

Workshop

Morphological Identification of Microfungi



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Workshop Objectives

To gain increased familiarity with the process of morphological identification of fungi on hosts.

Morphological identification of fungi on their hosts involves:

1. Careful examination of the host under a dissecting microscope for patterns of infection and presence of sporulating structures.
2. Observation of the fungus under a compound microscope for details of spore shape, size, color and other attributes, in addition to conidiophore/conidigenous cell structure and details, fruiting body size, shape, tissue type and other details.
3. Exploration of the relevant literature about the fungus including original descriptions, detailed monographs and taxonomic studies. Arrival at a name for an unknown fungus involves understanding the history of different names for that fungus, and the different ways in which related groups of fungi may have been circumscribed.

In this workshop participants will examine provided samples to develop or increase familiarity with different fungal groups and their related structures. The emphasis is not necessarily on identification of the specific fungi in this workbook, but on the process of examination and developing an eye for the different structures used in morphological identification. A variety of resources that are particularly helpful for fungal identification will also be covered.

Acknowledgements

Huge thanks to Karen Rane and Dave Clement for all of their help. Karen and her lab collected the vast majority of samples for the workshop, without which this workbook and the workshop itself would not have been possible. Karen and Dave provided a ton of logistic support and behind the scenes work to make this all possible.

A timeline of mycology (with an emphasis on classification and identification of microfungi):

- 1665 Hooke published the first illustrations of fungi, including *Mucor* and *Phragmidium*.
- 1729 Micheli published *Nova Plantarum Genera* (including *Aspergillus* and *Botrytis*). (Micheli described at least 900 fungi.)
- 1801 Persoon published classifications of microfungi based on open or closed spore-bearing structures.
- 1821- Fries published *Systema Mycologicum* with four classes, four orders and four tribes. He later subdivided class
1832 Fungi into two classes. Fries continued to try to make sense of the fungi and published a second group of volumes (1836-1838)
- 1837- Corda published *Icones fungorum hucusque cognitorum*, with many currently recognizable fungi (His name is
1854 associated with many well-known fungi including *Colletotrichum* and *Chalara*)
- 1854 DeBary demonstrated that *Aspergillus glaucus* and *Eurotium herbariorum* are the same fungus. Between 1866 and 1884 he also published classifications of fungi that withstood the test of time for decades.
- 1861- Tulasne brothers published *Selecta Fungorum carpologia*, with excellent illustrations of a variety of fungi, and
1865 illustrating that some fungi had two states (sexual and asexual).
- 1884 Saccardo began his *Sylloge Fungorum*. His classifications were challenged by Potebnia, von Hoehnel, Grove, Costantin, Vuillemin, Mason and others, but his classification based on spore shape remained the primary one used until the 1950s.
- 1953 Hughes published "Conidiophores, Conidia and Classification", outlining the characters of conidiophore and conidium development used to separate groups of fungi.
- 1968- Many mycologists began to synthesize information on various groups of conidial fungi, developing systems
1980 of classification still used today. These mycologists took the time to look at specimens of various groups and tried to make sense of their relationships based on the morphology of the spores, as well as the development of the structures giving rise to these spores.
Notable names from this period include Ellis, Kendrick, Sutton, Nag Raj, Cole, Morgan Jones, Hughes, Pirozynski, Deighton, Subramanian
- (1985 Kary Mullis invents PCR)

Mycologists soon recognized the merits of being able to classify fungi based on their genetic relatedness, as shown by DNA sequence comparison. In some cases DNA sequence analysis supports previous classifications based on morphology, and in some cases shows unexpected relationships between morphologically dis-similar fungi. Morphological examination of fungi is still central to mycology, though, and is the only method of identification for a very many fungi that have not yet been sequenced.

Morphological classification systems

Saccardo divided fungi into groups by spore shape, septation and color. The terms he used are still relevant today.

Amerospore: aseptate spores	Scolecospore: long, thin spores
Didymospore: 1-septate spores	Staurospore: "star shaped"
Phragmospore: spores with >1 horizontal septa	Helicospore: spiral shaped spores
Dictyospore: spores with horizontal and vertical septa	

Hughes recognized 8 methods of conidial development:

- I: blastic-synchronous (e.g. *Botrytis*) or blastic-acropetal (e.g. *Cladosporium*)
- II: blastic-sympodial (e.g. *Nodulisporium*)
- III: blastic-annelidic (e.g. *Scopulariopsis*)
- IV: blastic-phialidic (e.g. *Penicillium*)
- V: thallic-meristem (e.g. *Oidium*)
- VI: blastic-tretic (e.g. *Alternaria*)
- VII: thallic-arthric (e.g. *Geotrichum*)
- VIII: basauxic (e.g. *Arthrinium*)

Most of the works used today for morphological identification of microfungi use a combination of these systems to classify the groups of fungi. This workshop will focus on using both systems in identifying microfungi.

Notes on nomenclature

Although scientists were naming fungi prior to the 1800s, official codification of fungal nomenclature did not begin until 1867 with the publication of the first attempt at developing rules of nomenclature of the "vegetable kingdom" (Paris Congress). A scan of the translation of these rules can be found at:

<http://biodiversitylibrary.org/page/36897756#page/74/mode/1up>

The code of nomenclature has undergone multiple changes since, including providing a "starting point" for names by sanctioning names published in Persoon's *Synopsis methodica Fungorum* (1801) and Fries' *Systema mycologicum* (1821-1832). Names published before these dates are not recognized. In 1908, a latin description or "diagnosis" was required as part of validly publishing a name for a fungus and starting in 1912 the sexual (considered "perfect") state of a fungus took priority as a name, with names of asexual fungi having a lesser status. In the 1950s unique types (single specimens associated with a name) became mandatory and later the ex-type concept (e.g. cultures arising from a type) was developed.

The most recent code, the Melbourne code, is called the International Code of Nomenclature of algae, fungi and plants. It can be found at <http://www.iapt-taxon.org/nomen/main.php> and most notably establishes the use of one name for fungi found as different morphs (asexual and sexual), and does away with the requirement for a Latin description. Some practical assistance in understanding the code can be found here: <http://www.mycologia.org/site/misc/FAQvers2.shtml>

Resources

Generally Useful Websites

SMML Fungus Host database: <http://nt.ars-grin.gov/fungaldatabases/fungushost/fungushost.cfm>

Mycobank: <http://www.mycobank.org/>

Cyberliber: <http://www.cybertruffle.org.uk/cyberliber/> (scans of literature, sometimes obscure)

Centraalbureau voor Schimmelcultures: <http://www.cbs.knaw.nl/index.php> (especially the publications pages, including all of the Studies in Mycology)

Ascofrance: <http://www.ascofrance.com/> (this is a website of ascomycete aficionados in Europe, mostly amateurs. It helps to read French, German and Spanish to navigate some of the posts, but they often have fantastic images.)

WSU Erysiphales database: <http://www.erysiphales.wsu.edu/>

All things hysteriaceous: <http://www.eboehm.com/>

The Botryosphaeria site: http://www.crem.fct.unl.pt/botryosphaeria_site/

The Rust Fungi of Australia: <http://collections.daff.qld.gov.au/web/key/rustfungi/Media/Html/about.html> (even if you can't get the Lucid key to work, the individual pages have great images)

Pest and Disease Image Library (Australia): <http://www.padil.gov.au/> (images of a variety of fungi and other organisms)

Bugwood network images: <http://www.invasive.org/species.cfm>

NZFungi: <http://nzfungi2.landcareresearch.co.nz/default.aspx?NavControl=home> (contains information on specimens in the New Zealand national collections, along with images for some)

CABI Descriptions of fungi and bacteria (<http://www.cabi.org/dfb/>)

Fungi Canadenses (<http://www.cbs.knaw.nl/index.php/mycoheritage/158-fungi-canadenses>)

Books

Various Fungi

Dictionary of the Fungi (most recent = 10th Ed.) Kirk, Cannon, Minter, Stalpers CABI (IMI, Kew, England)

Cole, G.T. and Kendrick, B. 1981. Biology of Conidial Fungi. Academic Press New York.

Hyphomycetes

Ellis, M.B. 1971. Dematiaceous Hyphomycetes. CABI (IMI) Kew, England)

Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

Seifert, et al. 2011. The Genera of Hyphomycetes. CBS-KNAW (Netherlands)

Coelomycetes

Raj, N. 1993. Coelomycetous Anamorphs with Appendage-Bearing Conidia. Mycologue Publications Canada

Sutton, B.C. 1980. The Coelomycetes. CABI (IMI, Kew, England)

Ascomycetes

Hanlin, R.T. 1990. Illustrated Genera of Ascomycetes Volumes I and II. APS Press

Sivanesan, A. 1984. The Bitunicate Ascomycetes and their anamorphs. Cramer, Vaduz.

Braun, U. and Cook, R.T.A. 2012. Taxonomic Manual of the Erysiphales (Powdery Mildews). APS Press

Guarro et al. 2012. Atlas of Soil Ascomycetes. APS Press

Basidiomycetes (rusts and smuts)

Arthur, J.C., Cummins, G.B. Manual of the Rusts in United States and Canada. 1962. Hafner Publishing New York

Cummins, G.B., Hiratsuka, Y. 2003. Illustrated Genera of Rust Fungi APS Press

Vanky, K. 2012. Smut Fungi of the World. APS Press

Sample Preparation

Tips and Tricks

1. Examine the host material thoroughly under the dissecting microscope (don't forget to turn it over!) Look for sporulation. In some cases, a single drop of sterile water on a lesion can stimulate the opening of fruiting bodies and the expulsion of spores. This drop can then be removed with a pipette and mounted on a slide to see free conidia. A water drop can also help soften dry tissues.
2. Remove fruiting bodies or conidia-bearing structures with the tip of a scalpel and mount in a drop of 85% lactic acid. Three techniques are useful here:
 - 1) Thin sections. Cut a small rectangle out of the leaf and slice it into thin sections by chopping (not slicing). Best for acervuli, and rust uredinia and telia.
 - 2) Popping a discrete fruiting body out with the tip of a scalpel. This works best for ascomycetes with perithecia or pseudothecia or coelomycetes with pycnidia.
 - 3) Scraping across the top of a section of host with a scalpel to remove hyphomycetes or superficial fruiting bodies (like chasmothecia).

Aim to remove ~ 5 fruiting bodies, or about 5-10 spore-bearing structures. You don't want too little material...but you don't want too much either. Removal of too much of the fungus is typical for beginners and something to guard against.

Place a coverslip over the drop of lactic acid and warm the slide at 50° C for about 5 minutes.

3. After you've warmed the slide have a look at it under low power (4X). Take note of the shape of any fruiting body. While looking at the slide under low power (or under the dissecting microscope), gently use the end of forceps or a pencil to squish the fungus by pressing very gently on the coverslip.
4. Look for conidia. What shape are they? What size? Septate, non-septate?
5. Try to find where the conidia are coming from. Scan the slide under 10X then 20X and look for conidiophores. You might need to re-warm the slide and squash again with a gentle side-to-side motion to separate fungal tissue.
6. Decide what group of fungi you're looking at. Is it a hyphomycete, coelomycete or ascomycete? Do you know the host? Look up the host and fungus group in the SMML database as a start. (If you don't know the host, begin looking at Sutton for coelomycetes and Seifert for hyphomycetes, Hanlin for ascomycetes, etc.)
7. Look at the list of fungi in the SMML database. Look up names you don't recognize in MycoBank to find sources of literature on those names.

Genera of fungi (and similar organisms) covered in this workbook

Hyphomycetes	page	“Ascomycetes”, Rusts, Powdery Mildews and Downy Mildews	
<i>Alternaria</i>	10		
<i>Cercospora</i>	11		
<i>Cladosporium</i>	13		
<i>Epicoccum</i>	15	Ascomycete	page
<i>Periconia</i>	16	<i>Phyllachora</i>	43
<i>Pseudocercospora</i>	17	Powdery Mildews	
<i>Ramularia</i>	19	<i>Erysiphe</i>	45
<i>Stemphylium</i>	21	<i>Podosphaera</i>	
Coelomycetes		Rusts	
<i>Blumeriella (Phloeospora)</i>	24	<i>Coleosporium asterum</i>	47
<i>Diplocarpon</i>	26	<i>Phragmidium</i>	49
<i>(Entomosporium)</i>		<i>Puccinia</i>	
<i>Diplocarpon (Marssonina)</i>	27	<i>Ravenelia</i>	50
<i>Colletotrichum</i>	28	<i>Uromyces</i>	
<i>Cryptocline</i>	31	Downy Mildew	
<i>Pestalotiopsis</i>	33	<i>Peronospora</i>	51
<i>Phoma</i>	35		
<i>Phyllosticta</i>	36		
<i>Septoria</i>	38		

HYPHOMYCETES

***Alternaria* Nees ex Fr. (1816)**

=*Elosia* Pers. (1822)

=*Macrosporium* Fr. (1832)

=*Rhopalidium* Mont. (1836)

=*Prathoda* Subram. (1956)

=*Chmelia* Svob.-Pol. (1966)

Type species: *Alternaria alternata* (Fries) Keissler

Distribution: Cosmopolitan. As a plant pathogen usually causes leaf spots, also a common saprobe.

Characters: *Spore production* on pale brown conidiophores, solitary or in fascicles.

Conidiogenesis from integrated and intercalary cells, conidial production leaves a scar.

Conidia catenate or solitary, pale to mid brown, with transverse and often longitudinal septa.

Can be confused with *Stemphylium*, *Ulocladium*, or other dictyosporous dark hyphomycetes.

References:

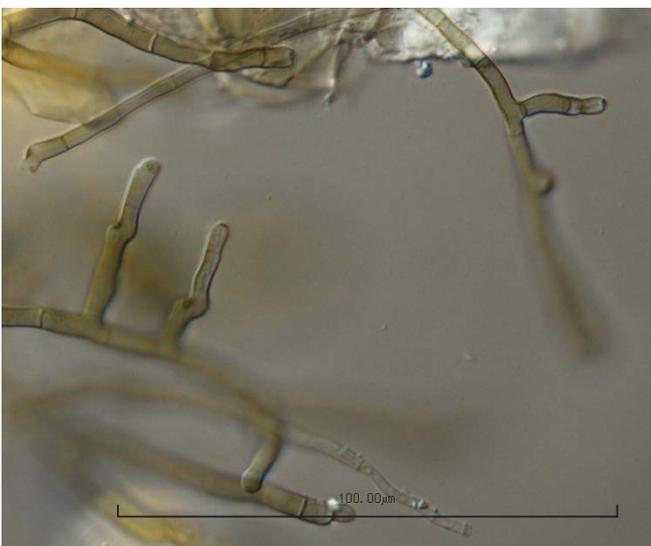
Ellis, M.B. 1971. Dematiaceous Hyphomycetes. CABI (IMI, Kew, England)

Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. CABI (IMI, Kew, England)

Seifert, et al. 2011. The Genera of Hyphomycetes. CBS-KNAW (Netherlands)

Simmons, E.G. 2007. *Alternaria* An Identification Manual. CBS-KNAW (Netherlands)

Woudenberg, J.H.C. et al. 2013. *Alternaria* redefined. Studies in Mycology 75:213-305



Conidiophores of Alternaria.



Conidia of Alternaria.

***Cercospora* Fresen (1863)**

= *Virgasporium* Cooke (1875)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Dothideomycetidae, Capnodiales, Mycosphaerellaceae, *Cercospora*

Type species of *Cercospora*: *Cercospora apii* Fresen. (1863)

Distribution: Widespread on Amaranthaceae and other plant families. Cercosporoid fungi are common on many plants.

Characters: *Spore production* on loose to dense fascicles of conidiophores.
Conidiogenesis on conidiophores pale brown near the base, mildly geniculate, spore scars dark, coronate.
Conidia hyaline, acicular, septa indistinct, for *C. beticola* 50-200 x 2.5-4µm.

Cercospora is one of a number of fungi that sporulate in a similar way and are known as “cercosporoid”. Genera of cercosporoid fungi include *Cercospora*, *Pseudocercospora*, *Stenella* and *Passalora*. These are differentiated based on the presence or absence of darkened conidiogenous loci, ornamentation of hyphae and pigmentation of the conidia.

Key to “true” cercosporoid genera (from Crous and Braun 2003)

1. Conidiogenous loci inconspicuous or subdenticulate, but always unthickened and not darkened or subconspicuous, i.e. unthickened, but somewhat refractive or rarely very slightly darkened, or only outer rim slightly darkened and refractive (visible as minute rings).....***Pseudocercospora***
1. Conidiogenous loci conspicuous, i.e., thickened and darkened throughout, only with a minute central pore.....2
2. With verruculose superficial secondary mycelium; conidia amero- to scolecosporous, mostly verruculose.....***Stenella***
2. If superficial secondary mycelium present, hyphae smooth or almost so.....3
3. Conidia hyaline or subhyaline, scolecosporous, acicular, obclavate-cylindrical, filiform, usually pluriseptate.....***Cercospora***
3. Conidia pigmented or, if subhyaline, conidia non-scolecosporous, ellipsoid-ovoid, short cylindrical, fusoid and only few septa.....***Passalora***

References:

- Chupp, C. 1954. A monograph of the fungus genus *Cercospora*. Ithaca, New York. Published by the author.
- Crous, P.W. and Braun, U. 2003. *Mycosphaerella* and its anamorphs: 1. Names published in *Cercospora* and *Passalora*. Centraalbureau voor Schimmelcultures, Utrecht.
- Seifert, et al. 2011. *The Genera of Hyphomycetes*. Centraalbureau voor Schimmelcultures, Utrecht.

***Cercospora beticola* Sacc. (1876)**

≡ *Cercosporina beticola* (Sacc.) K. Nakata, T. Nakajima & K. Katimoto (1915)

= *Cercospora anthelmintica* G.F. Atk. (1892)

= *Cercospora betae* Sacc. (1892)

≡ *Fusarium betae* Rabenh. (1859) Note: Invalid. Nomen nud.

= *Cercospora chenopodiicola* Bres. (1900)

= *Cercospora longissima* Cooke & Ellis (1889)

= *Cercospora spinaciae* Oudem. (1900)



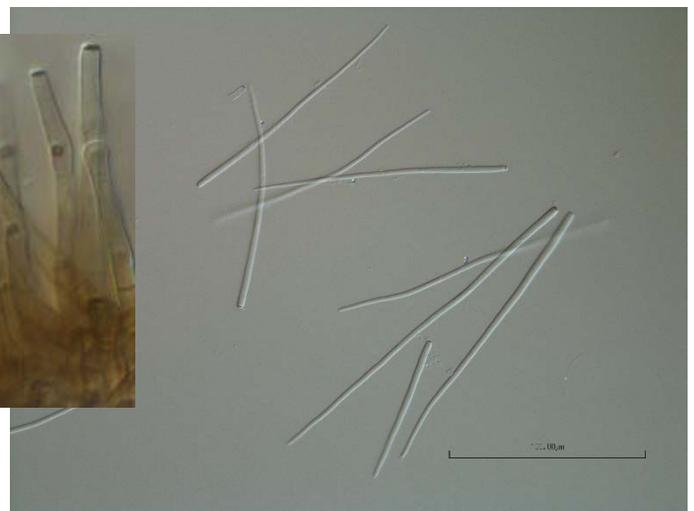
Leaf spots on Beta vulgaris caused by Cercospora beticola.



Cercospora sporulating in a lesion on Beta vulgaris.



Fascicle of conidiophores of Cercospora beticola (inset, close up of conidiophores showing scars).



Acicular conidia of Cercospora beticola.

***Cladosporium* Link (1816)**

- ≡ *Sporocladium* Chevall. (1826)
- = *Azosma* Corda (1831)
- = *Mydonosporium* Corda (1833)
- = *Myxocladium* Corda (1837)
- = *Heterosporium* Klotzsch ex Cooke (1877)
- = *Polyrhizium* Giard (1889)
- = *Acrosporella* Riedl & Ershad (1977)
- = *Beejadwaya* Subram. (1978)
- = *Spadicesporium* V.N. Boriss. & Dvořinos (1982)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Dothideomycetidae, Capnodiales, Davidiellaceae

Type species: *Cladosporium herbarum* (Pers.) Link (1816)

Distribution: Cosmopolitan. Very common in air samples, widespread saprobes. Some species are pathogens.

Characters: *Spore production* on brown conidiophores.
Conidiogenesis polyblastic, ramoconidia often present, cicatrized scars prominent.
Conidia usually catenate, shape variable (cylindrical, fusiform, doliiform, ovoid), distinctly rotuberant scars, pale to dark brown, smooth or verruculose, 0-3 (sometimes more) septa.

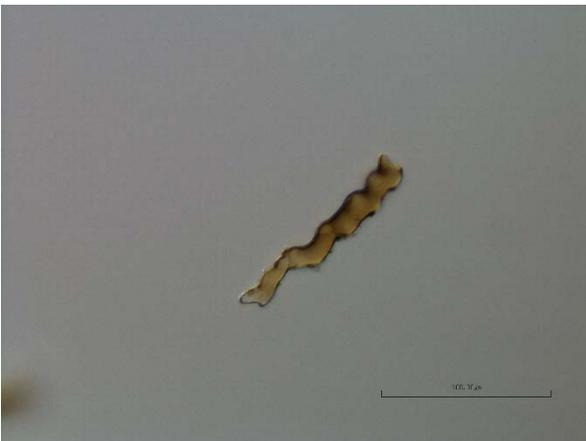
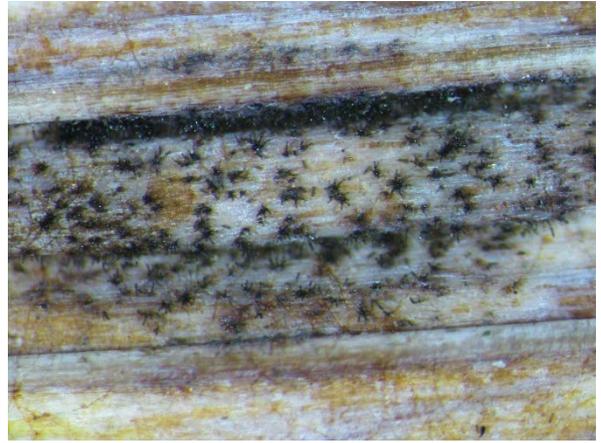
References:

- Bensch et al. 2012. The genus *Cladosporium*. Studies in Mycology, CBS-KNAW, Utrecht
- Ellis, M.B. 1971. Dematiaceous Hyphomycetes. CABI (IMI) Kew, England
- Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. CABI (IMI) Kew, England
- Seifert, et al. 2011. The Genera of Hyphomycetes. CBS-KNAW (Netherlands)

Images: *Below*, conidiophores and conidia of a common, saprobic *Cladosporium* sp.

Facing page, Top (clockwise from left) Leaf spot on *Iris* caused by *Cladosporium iridis*, Close up of sporulation of *C. iridis*, Conidia of *C. iridis*, Conidiophores of *C. iridis*. *Bottom* (clockwise from left) Leaf spots on *Dianthus* caused by *Cladosporium echinulatum*, Close up of sporulation of *C. echinulatum*, Conidia of *C. echinulatum*, Conidiophore of *C. echinulatum*.





***Epicoccum nigrum* Link (1815)**

= *Epicoccum asterinum* Pat. (1912)

= *Phoma epicoccina* Punith., Tulloch & J.G. Leach (1972) Note: *Phoma epicoccina* is a synonym of *Epicoccum nigrum*.

= *Epicoccum purpurascens* Ehrenb. (1818)

= *Epicoccum vulgare* Corda (1837)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae, *Epicoccum*

Type species: *Epicoccum nigrum* Link.

Distribution: Cosmopolitan. Saprobic on host material.

Characters: Spore production sporodochial.
Conidiogenesis on short, densely packed conidiophores, monoblastic.
Conidia brown, solitary, subspherical or pyriform, dictyospores with a rough outer wall.

Can be confused with smuts, bits of dirt or debris on the host.

References:

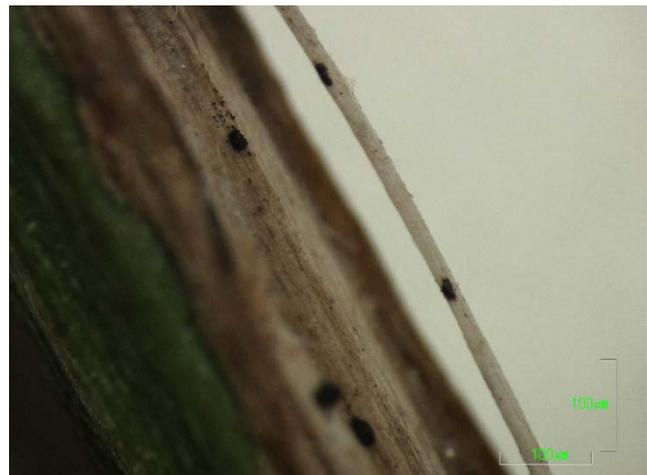
Ellis, M.B. 1971. Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

Seifert, et al. 2011. The Genera of Hyphomycetes. CBS-KNAW (Netherlands)



Epicoccum sporodochia in a necrotic leaf spot.



Epicoccum sporodochia on a stem



Sporodochia of *Epicoccum*



Single conidium of *Epicoccum*

***Periconia* sp.**

=*Sporodum* Corda (1837)

=*Trichocephalum* Costantin, (1888)

=*Harpocephalum* G.F. Atk. (1897)

=*Pachytrichum* Syd.(1925)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales

Type species: *Periconia lichenoides* Tode ex Mérat

Distribution: Cosmopolitan. Saprobic on host.

Characters: *Spore production* from conidiophores, usually with a stipe and spherical head.
Conidiogenesis monoblastic or polyblastic.
Conidia catenate, usually spherical, pale to dark brown, verruculose to echinulate, aseptate.

Could possibly be confused with *Aspergillus*.

References:

Ellis, M.B. Dematiaceous Hyphomycetes. 1971. CABI (IMI, Kew, England)

Ellis, M.B. More Dematiaceous Hyphomycetes. 1976. CABI (IMI, Kew, England)

Seifert, et al. The Genera of Hyphomycetes. 2011. CBS-KNAW (Netherlands)

***Periconia byssoides* Pers.**



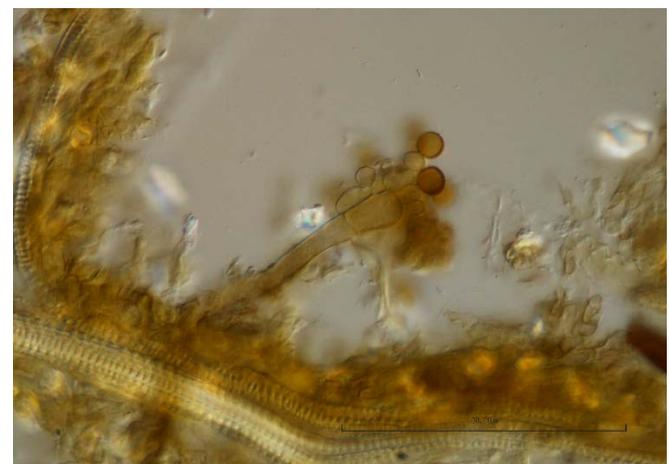
Periconia in a lesion.



Periconia on a stem.



Conidiophore and conidia of Periconia



Conidia forming on a Periconia conidiophore.

***Pseudocercospora* Speg. (1910)**

=Cercosporiopsis Miura (1928)

=Ancylospora Sawada (1944)

=Helicomina L.S. Olive (1948)

=Cercocladospora G.P. Agarwal & S.M. Singh (1974)

=Semipseudocercospora J.M. Yen (1983)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Dothideomycetidae, Capnodiales, Mycosphaerellaceae

Type species: *Pseudocercospora vitis* (Lév.) Speg. (1910)

Distribution: Widespread. Causes leaf spots on many hosts.

Characters: *Spore production* from fascicles of conidiophores in sporodochia with a basal stroma.
Conidiogenesis from unbranched, pale brown to brown conidiophores with inconspicuous broad scars (not cicatrized scars).
Conidia long, thin (scoleospores), sometimes didymo, phragmo or dictyosporous, pale brown to brown.

See notes under *Cercospora* for differences between *Pseudocercospora* and other cercosporoid genera.

References:

Ellis, M.B. 1971. Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

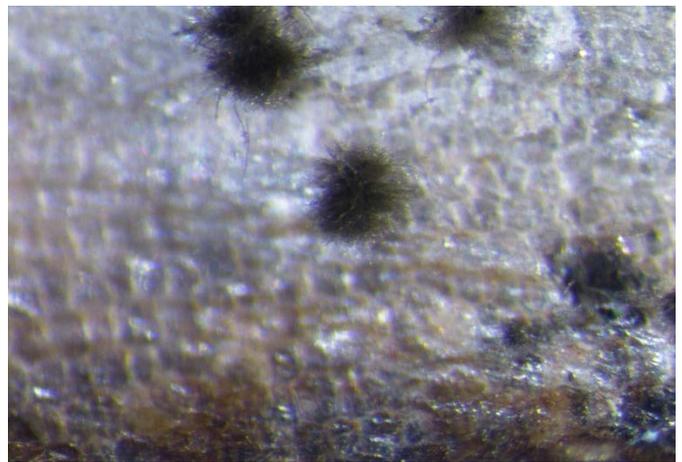
Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

Seifert, et al. 2011. The Genera of Hyphomycetes. CBS-KNAW (Netherlands)

***Pseudocercospora dendrobii* Goh & W.H. Hsieh (1990)**



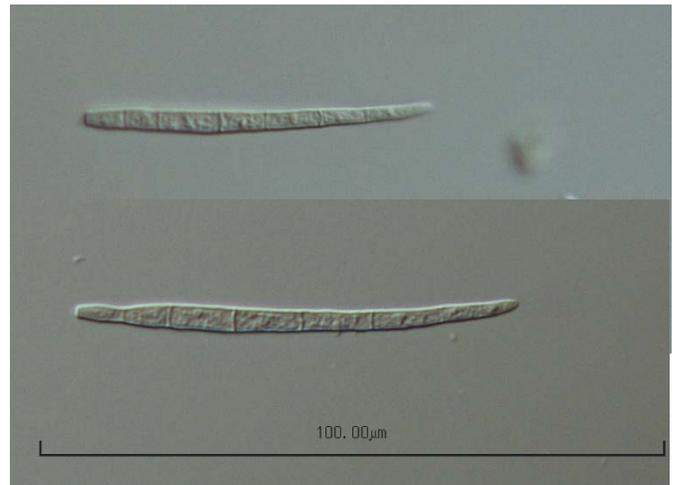
Leaf spot on Dendrobium.



Pseudocercospora sporulating on Dendrobium.



Fascicle of conidiophores of P. dendrobii



Conidia of Pseudocercospora dendrobii.



Close-up of conidiophores of a Pseudocercospora sp.

***Ramularia grevilleana* (Oudem.) Jorst. (1945)**

- ≡ *Cylindrosporium grevilleanum* Oudem. (1873)
- ≡ *Isariopsis grevilleana* (Oudem.) J. Schrot. (1897)
- ≡ *Ramularia tulasnei* Sacc. (1886)
- = *Ramularia anserina* Allesch. (1896)
- = *Ramularia arvensis* Sacc. (1882)
- = *Ramularia fragariae* Peck (1879)
- = *Sphaeria fragariae* Tul. & C. Tul. (1856)
 - ≡ *Mycosphaerella fragariae* (Tul. & C. Tul.) Lindau (1897)
 - ≡ *Sphaerella fragariae* (Tul. & C. Tul.) Sacc. (1882)
- = *Stigmatea fragariae* Tul. & C. Tul. (1863)
- = *Ramularia martianoffiana* Thüm. (1878)
- = *Ramularia modesta* Sacc. (1881)
- = *Ramularia punctiformis* Sacc. (1904)
- = *Ramularia tulasnei* var. *fragariae-vescae* C. Massal. (1908)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Dothideomycetidae, Capnodiales, Mycosphaerellaceae,
Ramularia

Type species of *Ramularia*: *Ramularia pusilla* Unger (1883)

Distribution: *R. grevilleana* is widespread on *Fragaria* spp., *Potentilla* spp., and other hosts in the Rosaceae.

Characters: *Spore production* from conidiophores in small, dense fascicles.
Conidiogenesis on hyaline conidiophores, producing thickened and darkened scars.
Conidia catenate, hyaline, narrowly ellipsoid-subcylindric, 8-55 x 1.5-5 µm, 0-3 septate.

Some *Ramularia* species can be confused with *Cladosporium*, or some cercosporoid fungi.

References:

- Seifert, et al. The Genera of Hyphomycetes. 2011. CBS-KNAW (Netherlands)
- Braun, U.** 1998. A Monograph of *Cercospora*, *Ramularia* and Allied Genera (Phytopathogenic Hyphomycetes). IHW-Verlag 2: 337.
- Braun, U., and Pennycook, S.R.** 2003. Nomenclature and typification of *Ramularia grevilleana*. Mycotaxon 88: 49-52.
- Sivanesan, A., and Holliday, P.** 1981. *Mycosphaerella fragariae*. C.M.I. Descr. Pathog. Fungi Bact. 708: 1-2.
- Videira, S.I.R., et al.** 2015. The rise of *Ramularia* from the *Mycosphaerella* labyrinth. Fung. Biol. 119: 823-843.

***Ramularia grevilleana* (Oudem.) Jorst. (1945)**



Leaf spots on Fragaria caused by R. grevilleana.



Sporulation of R. grevilleana.



Conidiophores of R. grevilleana.



Conidia of R. grevilleana.

***Stemphylium* Wallr. (1833)**

=*Scutisporium* Preuss (1851)

=*Epochniella* Sacc. (1880)

=*Thyrodochium* Werderm. (1924)

=*Soreymatosporium* Sousa da Câmara (1930)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Pleosporaceae

Type species: *Stemphylium botryosum* Wallr. (1833)

Distribution: Cosmopolitan. Saprobic or pathogenic.

Characters: *Spore production* on conidiophores, macronematous and mononematous.
Conidiogenesis monoblastic from terminal cells, swollen and often percurrent.
Conidia pale to mid-brown, obclavate or subspherical, verrucose, dictyospores.

References:

Ellis, M.B. 1971. Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

Ellis, M.B. 1976. More Dematiaceous Hyphomycetes. CABI (IMI) Kew, England

Seifert, et al. 2011. The Genera of Hyphomycetes. CBS-KNAW (Netherlands)

Stemphylium botryosum Wallr. (1833)



Leaf spots on *Spinacia oleracea*.



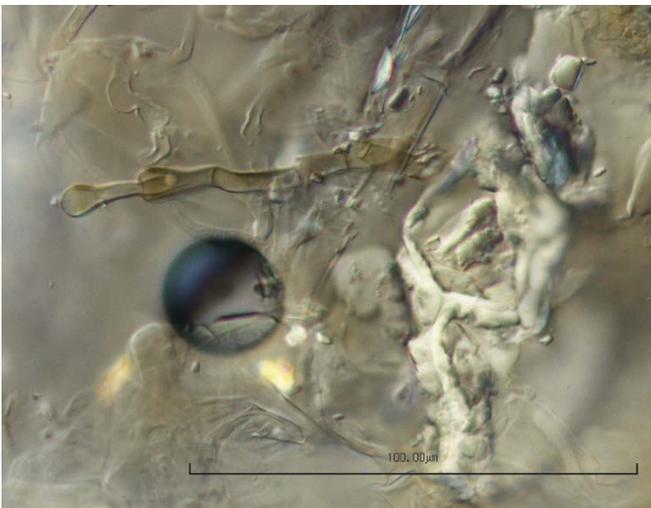
Close-up of *Stemphylium* sporulating.



Stemphylium botryosum conidium and conidiophore.



Stemphylium botryosum conidia, inset shows ornamentation.



Stemphylium conidiophore, showing percurrent proliferation.

COELOMYCETES

***Blumeriella jaapii* (Rehm) Arx 1961**

- ≡ *Pseudopeziza jaapii* Rehm 1907
- ≡ *Higginsia jaapii* (Rehm) Nannf. 1932
- = *Coccomyces hiemalis* B.B. Higgins 1913
 - ≡ *Higginsia hiemalis* (B.B. Higgins) Nannf. 1932
 - ≡ *Blumeriella hiemalis* (B.B. Higgins) Põldmaa 1967
- = *Cylindrosporium hiemalis* Higgins 1914
 - ≡ *Phloeospora hiemalis* (B.B. Higgins) Põldmaa 1967
- = *Coccomyces lutescens* B.B. Higgins 1914
 - ≡ *Higginsia lutescens* (B.B. Higgins) Nannf. 1932
- = *Cylindrosporium lutescens* B.B. Higgins 1914
- = *Ascochyta padi* Lib. 1832
- = *Cylindrosporium padi* P. Karst. 1884
 - ≡ *Phloeospora padi* (P. Karst.) Petr. 1919
- = *Septoria padi* Lasch 1842
- = *Coccomyces prunophorae* B.B. Higgins 1914
 - ≡ *Higginsia prunophorae* (B.B. Higgins) Nannf. 1932
 - = *Cylindrosporium prunophorae* B.B. Higgins 1914
- ≡ *Microgloeum pruni* Petrak (1922)

Type species of *Blumeriella*: *Blumeriella jaapii* (Rehm) Arx (1961)

Distribution: Widespread, causes leaf spots and shot-hole on *Prunus* spp.

Characters: **Phloeospora-anamorph:**

Spore production in acervuli.

Conidiogenesis from holoblastic conidiogenous cells, 1-2 broad, flat, apical scars.

Conidia scolecosporous, 1-septate, 69-74 x 3 µm.

Microgloeum-anamorph:

Spore production in acervuli.

Conidiogenesis from hyaline, septate, branched conidiophores, holoblastic.

Conidia amerospores, cylindrical, tapered toward base, 7.5-9.5 x 1.5 µm.

References:

Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England

***Blumeriella jaapii* (Rehm) Arx 1961**



Leaf spots on Prunus sp.



Acervuli of B. jaapii exuding spores.



Conidiogenous cells of phloeospora state (left) and conidiophores of microgloem state (right) and macroconidia of Blumeriella.



Macro- and microconidia of Blumeriella jaapii.

***Diplocarpon mespili* (Sorauer) B. Sutton (1980)**

- ≡ *Stigmatea mespili* Sorauer (1878)
- = *Fabraea maculata* Atk. (1951)
 - ≡ *Diplocarpon maculatum* (Atk.) Jørst. (1945)
- = *Entomosporium maculatum* Lév. (1857 [1856])
- = *Entomosporium maculatum* var. *domesticum* (Sacc.) Grove (1884)
- = *Xyloma mespili* DC. (1815)
 - ≡ *Entomosporium mespili* (DC.) Sacc. (1880)

Fungi, Ascomycota, Pezizomycotina, Leotiomycetes, Leotiomycetidae, Helotiales

Type species of *Entomosporium*: *Entomosporium mespili* (DC.) Sacc (1880)

Distribution: Widespread on Rosaceae.

Characters (anamorph):

Spore production in acervuli.

Conidiogenesis from shorter to elongated conidiophores, conidiogenous cells holoblastic.

Conidia consisting of a larger basal and upper cell, with 2 or more lateral cells on upper region of lower cell. Apical and lateral cells have single, unbranched appendages, conidia 15-22 x 5-10 µm.

References:

- Raj, N. Coelomycetous Anamorphs with Appendage-Bearing Conidia. 1993. Mycologue Publications Canada
- Sutton, B.C. The Coelomycetes. 1980. CABI (IMI, Kew, England)

Leaf spots on Rosa caused by Diplocarpon mespili.

Acervuli in lesions caused by D. mespili.

***Diplocarpon rosae* F.A. Wolf (1912)**

= *Asteroma rosae* Lib. 1827

≡ *Marssonina rosae* (Lib.) Died. 1915

≡ *Actinonema rosae* (Lib.) Fr. 1849

Fungi, Ascomycota, Pezizomycotina, Leotiomyces, Leotiomycetidae, Helotiales, Dermateaceae, Marssonina

Type species of *Diplocarpon*: *Diplocarpon rosae* F.A. Wolf (1912)

Distribution: Cosmopolitan. Causes black spot on *Rosa*.

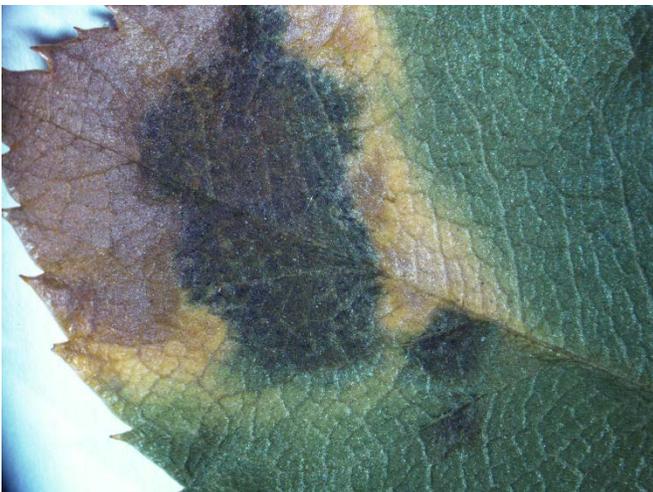
Characters: *Spore production* in subcuticular acervuli.

Conidiogenesis from hyaline conidiophores, irregularly branched, with holoblastic, annellidic conidiogenous cells.

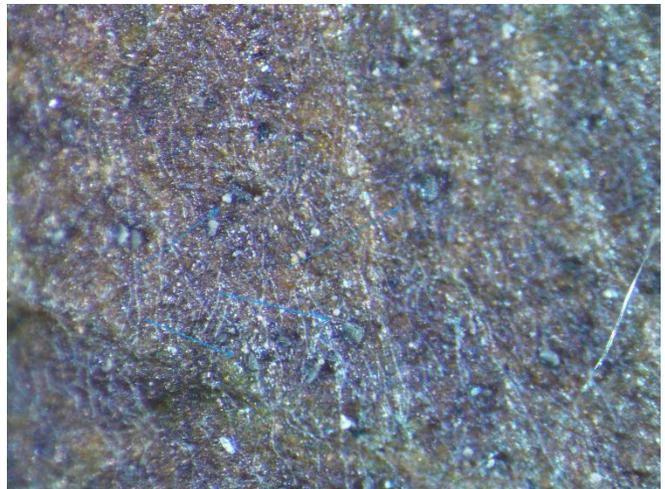
Conidia slightly curved, base truncate, apex obtuse, 13.5-16.5 x 4.5-5.5 μm

References:

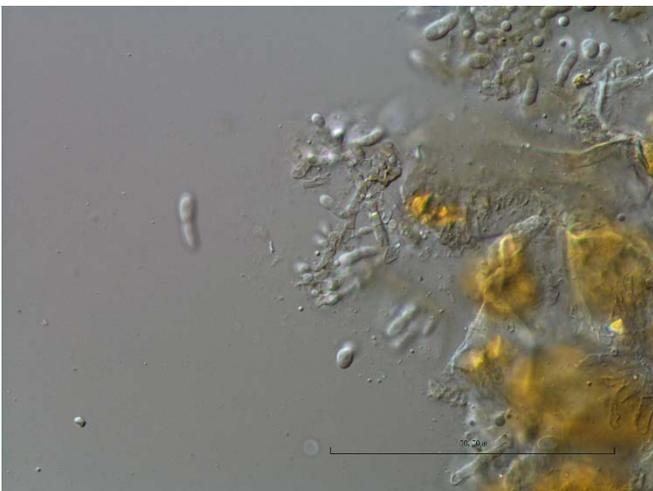
Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England



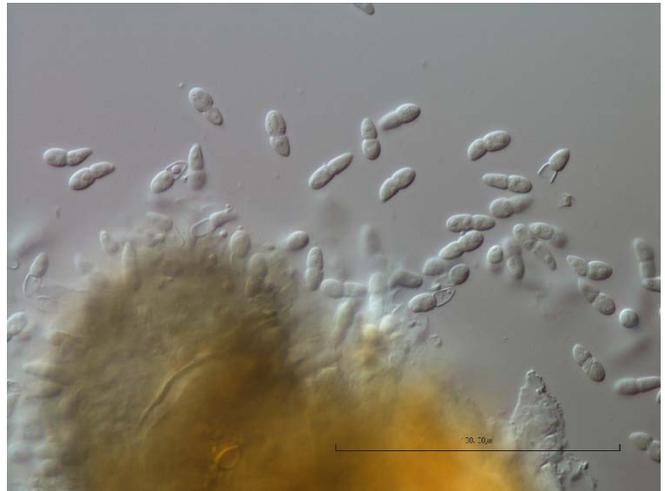
Blackspot on Rosa.



Acervuli of Diplocarpon rosae.



Conidiophores of Diplocarpon rosae.



Conidia of Diplocarpon rosae.

***Colletotrichum* Corda (1831)**

=*Dicladium* Ces. (1852)
=*Steirochaete* A. Braun & Casp (1854)
=*Fellneria* Fuckel (1867)
=*Phellomyces* A.B. Frank (1898)
=*Colletotrichopsis* Bubák (1904)
=*Didymariopsis* Speg. (1910)
=*Gloeosporiopsis* Speg. (1910)
=*Fominia* Girz. (1927)
=*Lophodiscella* Tehon (1933)
=*Blennorella* Kirschst. (1944)
=*Ellisiellina* Sousa da Câmara (1949)
=*Rostrospora* Subram. & K. Ramakr., (1952)
=*Colletostroma* Petr. (1953)
=*Peresia* H. Maia (1960)

Fungi, Ascomycota, Pezizomycotina, Sordariomycetes, Sordariomycetidae, Glomerellaceae

Type species: *Colletotrichum lineola* Corda (1832)

Distribution: Cosmopolitan. Endophytic, causes anthracnose on a wide variety of hosts. Associated with every vascular plant?

Colletotrichum is one of the most commonly intercepted fungi at U.S. ports and one of the most often identified fungi in NPDP labs. The breadth of diversity in this genus has been studied in depth, but many new species are likely still out there awaiting discovery. See the references below for a few overview studies.

Characters: *Spore production* in acervuli, subcuticular or epidermal. *Setae* present or absent, brown, smooth, septate, abundant or sparse.
Conidiogenesis from hyaline to brown conidiophores, enteroblastic, phialidic, periclinal thickening sometimes prominent.
Conidia hyaline, aseptate, cylindrical and straight or falcate, smooth (with an appendage in one species complex).

References:

Crouch, J.A. 2014. *Colletotrichum caudatum* s.l. is a species complex. IMA Fungus 5:17-30
Damm et al., 2013. The *Colletotrichum orbiculare* species complex: important plant pathogens of field crops and weeds. Fungal Diversity, 61:29-59
Damm et al., 2012. The *Colletotrichum boninense* species complex. Studies in Mycology 73:1-36
Damm et al., 2009. *Colletotrichum* species with curved conidia from herbaceous hosts. Fungal Diversity 39:45-87
Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England
Weir et al. 2012. The *Colletotrichum gloeosporioides* species complex. Studies in Mycology, 73:115-180

Colletotrichum orbiculare



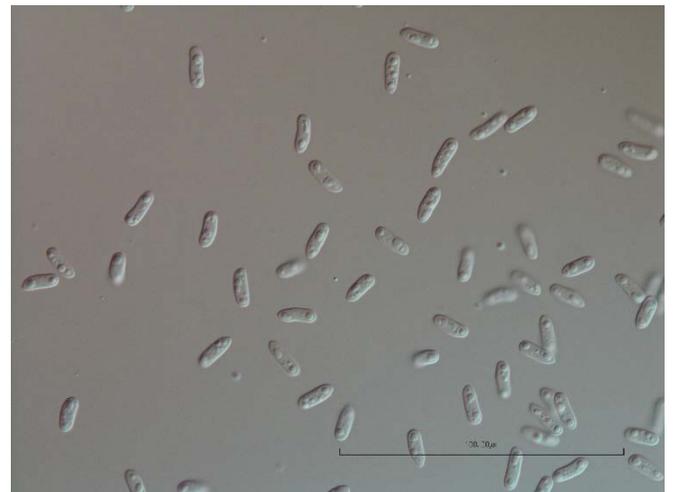
Leaf spots on Cucumis.



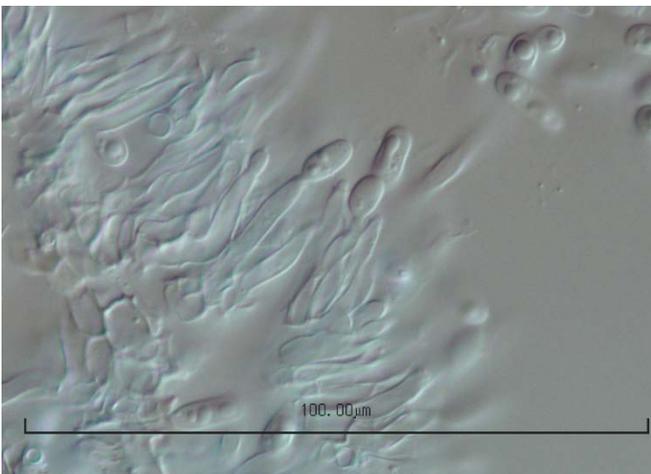
Close up of acervuli sporulating on Cucumis leaf.



Cross section of *Colletotrichum* acervulus. A seta is visible in the background.



Conidia of *Colletotrichum orbiculare*.



Close up of conidiophores and phialides of *C. orbiculare*.

Colletotrichum trichellum



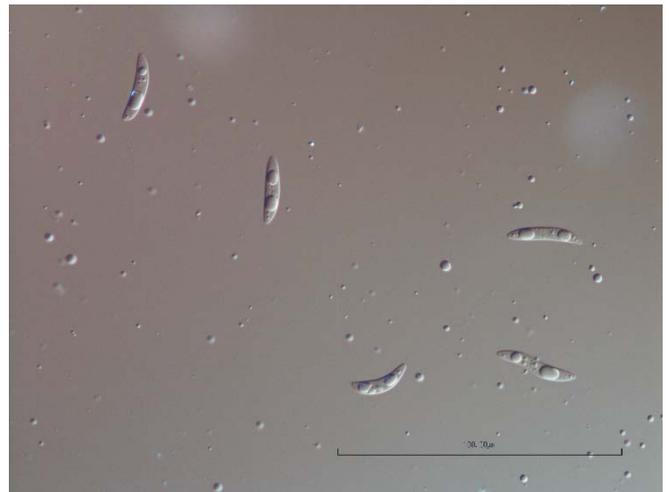
Leaf spots on Hedera.



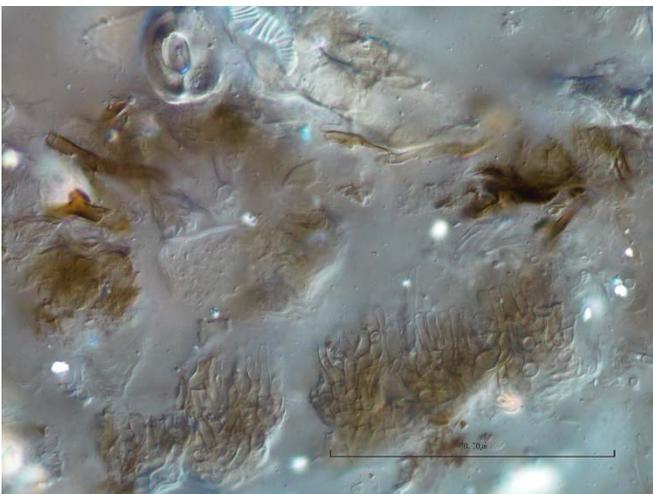
Close up of acervuli of *C. trichellum* on Hedera.



Setae of *C. trichellum*.



Conidia of *Colletotrichum trichellum*.



Conidiophores of *Colletotrichum trichellum*.



Close up of a seta and phialidic conidiophores of *C. trichellum*.

***Cryptocline betularum* (Ellis & G. Martin) Arx (1957)**

≡ *Monostichella betularum* (Ellis & G. Martin) Redlin

≡ *Gloeosporium betularum* Ellis & G. Martin (1882)

≡ *Gloeosporidium betularum* (Ellis & G. Martin) (1923)

Fungi, Ascomycota, Pezizomycotina, Leotiomyces, Leotiomycetidae, Helotiales, Cryptocline

Type species of *Cryptocline*: *Cryptocline effusa* Petr., Annales Mycologici (1924)

Distribution: Causes leaf spots on *Betula*.

Characters: *Spore production* in acervuli, epidermal or subepidermal.
Conidiogenesis enteroblastic, phialidic, conidiogenous cells cylindrical with 1-2 percurrent proliferations.
Conidia hyaline to very pale brown, cylindrical to ellipsoid with a flat base, 7.5-9.5 x 4-5 µm.

References:

Morgan-Jones, G. 1971. Conidium ontogeny in Coelomycetes. I. Some amerosporous species which possess annellides.

Can. J. Bot. 49:1921-1929

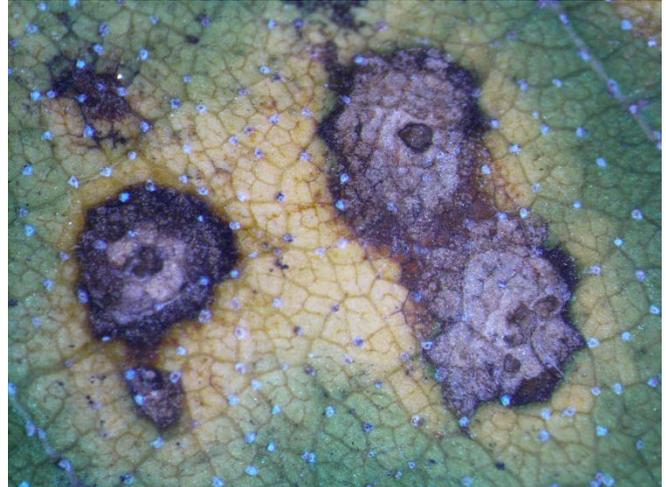
Morgan-Jones, G. 1973. Genera coelomycetarum. VII. *Cryptocline* Petrak. Can. J. Bot. 51:309-325

Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England

***Cryptocline betularum* (Ellis & G. Martin) Arx (1957)**



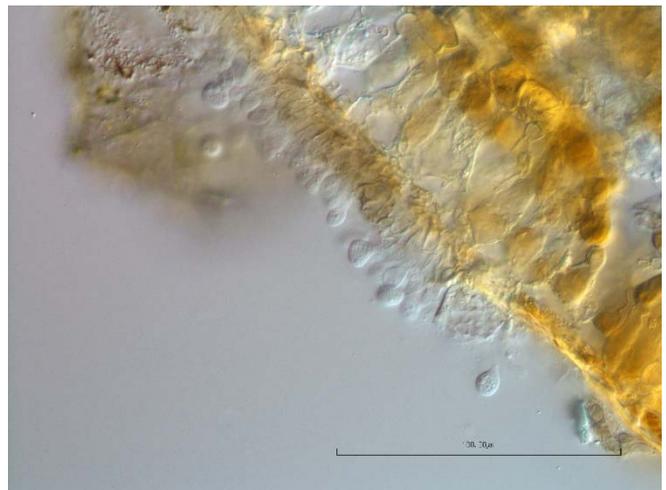
Leaf spots on Betula.



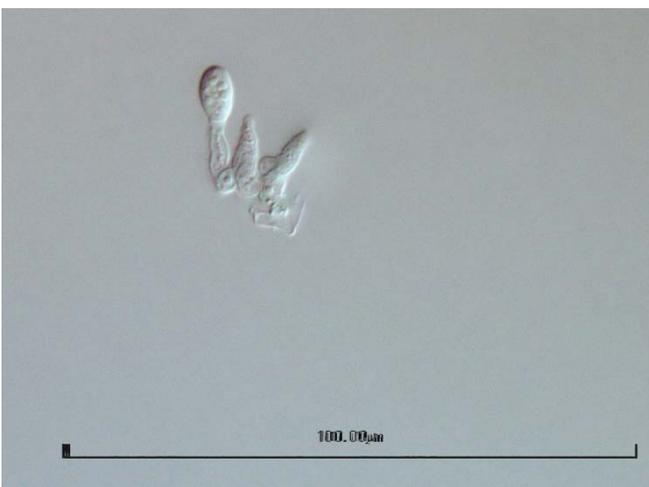
Acervuli in lesions on Betula.



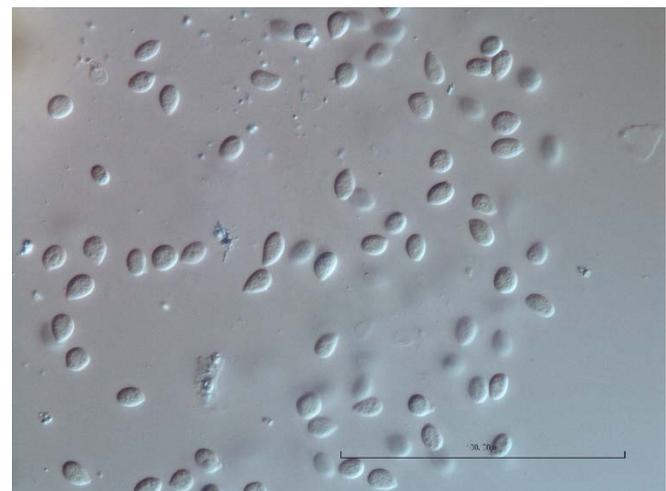
Acervulus of Cryptocline betularum.



Conidiogenous cells and conidia of Cryptocline betularum.



Conidiogenous cells of Cryptocline betularum showing percurrent proliferations.



Conidia of Cryptocline betularum.

***Pestalotiopsis* Steyaert (1949)**

= *Discosiopsis* Edward, KrP. Singh, S.c. Tripathi, M.K. Sinha & Ranade (1974)

Fungi, Ascomycota, Pezizomycotina, Sordariomycetes, Xylariomycetidae, Xylariales, Amphisphaeriaceae

Type species: *Pestalotiopsis guepinii* (Desm.) Steyaert (1949)

Distribution: Cosmopolitan. Endophytic on most plants, can cause leaf spots and other symptoms.

Characters: *Spore production* in acervuli, epidermal to subepidermal.
Conidiogenesis from hyaline, cylindrical, thin conidiophores, holoblastic, annellidic.
Conidia fusiform, septate, basal cell usually with a single short appendage, apical cell with 2 or more appendages, median cells at least colored, often brown to pale brown.

For a number of years mycologists, especially Guba and Steyaert, debated the proper placement of *Pestalotia* and *Pestalotiopsis*. Essentially, Guba called everything he saw *Pestalotia*, while Steyaert felt *Pestalotia* only comprised one species, with everything else being a *Pestalotiopsis*. Jeewon et al. provide a summary of the historical treatment by Guba and Steyaert of the fungi called *Pestalotia* and *Pestalotiopsis*, plus DNA evidence supporting the conclusions of Steyaert and Nag Raj. *Pestalotia* is a monotypic genus, represented by the species *Pestalotia pezizoides*. Pretty much everything else that fits the morphological characters used to identify a *Pestalotia/Pestalotiopsis* (appendaged conidia with 2-3 apical and one basal appendage, multiple septa with darkened median cells, etc.) should be called *Pestalotiopsis*. Much more work needs to be done on this group to determine inter- and intraspecies boundaries.

References:

- Guba, E.F. 1961. Monograph of *Monochaetia* and *Pestalotia*. Harvard Univ. Press, Cambridge
- Jeewon, R. et al. 2001. Phylogenetic relationships of *Pestalotiopsis* and allied genera inferred from ribosomal DNA sequences and morphological characters. *Molecular Phylogenetics and Evolution* 25:378-392
- Raj, N. 1993. Coelomycetous Anamorphs with Appendage-Bearing Conidia. Mycologue Publications Canada
- Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England

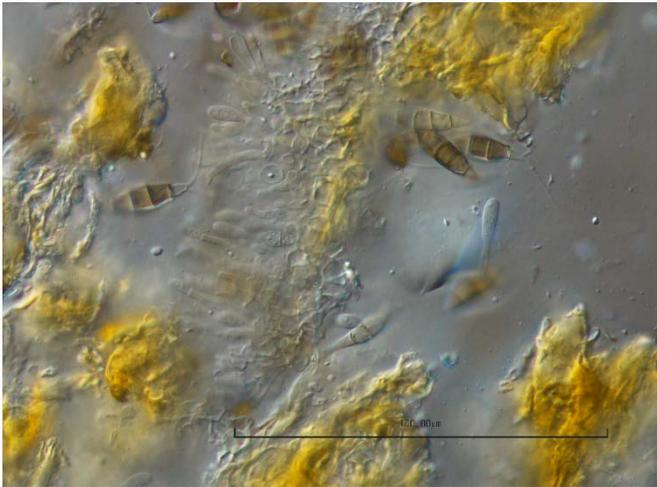
***Pestalotiopsis* sp. on *Thuja* sp.**



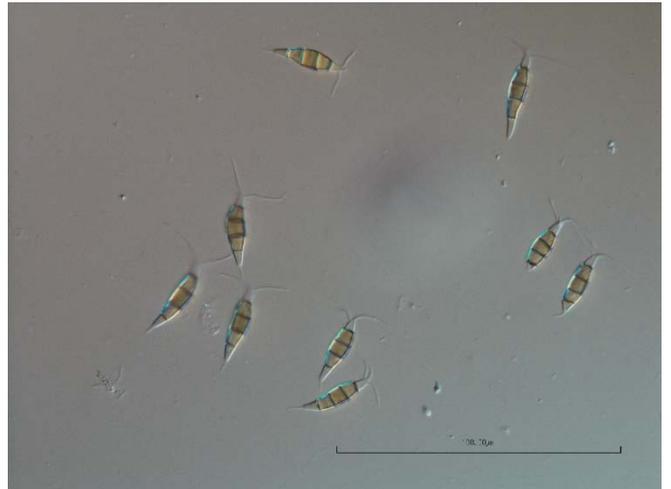
Dieback of Thuja.



Close up of Pestalotiopsis sporulation on Thuja.



Part of a Pestalotiopsis acervulus with conidiophores.



Conidia of Pestalotiopsis.



Detail of conidiophores of Pestalotiopsis.

***Phoma* Sacc (1880)**

- =Macropodiella Speg.(1908)
- =Chlamydosporium Peyronel(1913)
- =Leptophoma Höhn. (1915)
- =Rhizosphaerella Höhn. (1917)
- =Sclerophomina Höhn.(1917)
- =Phomopsina Petr.(1922)
- =Pseudosclerophoma Petr. (1923)
- =Vialina Curzi (1935)
- =Paraphoma Morgan-Jones & J.F. White (1983)

Type species of *Phoma*: *Phoma herbarum* Westend. (1852)

Distribution: Widespread. On every vascular plant? Saprobic and pathogenic.

Characters: *Spore production* in pycnidia with distinct ostioles.

Conidiogenesis from enteroblastic, phialidis conidiogenous cells.

Conidia hyaline, aseptate, ellipsoid, small (ranging from 5 to 10 µm long and 1.5-3 µm wide).

References:

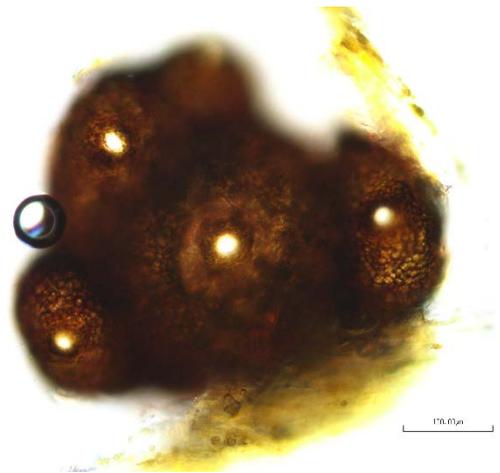
Boerema et al. 2004. *Phoma* Identification Manual CABI (IMI) Kew, England

Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England

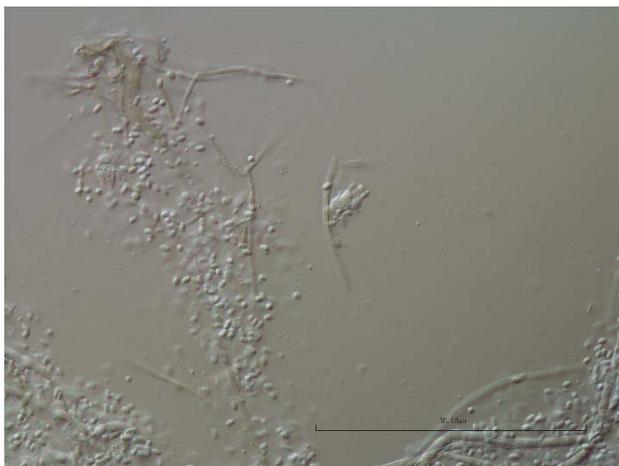
See also Studies in Mycology issues about *Phoma* and related genera.



Pycnidia of Phoma sp. in a leaf spot



Ostiolate pycnidia of a Phoma sp.



Conidia and conidiogenous cells of a Phoma sp.



Close-up of conidiogenous cells of a Phoma sp.

***Phyllosticta* Pers. (1818)**

=*Phyllosphaera* Dumort. (1822)

=*Macrophyllosticta* Sousa da Câmara, (1929)

=*Caudophoma* B.V. Patil & Thirum. (1968)

=*Guignardia* Viala & Ravaz (1892) (teleomorph state)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Botryosphaeriales, Botryosphaeriaceae

Type species: *Phyllosticta convallariae* Pers. (1818)

Distribution: Common cause of leaf spots on a wide variety of hosts. Notable species include *P. citricarpa* (cause of Citrus Black Spot and *P. capitalensis*, a common endophyte).

Characters: *Spore production* in pycnidial ostiolate conidiomata.
Conidiogenesis from conidiogenous cells, holoblastic with percurrent proliferations.
Conidia subglobose, ovoid, hyaline, often truncated at base, enclosed in a mucilaginous sheath and with a mucilaginous apical appendage. Conidia usually in the 8-12 x 5-7 µm range. *Microconidia* sometimes produced (“Leptodothiorella”). Microconidia hyaline, dumb-bell shaped, 5-7 x 1.5-2.5 µm.

Can be confused with *Phomopsis* and *Phoma* when identifying under the dissecting scope. Some *Phyllosticta* spp. don't have appendages and could be confused with *Diplodia*-like fungi. Many older names of *Phyllosticta* are no longer valid. See the book by Van der AA for a comprehensive list of species accepted in *Phyllosticta*, and those no longer accepted in the genus.

References:

Van der AA, H.A. and S. Vanev. 2002. A Revision of the Species Described in *Phyllosticta*. APS Press.

Nag Raj, T.R. 1993. Coelomycetous Anamorphs with Appendage-Bearing Conidia. Mycologue Publications
Canada

***Phyllosticta minima* (Berk. & M.A. Curtis) Underw. & Earle (1897)**

≡ *Sphaeropsis minima* Berk. & M.A. Curtis (1874)

= *Phyllosticta acericola* Cooke & Ellis (1879)

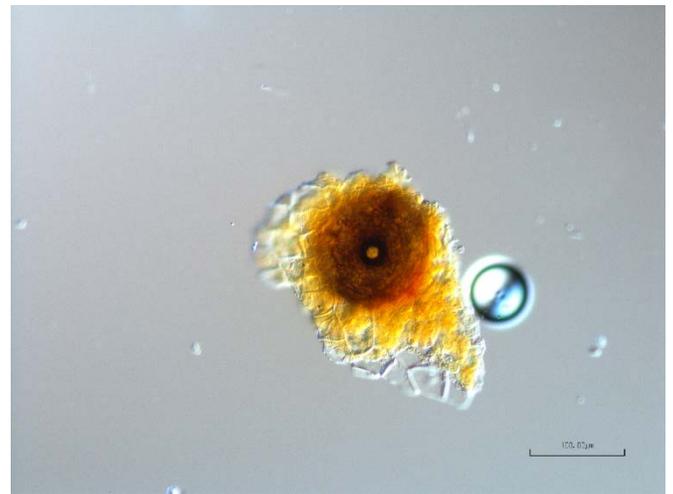
= *Phyllosticta arida* Earle (1898)



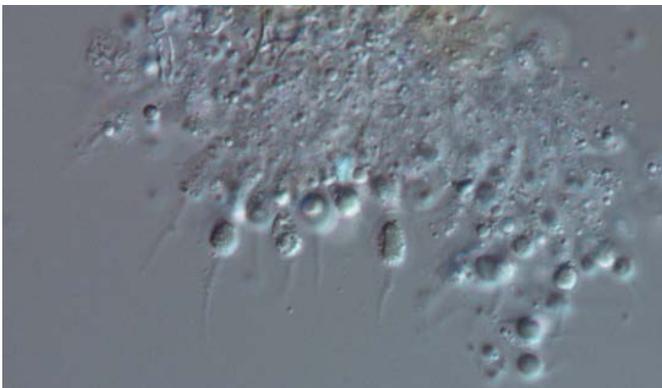
Leaf spots on three species of Acer.



Phyllosticta pycnidia in a leaf lesion.



Pycnidium of Phyllosticta showing the ostiole.



36 *Phyllosticta conidia forming in the pycnidium.*



Phyllosticta conidia.

***Septoria* sp. Sacc. (1884)**

=*Septaria* Fr. (1821)

=*Spilosphaeria* Rabenh. (1857)

Fungi, Ascomycota, Pezizomycotina, Dothideomycetes, Dothideomycetidae, Capnodiales, Mycosphaerellaceae

Type species: *Septoria cytisi* Desm.

Distribution: Common cause of leaf spots on a wide variety of hosts. Species include *Septoria rudbeckiae*, *Septoria cornina*, *Septoria apiicola*.

Characters: *Spore production* in pycnidial conidiomata with a central ostiole.
Conidiogenesis holoblastic, conidiophores reduced to conidiogenous cells.
Conidia hyaline, multiseptate, filiform. Conidial size usually 50-100 x 3-5 µm.

Can be confused with *Phloeospora*. Sometimes confused with cercosporoid hyphomycetes.

Conidiogenesis is an important character to observe for this genus.

References:

Sutton, B.C. 1980. The Coelomycetes. CABI (IMI) Kew, England

Priest, M.J. 2006. Fungi of Australia: Septoria. 2006. CABI (IMI) Kew England

Verkley, G.J.M. et al. 2013. A new approach to species delimitation in *Septoria*. Studies in Mycology 75:213-305

Quadvlieg, W. 2013. Sizing up Septoria. Studies in Mycology 75:307-390

Note: *Septoria* as a form genus encompasses a variety of morphological forms and has been, and likely will continue to be, subdivided into different genera. See the papers listed in Studies in Mycology for more information.

Septoria apiicola Speg. (1887)

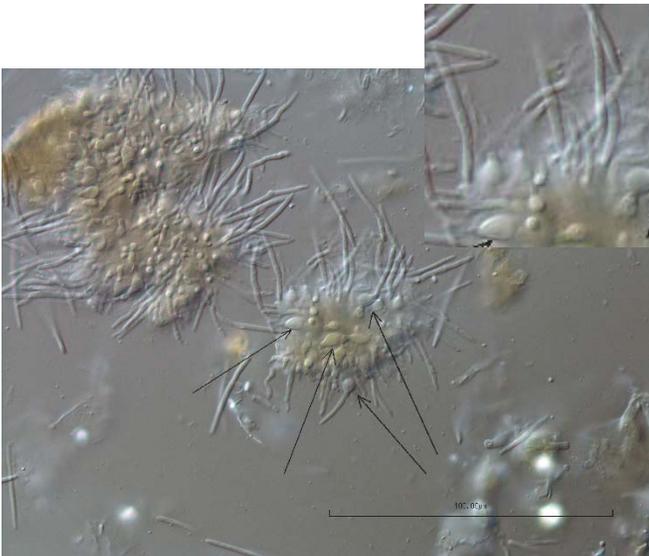
- ≡ *Rhabdospora apiicola* (Speg.) Kuntze (1898)
- = *Septoria apii* Chester (1891)
- = *Septoria apii-graveolentis* Dorogin (1915)
- = *Septoria petroselinii* var. *apii* Briosi & Cavara (1891)



Leaf spots on *Apium graveolens*



Close-up of *Septoria pycnidia* on leaf spot.



Conidia and conidiogenous cells of Septoria apiicola (inset, close up of conidiogenous cells of *S. apiicola*).



Conidia of Septoria apiicola.

***Septoria castaneicola* Desm. (1847)**

≡ *Phloeospora castanicola* (Desm.) D. Sacc.

≡ *Septoria castanicola* Desm. (1847)

≡ *Phloeospora castaneicola* (Desm.) D. Sacc. (1911)

≡ *Stromatoseptoria castaneicola* (Desmazières) Quaedvlieg, Verkley & Crous (2013)

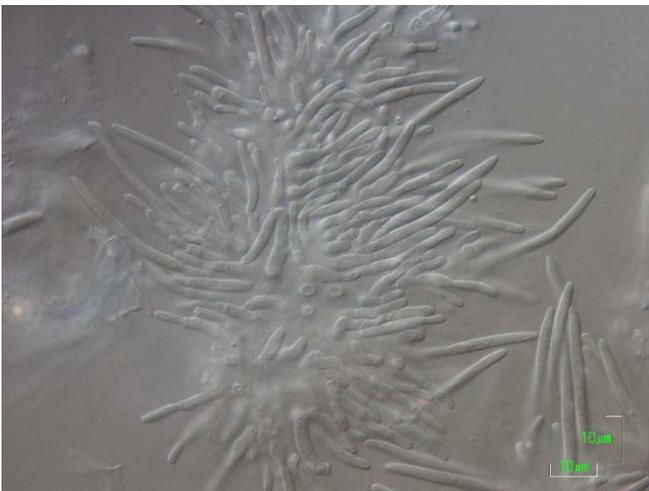
Note: Although Quaedvlieg et al. placed this fungus in the newly erected genus *Stromatoseptoria*, MycoBank still lists the current name as *Septoria castaneicola* with *Stromatoseptoria castaneicola* as a synonym. Stay tuned....



Leaf spots on Castanea.



Close-up of a pycnidium with emerging cirrus of conidia.



Conidiogenous cells and conidia.



Conidiogenous cells and conidia.

OTHER GROUPS OF FUNGI

A detailed discussion of morphological identification of ascomycete fungi producing ascomata, as well as the rusts, powdery and downy mildews is beyond the scope of this workshop.

However, we have some samples available with these fungi and looking at these is a useful exercise.

The following pages illustrate morphological features of fungi on some of the samples available for this workshop.

ASCOMYCETES

(or, ascomycetous fungi producing sexual stage structures)

Phyllachora on *Calamagrostis*

POWDERY MILDEWS

Erysiphe paeoniae on *Paeonia*

Podosphaera aphanis on *Fragaria*

Erysiphe magnifica on *Magnolia*

RUSTS

Coleosporium asteriae on *Solidago*

Images of assorted other rust fungi

DOWNY MILDEW

Peronospora belbahrii on *Ocimum*

***Phyllachora* Nitschke ex Fuckel (1870)**

=Sirentyloma Henn. (1895)
=Discomycopsella Henn.(1902)
=Pseudomelasmia Henn.(1902)
=Metachora Syd. & E.J. Butler (1911)
=Endophyllachora Rehm,(1913)
=Catacauma Theiss. & Syd., (1914)
=Placostroma Theiss. & Syd. (1914)
=Endodothella Theiss. & Syd. (1915)
=Phaeotrabiella Theiss. & Syd. (1915)
=Phragmocarpedia Theiss. & Syd.(1915)
=Phragmocauma Theiss. & Syd., (1915)

=Clypeostigma Höhn.(1919)
=Puiggarina Speg.(1919)
=Halstedia F. Stevens (1920)
=Clypeotrabutia Seaver & Chardón (1926)
=Endotrabutia Chardón (1930)
=Phaeotrabutia Orejuela (1941)
=Tolediella Viégas, Bragantia (1943)

Fungi, Ascomycota, Pezizomycotina, Sordariomycetes, Phyllachorales, Phyllachoraceae

Type species: *Phyllachora graminis* (Pers.) Fuckel, (1870)

Distribution: Cosmopolitan, depending on host. Causes a tar spot.

Characters: *Spore production* in asci formed in subglobose perithecia that are often crowded together in groups on the host.

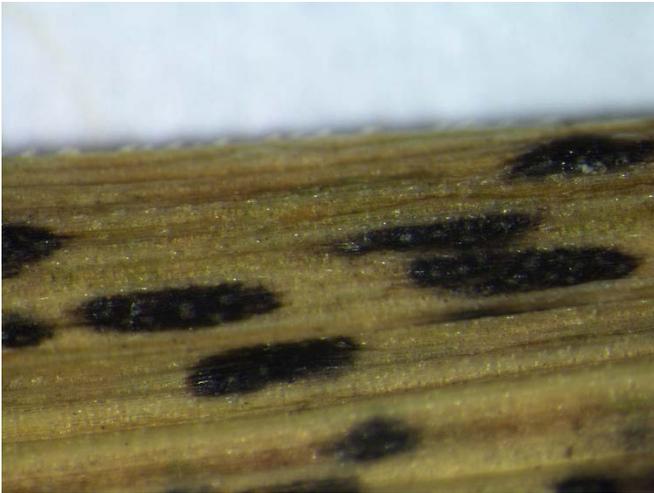
Asci unitunicate, cylindrical with 8 ascospores. *Paraphyses* filiform, often longer than the asci.
Ascospores hyaline, 1-celled, oval to globose.

Phyllachora spp. are associated with a Linochora anamorph state, which produces short filiform conidia from phialides in conidiomata that are often in the same lesion as the ascigerous state.

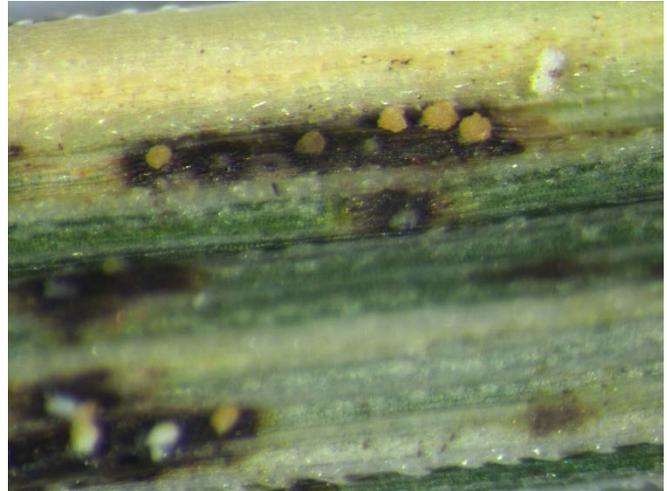
References:

Hanlin, R.T. 1990. Illustrated Genera of Ascomycetes Volumes I and II. APS Press
Parbery, D.G. 1967. Studies on graminicolous species of *Phyllachora* Nke. In Fckl. V. A taxonomic monograph. Aust. J. Bot. 15:271-375
Parbery, D.G. 1971. Studies on graminicolous species of *Phyllachora* Nke. In Fckl. VI.* Additions and Corrections to Part V. Aust. J. Bot. 19:207-235
Also see CABI (IMI) descriptions of individual species.

Phyllachora sp. (cf. *graminis*) on *Calamagrostis*



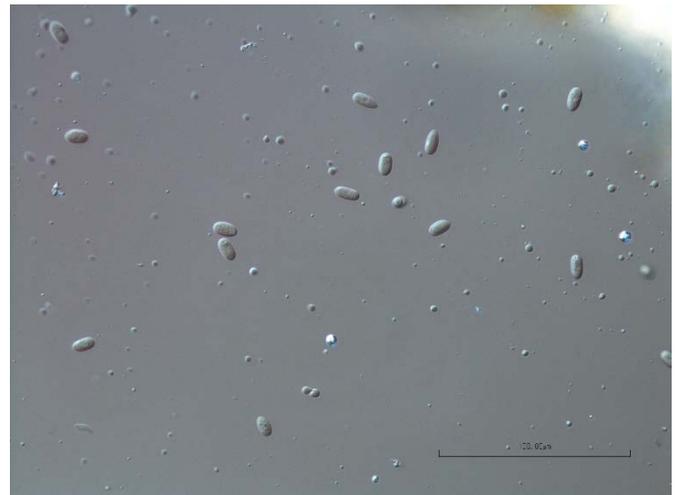
Tar spot on *Calamagrostis*.



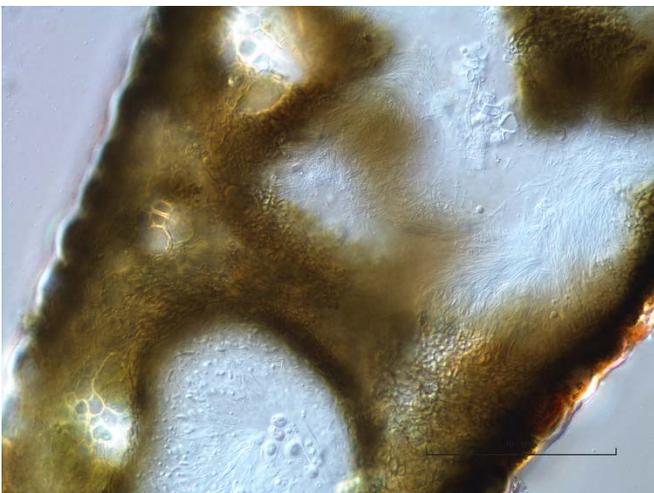
Asci being released from *Phyllachora* ascomata on *Calamagrostis*.



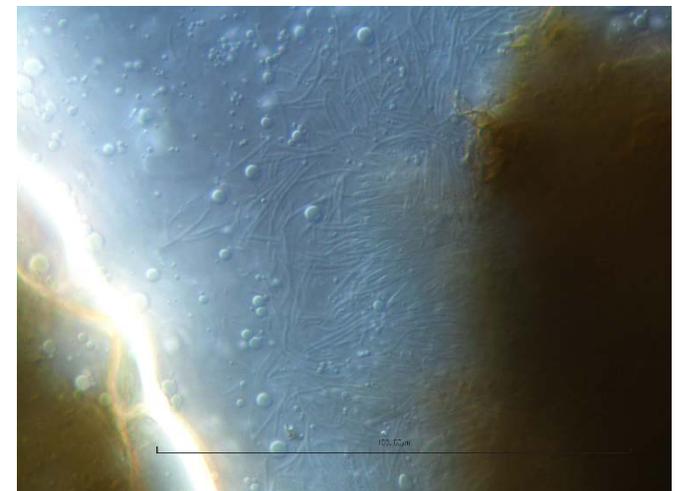
Cross section of a *Phyllachora* ascoma showing asci, ascospores and paraphyses.



Ascospores of *Phyllachora* on *Calamagrostis*.



Cross section showing an ascoma of *Phyllachora* next to a conidioma of the anamorph (*Linochora*) state.



Phialides and conidia of the anamorph *Linochora* state.

Powdery Mildews

Fungi, Ascomycota, Pezizomycotina, Leotiomyces, Leotiomycetidae, Erysiphales

***Erysiphe magnifica* (U. Braun) U. Braun & S. Takam. (2000)**

≡ *Microsphaera magnifica* U. Braun (1983)

Type species of Erysiphe: *Erysiphe polygoni* DC. (1805)

Distribution: Widespread, especially northern hemisphere. Hosts: Magnolia and Nelumbo.

Characters: Conidia formed singly, ellipsoid-ovoid, doliform, 20-38(42) x (10)12-20(-22), Chasmothecia 75-90-145, apices branched, asci 2-10, ascospores (16)20-30(33) x (7.5)9-15, hyaline

***Erysiphe paeoniae* R.Y. Zheng & G.Q. Chen (1981)**

Type species of Erysiphe: *Erysiphe polygoni* DC.(1805)

Distribution: Asia, Australia, USA (Texas).

Characters:Conidia formed singly, ellipsoid-ovoid, 20,25,50,55, Chasmothecia 70,90,125,135, appendigas variable, branched in coral-like manner, asci 3,12,16, ascospores 12,16,25, 7,10,13.5, hyaline

***Podosphaera aphanis* var. *aphanis* (Wallr.) U. Braun & S. Takam. 2000**

≡ *Alphitomorpha aphanis* Wallr. 1819

≡ *Podosphaera aphanis* (Wallr.) U. Braun & S. Takam. 2000

≡ *Sphaerotheca aphanis* (Wallr.) U. Braun 1982

≡ *Sphaerotheca aphanis* var. *aphanis* (Wallr.) U. Braun 1984

= *Oidium agrimoniae* Sawada 1933

= *Oidium fragariae* Harz 1887

≡ *Sphaerotheca fragariae* (Harz) Erikss. 1928

= *Oidium ruborum* Rabenh. 1878

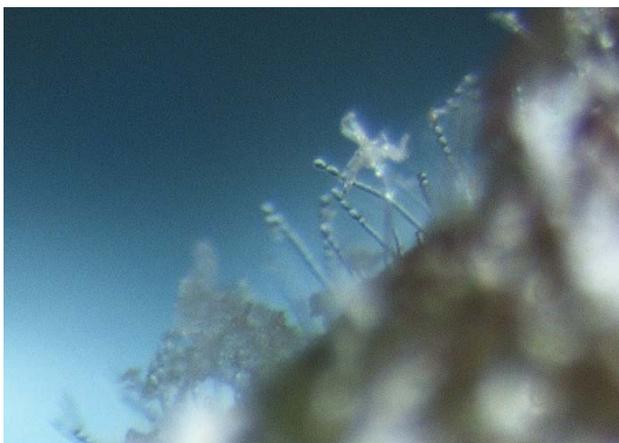
Type species of Podosphaera: *Podosphaera myrtilina* Kunze (1823)

Distribution: Widespread, multiple hosts.

Characters: Conidia catenescant, with fibrosin bodies, ellipsoid-ovoid, 20-25-40-45 x 10-14-26, Chasmothecia 70-100-120, appendages mycelioid, asci 6-8 spored, ascospores ellipsoid 16-18-26-30 x 11-21, hyaline

Reference:

Braun, U. and Cook, R.T.A. 2012. Taxonomic Manual of the Erysiphales (Powdery Mildews) CBS-KNAW, Utrecht.



Erysiphe sp. sporulating on a leaf.

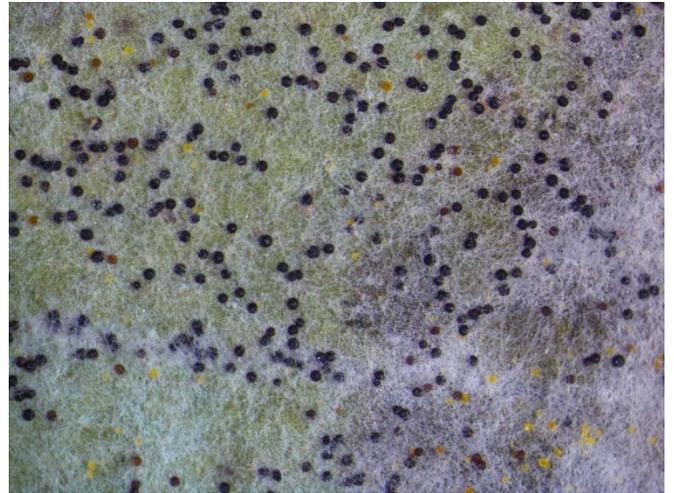


Erysiphe sp. conidiophore and conidia.

Erysiphe paeoniae R.Y. Zheng & G.Q. Chen (1981)



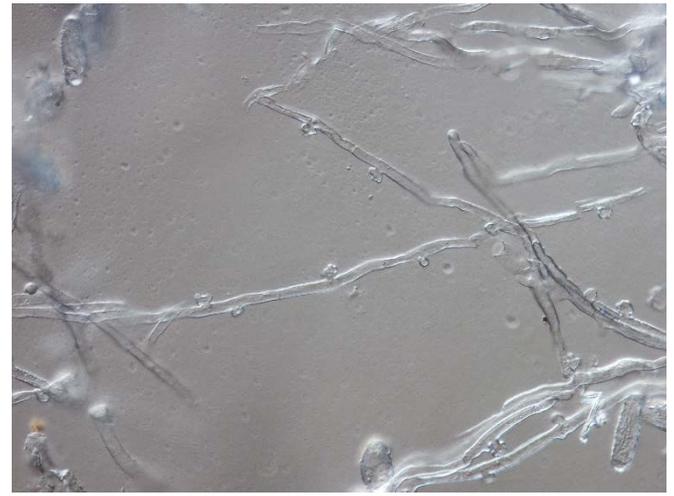
Powdery mildew on peony.



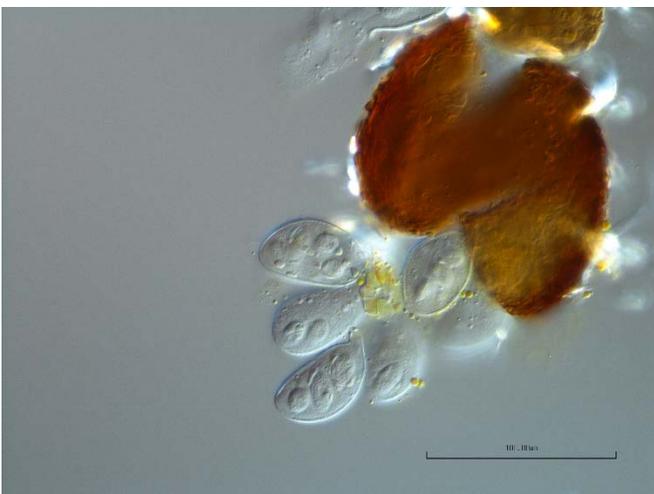
Chasmothecia of Erysiphe paeoniae.



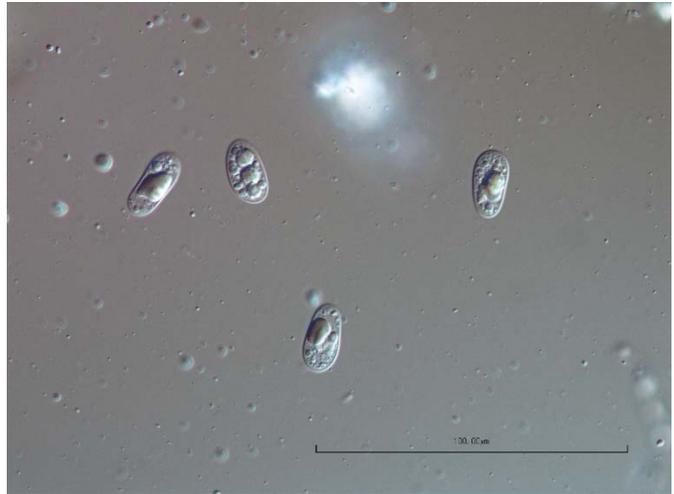
Chasmothecia of Erysiphe paeoniae.



Appressoria of Erysiphe paeoniae.



Asci and ascospores of Erysiphe paeoniae.



Ascospores of Erysiphe paeoniae.

Rusts

Fungi, Basidiomycota, Pucciniomycotina, Pucciniomycetes, Pucciniales

Below is a sampling of the diversity of rust fungi. See the references for more.

References:

***Phragmidium speciosum* (Fr.) Burrill (1875) Host(s): *Rosa* spp.**



***Puccinia* sp. on *Penstemon* sp.**



Puccinia esclavensis* Dietel & Holw. on *Mirabilis



Ravenelia mesillana* Ellis and Barthol. on *Senna

Uromyces ciceris-arietini* (Grognot) Jacz. & G. Boyer on *Cicer arietinum



***Coleosporium asterum* (Dietel) Syd. & P. Syd. (1914)**

- ≡ *Stichopsora asterum* Dietel 1899
- = *Peridermium montanum* Arthur & F. Kern 1906
- = *Uredo solidaginis* Schwein. 1822
 - ≡ *Coleosporium solidaginis* (Schwein.) Thüm. 1878

Fungi, Basidiomycota, Pucciniomycotina, Pucciniomycetes, Pucciniales, Coleosporiaceae, Coleosporium

Type species of *Coleosporium*: *Uredo rhinanthacearum* DC., (1808)

Distribution: Asia, North America on Asteraceae. Aecia on *Pinus* spp.

Characters (on Asteraceae): Uredina and Telia occur on the same leaves, often next to one another.

Uredinia subepidermal, erumpent.

Urediniospores verrucose, echinulate.

Telia subepidermal, as low cushions, gelatinous when wet.

Teliospores 1-celled, pseudocatenulate.

Other rusts on Asteraceae include *Puccinia* spp. and *Uromyces* spp.

References:

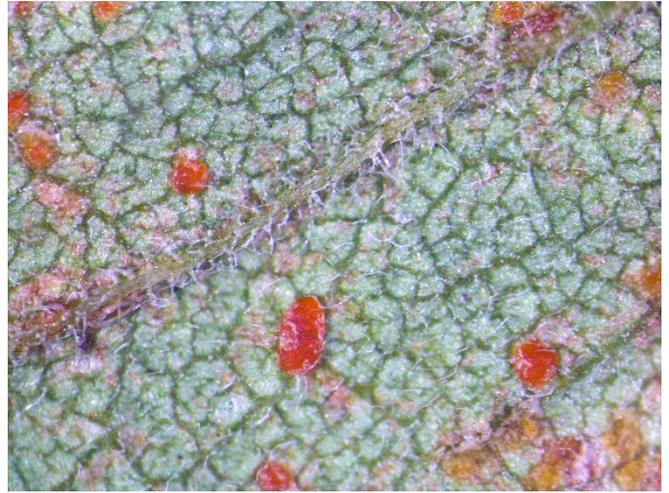
Arthur, J.C., Cummins, G.B. 1962. Manual of the Rusts in United States and Canada. Hafner Publishing New York

Cummins, G.B., Hiratsuka, Y. 1983. Illustrated Genera of Rust Fungi. APS Press

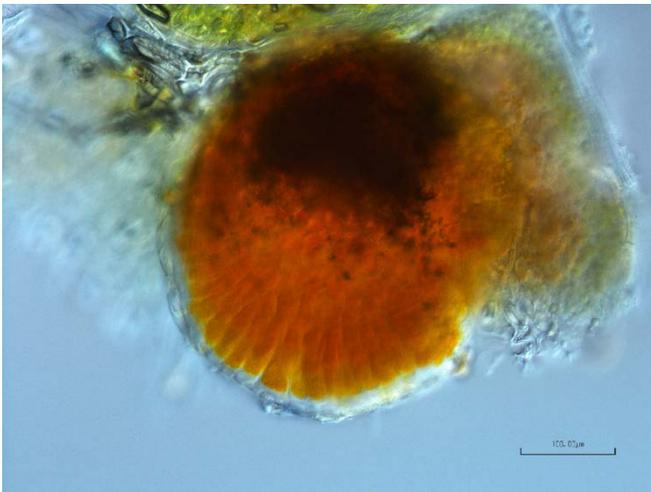
***Coleosporium asterum* (Dietel) Syd. & P. Syd.**



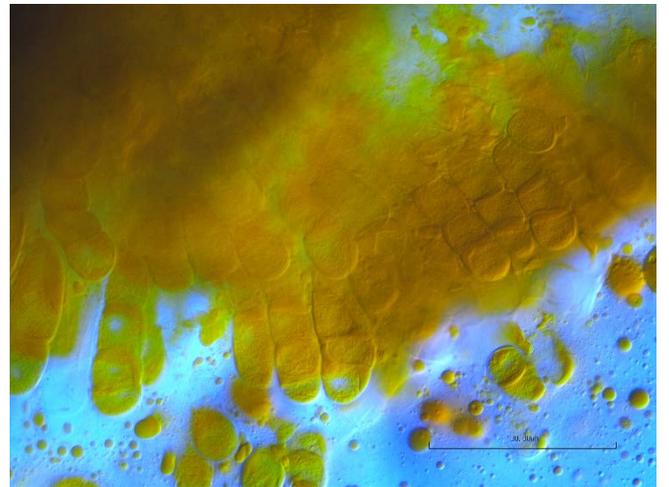
Rust on Solidago



Telia of C. asterum on Solidago



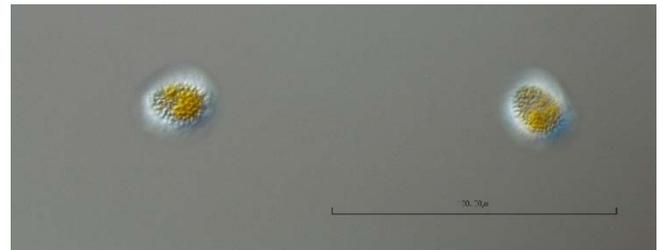
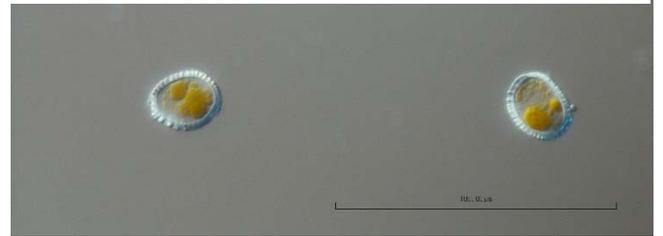
Telium of C. asterum



Teliospores of Coleosporium asterum



Uredinium of Coleosporium asterum



Urediniospores of C. asterum showing wall thickness (top) and spines (bottom).

***Peronospora* Corda (1837)**

Chromista, Oomycota, Oomycetes, Peronosporales, Peronosporaceae

Type species: *Peronospora rumicis* Corda (1837)

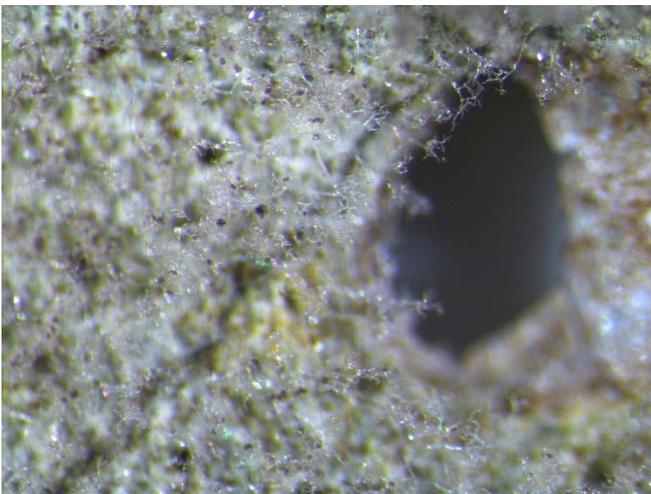
Distribution: Widespread. Causes downy mildew on a wide variety of hosts.

Characters: *Spore production* on highly branched hyaline conidiophores.
Conidia olive brown, obovoid, 29-33 x 23-26µm.

Reference:

Thines et al. 2009. Identity of the downy mildew pathogens of basil, coleus, and sage with implications for quarantine measures. *Mycological Research* 113:532-540

***Peronospora belbahrii* Thines 2009**



P. belbahrii sporulating on an *Ocimum* leaf.



Conidiophore and conidia of *P. belbahrii*.



Conidiophore of *P. belbahrii*.



Conidia of *P. belbahrii*.