. Dodge 1927
= Chrysonilia crassa (Shear & B.O. Dodge)
Arx, Sydowia 34: 17 (1981)
Ophiocordyceps sinensis

Current Name:


Synonymy:

*Sphaeria sinensis* Berk., *London J. Bot.* **2**: 207 (1843)
*Cordyceps sinensis* (Berk.) Sacc., *Michelia* **1**(no. 3): 320 (1878)
“One Fungus, One Name”

-Melbourne Code, 2011, by
International Code of Nomenclature for Algae, Fungi and Plants

Enforced from 1 Jan. 2013
Thank you for your attention