

Zeitschrift: Mycologia Helvetica
Herausgeber: Swiss Mycological Society
Band: 6 (1994)
Heft: 1

Artikel: The genus concept in fungi : an ecologist's point of view
Autor: Petrini, Orlando
DOI: <https://doi.org/10.5169/seals-1036330>

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

Download PDF: 09.08.2025

ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>

The genus concept in fungi: an ecologist's point of view

Orlando Petrini

Mikrobiologisches Institut, ETH-Zentrum
CH-8092 Zürich

All ecological studies rely on the description of the community of organisms present in the ecosystem. This first and unavoidable task requires detailed census work to prepare complete species lists that will be used in future investigations. In this respect, fungal ecology is no exception. The problems, as usual, arise when the researcher tries to identify the mycota present in the ecosystem or, even worse, isolated from it and kept in pure culture. The taxonomy of fungi is still far from being complete; moreover, for a large number of taxa, comprehensive studies that would allow a quick identification of the organisms are lacking.

Imagine now a fungal ecologist working in an arctic-alpine habitat and trying to identify a pycnidial coelomycete with ominous rod-shaped, hyaline, small conidia on phialides. The number of genera with these characters given by Sutton (1980) in the Phialopezizomycetaceae is daunting! Is the fungus an *Asteromella* or an *Aposphaeria* or a *Phoma* or could it be one of those monotypic, exotic genera so far described only from a small Caribbean tropical forest and, admittedly, very unlikely to occur in alpine meadows? One can argue, of course, that the species, and not the genus, is important in ecological studies, but how can you get to the right species if you do not know in which genus it could have been classified? In this and similar cases, nervous breakdown or at least major frustration with taxonomists is assured.

A natural system to organize species is essential to understand their biology and ecology and the genus is certainly essential for prediction of biological potential. The schemes designed by taxonomists, however, should enable not only specialists but also novices (and ecologists usually belong to the latter) to identify specimens to the species. Taxonomy and ecology are two disciplines that share a number of common features. For both it is essential to know as much as possible about morphology, because morphological attributes are of paramount importance not only for identification purposes but also for the understanding of ecological adaptations to the ecosystem. Physiological requirements can be useful taxonomic markers (e.g., Mugnai et al., 1989; Leuchtmann & Clay, 1990; Sieber-Canavesi et al., 1991) and they are also extremely important to analyze the activity and the requirements of

selected fungi in a given habitat. In taxonomy, autecology can be used to further characterize a taxon; in ecology, the taxonomic position of organisms inhabiting the same habitat may help to understand their interactions in the ecosystem.

Both taxonomist and ecologist, thus, are interested in the study of morphological features and of the physiological or biochemical attributes of a given taxon. The goals of taxonomy and ecology, however, are very distinct: while the taxonomist aims at a phylogenetically correct classification of organisms not only at the specific but also at higher taxonomic levels, the ecologist is primarily interested in the correct identification of individual species, only later turning to the synecological implications of the taxonomic interrelationships among species. Clearly at this point the ecologist's need for well-defined and easily identifiable genera in view of the subsequent species identification may clash with the taxonomist's definition of a given genus, often based on characters that are often found only during a limited time of the organism's life and intended to describe as exactly as possible phylogenetic relationships.

The taxonomist's need: clear-cut delimitation of genera to establish sound phylogenetic hypotheses. Cases for splitters and lumpers.

1. *Hypoxylon* and *Rosellinia*

Hypoxylon species are usually very easily recognized by the shape of their stromata and by a number of additional features that make them ideal objects for experimental studies. The genus *Rosellinia* Ces. et de Not. can also be recognized quite easily, although it shares a number of morphological features with members of the section Primo-Cinerea within *Hypoxylon* Bull. (Petrini & Müller, 1986). This has tempted some authors to include *Rosellinia* in *Hypoxylon* (Table 1). In my opinion, however, there are good reasons to maintain *Rosellinia* as a separate genus (Table 2). In fungal ecology, this is perhaps one of the rare cases where the conservation of two separate taxa is more helpful than reducing them into synonymy. As a matter of fact, in a large number of occasions the members of *Rosellinia* are easily recognized by the presence of a subiculum underneath the mainly uniperitheciate stromata. Only rarely borderline cases are encountered that can be accommodated in either genus. These, however, are exceptions and therefore do not really bother the fungal ecologist. The advantage of having two distinct genera, in this case, is obvious: both ecologists and taxonomists will be able to rapidly reduce the number of species to be considered, thus saving time and tedious literature work.

Table 1: Reasons to merge <i>Rosellinia</i> with <i>Hypoxylon</i> sect. Primo-Cinerea.	
Source	Similarities
Martin (1967)	<ul style="list-style-type: none">- Stromata uni- to multiperithecial- Uniform structure of the stromata- Shape of ascal plug- On inaequilateral spores the germ slits ar on the least convex side- Hyaline sheath around the ascospores- Anamoprh: <i>Nodulisporium</i> or <i>Geniculosporium</i>
Pouzar (1985)	<ul style="list-style-type: none">- Stromata uni- to multiperitheciate
Whalley & Whalley (1977)	<ul style="list-style-type: none">- Shape of ascal plug- On inaequilateral spores the germ slits ar on the least convex side- No pigments in the stromata
Proposal: <i>Rosellinia</i> and <i>Hypoxylon</i> section Primo-Cinerea merged in <i>Hypoxylon</i> sect. Entoleuca	

Table 2: Reasons to separate <i>Rosellinia</i> and <i>Hypoxylon</i> sect. Primo-Cinerea (Petrini & Müller 1986, L. E. Petrini-Klieber, pers. comm.)		
Morphological characters	<i>Hypoxylon</i> sect. Primo-Cinerea	<i>Rosellinia</i>
Stromata	<ul style="list-style-type: none">- Developing on the host surface, often with the basis immersed in the substrate.- Rarely uniperithecial, few to many perithecia present, covered by an ectostroma shared by all perithecia.	<ul style="list-style-type: none">- developing on a subiculum that covers young stromta almost entirely; stromata later emerging from the subiculum, superficial.- mainly uniperithecial, rarely (and then dependent on the substrate) few perithecia.
Anamorph	<ul style="list-style-type: none">- Sometimes present on young stromata.	<ul style="list-style-type: none">- developing on the subiculum.
Cellular appendage on the ascospores	<ul style="list-style-type: none">- Disappears at maturity.	<ul style="list-style-type: none">- cellular appendage and slimy caps or sheaths still present at maturity.

2. *Gremmeniella* versus *Ascocalyx*: the ecological and phytopathological debate

The taxonomic position of *Gremmeniella* Morelet and *Ascocalyx* Naumov has longly been debated. Müller & Dorworth (1983) included species of *Gremmeniella* in *Ascocalyx*, mainly on the basis of serological and morphological evidence. Later Petrini et al. (1989) demonstrated that these two genera can be separated using their electrophoretic profiles and the conidiomatal structures of their anamorphs. Conidia and asci of *A. abietis*

develop sequentially on the same stroma, whereas apothecia and pycnidia of *G. abietina* are two distinct structures (Kujala, 1953).

Ecologically, the two genera are well-defined because they occupy two distinct niches. *A. abietis*, for instance, is a saprotrophic organism, whereas *Gremmeniella* spp. are antagonistic symbionts (Petrini et al., 1989). This, together with the morphological attributes makes their identification comparatively easy, also allowing a rapid diagnosis of the pathogenic *Gremmeniella* spp. by the forest pathologist.

In this case, almost complete concordance exists between the taxonomist's, the plant pathologist's, and the ecologist's needs.

3. Do *Helicogermislita* and *Anthostomella* really belong to two different genera?

The generic name *Helicogermislita* was introduced in 1983 by Hawksworth and Lodha to accommodate *H. celastri* (S. Kale & V. Kale) Lodha & D. Hawksworth. The most distinctive character of this fungus is the helical germ slit visible on the surface of the ascospores. Helical germ slits, however, are known also for at least one species in *Anthostomella*, viz. *A. vincensii* G. Arnaud. Germ slits in other ascomycetous genera such as *Entosordaria* (Sacc.) Speg. (Müller, 1958) or *Amphisphaeria* Ces. et de Not. (Karsten, 1873) are helicoid, straight, or even lacking.

The iodine-negative reaction of the xylariaceous ascal plug, used by Hawksworth & Lodha (1983) to justify the erection of *Helicogermislita*, is also a weak diagnostic character. The iodine reaction of many species of the Xylariaceae is ambiguous, seen in some collections and wanting in others. There is even the possibility that the iodine reaction is linked with the existence of different races of the same species (Parker & Reid, 1969; Kohn & Korf, 1975; Petrini, 1982).

The helicoid germ slit does not correlate with other features to form a unique suite of characters that is essential for a monophyletic genus. *Helicogermislita* obviously shares many characters with *Anthostomella* and the erection of *Helicogermislita* is very debatable (Petrini et al., 1987). From the ecologist's point of view, the inclusion of *Helicogermislita* in *Anthostomella* is almost unavoidable. Not only do both genera occupy similar ecological niches and show related physiological requirements, their morphological differentiation is also reserved only to specialists and is based on very weak diagnostic features.

4. The Herpotrichiellaceae

The Herpotrichiellaceae Munk (1953) is a well-defined family that includes saprobes found on decaying wood and bark, leaves or decaying fungal sporocarps (Müller et al., 1987). The six genera included in the family by von Arx & Müller (1975) and Barr (1979) are separated on the basis of their ascospores. Distinctive as the ascospores are, they represent only one character which has low value as a generic determiner when compared to the overwhelmingly large number of features of teleomorphs and anamorphs that are shared among the species. Müller et al. (1987) retained only *Capronia* Sacc. and *Acanthostigmella* von Höhnelt in the Herpotrichiellaceae. They carefully considered the morphological and ecological characters that link species of the complex, tried to bring together collections with shared morphological anatomy, life-cycle and biology and to outline a monophyletic group.

The decision taken by Müller et al. (1987) has also practical significance. The presence within this group of too many borderline cases makes the delimitation of a larger number of genera within the Herpotrichiellaceae almost impossible.

5. The anamorph-teleomorph connexions: *Ceratocystis* and *Ophiostoma*, *Calonectria* and *Nectria*

Anamorph-teleomorph connexions have often proven to be extremely useful in delimiting genera in the Ascomycetes. *Ceratocystis* Ellis et Halsted and *Ophiostoma* H. et P. Sydow are virtually identical in morphology and ecology. *Ceratocystis*, however, is characterized by the absence of cellulose, presence of chitin and rhamnose in the cell wall, by its sensitivity to cycloheximide and by its *Chalara* anamorph. The cell wall of *Ophiostoma*, on the other hand, contains cellulose in addition to chitin and rhamnose, is resistant to cycloheximide and its conidia are formed holoblastically (de Hoog, 1974; de Hoog & Scheffer, 1984). Analysis of all these features lead Barr (1990) to include *Ophiostoma* in the Microascales, family Ophiostomataceae, and *Ceratocystis* in the Sordariales, family Lasiosphaeriaceae. More recently Samuels (pers. comm.) has decided to include the Ophiostomataceae in the Xylariales, particularly, but not only, on account of the typical xylariaceous teleomorph. In the case of *Ceratocystis* and *Ophiostoma*, therefore, careful study of the holomorph has suggested even different orders for the genera.

The hypocrealean *Calonectria* deNot., circumscribed by Rossman (1979) and now restricted to species with orange to scarlet or dark umber ascocarps, has scaly to warty walls, lacks a stroma and has a *Cylindrocladium* anamorph,

which is never formed in species of *Nectria* Fr. Knowledge of the anamorph is not necessary for the generic identification of *Calonectria* and *Nectria*, but it may be useful for the ecologist to know that the teleomorph of an isolate with *Cylindrocladium* anamorph is likely to be a species of *Calonectria*. The individual attributes of the anamorph and of the teleomorph combine to define a holomorph. Subtle features of either anamorph or teleomorph, however, may have been overlooked (e.g., thickness of the wall of sterile appendages or their septation) or undervalued in the past and more conspicuous ones overvalued (e.g., ascospore septation). For instance, *Cylindrocladiella* Boesewinkel can be excluded from *Cylindrocladium* not only because of morphological features but also because its teleomorph is in *Nectria* subg. *Dialonectria* Sacc. (Samuels et al., 1991).

Additional work is certainly needed in taxonomy to establish further connexions, as it brings extremely valuable information that can be used not only by taxonomists but also by ecologists to link field observations, where in prevalence only the teleomorphs are detected, with results of experimental work carried out with isolates producing only the anamorphic form.

The ecologist's need: landing at the species level after safe navigation in the (usually too large) generic sea

Fungal ecology work can be carried out at two levels. Field observations and collection of fruiting bodies are necessary to conduct preliminary investigations leading to the formulation of working hypotheses. Investigation of colonization patterns and analysis of distribution and abundance, as well as further experimental, ecophysiological work and population genetics, on the other hand, make extensive use of cultures. The isolation of strains from the habitats investigated is the first step to be taken in establishing models to be used in experimental ecology. The second step, the identification of the isolates, is mostly very laborious and cumbersome. It is also, in many cases, the first step in the insurgence of hatred toward taxonomists.

Most taxonomic work up to now has been performed on herbarium specimens and identification keys based on these studies often rely upon morphological characters visible only on the host or on preserved dead and dry material. Such keys are generally not useful for identifying specimens in artificial culture.

1. Where are the characters gone? *Cryptocline* versus *Cryptosporiopsis* versus *Discula*.

Cryptocline Petrak apud H. Sydow et Petrak, *Cryptosporiopsis* Bubák et Kabát, and *Discula* Sacc. are three coelomycetous form-genera in the suborder

Phialostromatineae Sutton (1980). Endophytic species are found in all three genera (Petrini, 1986; Petrini, 1991), some of which can be antagonistic symbionts (Sutton, 1980). The importance of these antagonists to the fungal ecologist and the plant pathologist is obvious.

While *Cryptocline* and *Discula* are mainly foliicolous, *Cryptosporiopsis* is usually restricted to bark. In addition, several characters allow an easy identification of specimens collected on the host (Table 3). The problems start when members of these genera are isolated into pure culture. Endophyte research has shown that while pycnidia of *Cryptocline* spp. and *Discula* spp. may form prevalently only on leaves, their mycelium extends throughout the plant as these fungi are frequently isolated from twigs and bark (Petrini, 1986; Petrini & Fisher, 1990). Moreover, the complex fructifications found in nature most often do not form in agar cultures (Table 3).

For the ecologist, and most often also for the taxonomist, only the personal, continuous experience with isolates of these three form-genera allows a more or less reliable, albeit mostly heuristic, identification at the generic level. With the exception of *Cryptosporiopsis*, where the conidial shape and dimension is in most cases a reliable diagnostic feature (Table 3), no objective and stable characters can be found that allow satisfactorily separation of these three genera. The situation is even more complicated by the presence in this complex of a cohort of several, mostly monospecific form-genera that are even less well-defined at the morphological — and sometimes even at the nomenclatural — level (Sutton, 1980).

2. The *Alternaria* nightmare

Fungal cultures of the *Alternaria* complex can be singled out mostly very easily. Their peculiar cultural characters allow to easily recognize the complex. The difficulties start in assigning a given isolate to one of the genera. The dichotomous keys (e.g. Ellis, 1971; 1976) mostly differentiate among *Alternaria* Nees : Fr., characterized by mostly catenate, obclavate and rostrate conidia, and *Embellisia* Simmons and *Ulocladium* Preuss, both with mostly solitary, not obclavate and not rostrate conidia. The problems, actually, lie within the “mostly” that sneaks in the generic descriptions of these form-genera. A specialist of this group will have mostly no trouble in assigning an isolate to a given genus. Any person – even an ecologist! – who repeatedly deals with these fungi will at good last develop the essential “taxonomic feeling” for them. The ecologist, however, very often is only a casual user! The identification of *Alternaria*-like fungi to the species is of course only a continuation of the generic nightmare, but this is obviously dictated by the

Table 3: Different characters of <i>Cryptocline</i> , <i>Cryptosporiopsis</i> and <i>Discula</i> on the host and in culture (partly after Sutton 1980)			
Morphological attributes	<i>Cryptocline</i>	<i>Cryptosporiopsis</i>	<i>Discula</i>
Mycelium:			
- on the host	immersed, branched, septate	immersed, branched, septate	immersed, branched, septate
- in culture	superficial to immersed	superficial to immersed	superficial to immersed
Conidiomata:			
- on the host	acervular, separate or confluent, textura angularis	acervular to stromatic, separate to confluent, textura angularis	acervular, separate or confluent, textura angularis
- in culture	acervular, separate or confluent, textura not defined	stromatic, convolute, confluent, textura not defined	acervular to stromatic, separate or confluent, textura not defined
Position of conidiomata:			
- on the host	epidermal to subepidermal, mostly on leaves	peridermal to subepidermal, mostly on bark	epidermal, mostly on leaves
- in culture	flat, appressed or slightly erect	raised, stromatic	flat, appressed or slightly erect
Conidiophores:			
- on the host	absent	absent	hyaline, septate and branched only at the base, tapered toward apices
- in culture	hyaline, aseptate, tapering toward apices	hyaline, aseptate, tapering toward apices	hyaline, septate and branched only at the base, tapering toward apices
Conidiogenous cells (on the host and in culture)	enteroblastic, phialidic, percurrently proliferating	enteroblastic, phialidic, percurrently proliferating	enteroblastic, phialidic
Conidia (on the host and in culture)	hyaline, aseptate, thin-walled, eguttulate or guttulate, smooth, cylindrical to doliiiform or ellipsoid, with broad, flat base	hyaline, aseptate, thin-walled, eguttulate or guttulate, smooth, straight or ellipsoid, base abruptly tapered to a distinct, truncate scar, apex obtuse	hyaline, aseptate, thin-walled eguttulate or guttulate, smooth, straight to slightly curved, ellipsoid or clavate, base obtuse to more or less truncate

enormous variation encountered in this complex. Very likely only molecular biology methods will help us to disentangle the conundrum, as I do not believe that morphology ever will, but also in this case there is a strong need for more taxonomists to work on this complex (possibly in close collaboration with ecologists and plant pathologists) and to help casual users in the identification of *Alternaria*-like specimens.

3. *Acremonium*, *Cylindrocarpon*, *Fusarium*, and *Verticillium*

The discussion of this group of anamorphs is almost preposterous and perhaps does not really belong here. The problems with these form-genera are reminiscent of those encountered in the *Phoma*-complex (van der Aa et al., 1990) and relate to the pleomorphism of many anamorphic fungi. In fact, a large number of species within these form-genera are taxonomically and very likely phylogenetically closely related, not last because of the relatedness of their teleomorphs. Moreover, there is a great deal of overlap of morphological features in these fungi and in many cases their conservation is dictated only by practical reasons. Cultures must be studied carefully according to the conditions specified in the corresponding identification guides to be sure that all morphological characters needed for the identification will be expressed, as some pleomorphic fungi tend to be very labile in culture. Isolates of *Cylindrocarpon* Wollenweber and *Fusarium* Link: Fr. often degenerate after repeated transfers: they no longer form macroconidia and will be placed erroneously in *Acremonium* Link. Moreover, some *Fusarium* species only rarely produce macroconidia in culture (Booth, 1971) and this complicates matters further. The formation of verticillate conidiophores in *Verticillium* is also no constant character. In many cases, the inexperienced ecologist will identify *Fusarium* isolates lacking macroconidia or *Verticillium* cultures with no verticillate conidiophores as *Acremonium*. This entails that he will never be able to find an adequate species in these two genera, even if lately some authors (e.g., Domsch et al., 1980) have started to document such cases and to include them in keys to species of related taxa.

To make the situation even more complicated, no clear-cut distinction can be made between *Acremonium* and *Phialophora*, since the differentiation is often based on arbitrary or at least subjective characters (Gams, 1971; Schol-Schwarz, 1970) and there is a large overlap between these two genera.

The situation is not likely to improve in the near future, but the steadily increasing body of information on species belonging to this and similar artificial complexes (see also Gams et al., 1990) may help taxonomists to find solutions that will be readily accepted by fungal ecologists. Clearly,

morphologically simple fructifications do not necessarily indicate biologically simple fungi. Simple morphological features may be developed by species whose closest relatives form more complex anamorphs. Biochemical studies should help to point to more natural groups, even in "intractable" genera such as the "simple" *Acremonium* and its relatives.

Conclusions

The ecologist's and the taxonomist's main preoccupations differ obviously greatly. Both, however, strive toward the common goal to understand the biology of these organisms. It is also very likely that natural groups will tend to occupy similar habitats, although experimental evidence for this assumption is still lacking.

In many cases, I find it not difficult to accept generic delimitations as they are formulated in taxonomy. Generic diagnoses are usually very convincing but I have troubles to transpose them in practical terms. The 'ecological' genus concept I have developed in the course of my investigations may be summarized in very few words: broad or narrow, but practical. The ecologist's primary concern is for the individual or the species and how they interact with other individuals or species; genera are useful as a file for names. On the other hand, I fully appreciate the taxonomists' diligent attempt to detect and describe phylogenetic relationships. Clearly there is no ready-made recipe to fully conciliate taxonomic and ecological needs. There are, however, a number of rules that can be used to reach a satisfactory agreement between 'phylogenetic' and 'ecological' taxonomy and I have tried to express them in the form of recommendations. I am aware that most taxonomists will find some of them difficult to follow, some very impractical and others plainly crazy. I also realize that some of the examples cited in the discussion may be partially incorrect from a taxonomic point of view, as I have been continuously looking at the problems from a merely practical point of view. I hope, however, that at least one or two of my recommendations, or parts of them, will help taxonomists in the search of what, very likely, does not exist: the concept of genus in fungal taxonomy that will make happy taxonomists, plant pathologists, and, why not? fungal ecologists.

Some suggestions to the taxonomists

1. Be aware of variability originating from growth conditions

Substrate-induced modifications of fungal structures are frequent. The substrate may induce the formation of peculiar morphological features in ascomata and conidiomata; the nutrient supply or the microclimate may

induce the expression of genes that in other conditions would remain cryptic. Both situations could falsify the taxonomist's analysis of morphological characters and lead to the erection of unnecessary taxa. A good taxonomist must use every available character and describe all variations. Describing a fungus only on the basis of the teleomorph or of cultural characters alone limits the usefulness of the work. At present, taxonomists are too sharply divided into "Teleists", who put the main emphasis on the features of the teleomorphs, and "Anaists", who are mainly concerned with the anamorphic forms of a fungus. The future, I believe, belongs to the "Holists"!

2. Use of cultural attributes

Temperature requirements, substrate utilization tests and growth on different media may provide additional information on the taxonomic position of isolates. Results from substrate utilization tests or spot tests as those described by Nobles (1958) or Stalpers (1978) could help to delimit more clearly taxa, not only at the specific but also at the generic level. In any case, try to grow a fungus on as many substrates as possible and include the cultural characters in the descriptions. In addition, if the organism grows readily on common substrates like malt agar, oat meal agar, or any other readily available media, stick to them and do not use many other exotic – and usually costly – substrates.

3. Always consider, if possible, anamorph-teleomorph connexions

The importance of cultural work to establish anamorph-teleomorph connexions is now widely recognized. At the generic level, knowledge of connexions between anamorphic form-genera and teleomorphic forms will allow the better delimitation of fungal genera, at the same time providing essential information useful in the identification of fungal isolates. While it must be decided from case to case whether the production of distinct anamorphs will imply the distinction of two different teleomorphic genera, the use and description of this additional character may be crucial in the decision-making process and in all cases will help the ecologist in the identification of species cultured in the course of experimental work.

4. Consider ecological characters for the delimitation of genera

Ecological attributes are highly variable and can be genetically unstable, but there are some situations where they may be helpful in the delimitation of taxa. For instance, the consistent colonization of related hosts or similar physiological requirements by a group of taxonomically related fungal species may be indicative of a close genetic relationship at a higher level.

5. Include biochemical and molecular markers in the set of characters to be used

Biochemical and molecular markers have now been successfully used to identify fungal species or intraspecific strain and race formation (Petrini et al., 1989; Leuchtmann & Clay, 1990; Metzenberg, 1991; Sieber-Canavesi et al., 1991). More recently, pulse-field gel electrophoresis techniques have been developed that help to assess the genomic composition in fungi (Mills & McCluskey, 1990). Meyer et al. (1991) have demonstrated that DNA fingerprinting may be useful to differentiate genera of fungi. Polymerase Chain Reaction (PCR) and RAPD marker techniques (Williams et al., 1990) are already or will soon be available in mycology to analyze small amounts of DNA. Although they may not replace morphological analysis, I am convinced that they can provide an invaluable help in the delimitation of taxa, at the same time providing the ecologists with powerful tools for the investigation of ecological processes *in vivo* (Chesselet, 1990).

6. Numerical taxonomy should not be forgotten

Numerical taxonomy has often been used incorrectly in taxonomic investigations. Inadequate methods have been applied to taxonomic data in too many occasions, thus leading to unclear or debatable results. This has made many fungal taxonomists understandably suspicious and somehow refractory to the use of numerical methods. Not pretending to be the ultimate solution to all problems, nevertheless numerical taxonomy may be helpful to select the most discriminatory characters within a given character set and at the same time will help to find out phenetic or phylogenetic relationships. The use of numerical taxonomy methods is already well established in taxonomy (e.g., Mugnai et al., 1989; Sieber-Canavesi et al., 1991) and user-friendly computer packages are available that allow quick and reliable data analysis. More recently discussed expert system shells will also help taxonomists in solving classification problems. For instance, the knowledge elicitation module that should be present in some expert systems shells currently in development may be used to generate suggestions for the construction of dichotomous or synoptic keys which would include the majority of the collections examined by the expert. The knowledge elicitation module will act therefore as a consultant to the expert, while not necessarily intended to replace him (Petrini et al., 1990).

7. Use only objective criteria to delimit taxa

The tools described above will allow to choose a number of reliable and objective characters that can be used to delimit genera. At this point, do not

forget to check for the objectivity of the character choosed. Ask a novice: if it is understood why a given attribute is used and, more important, that attribute has been easily recognized, you may be reassured about your decision and you may go over to the next control step, i.e.

8. Never forget to prepare a control key

A key to the recognized genera is always the best check for consistency of data, but it is necessary to submit it to rigorous testing by having it used by comparatively inexperienced taxonomists (use the next available fungal ecologist!). In my opinion, a taxon will only be acceptable when it can be easily identified by a generalist. Else, look for more appropriate discriminatory characters or consider the possibility of discrimination at a lower level. The use of sub-genera or sections may be an alternative.

9. Include related genera and species in your keys

The possibility of describing fungal genera containing no borderline cases will never exist. It is therefore advisable to include in keys taxa that can be easily mistaken by non-experts as belonging to related genera, if indeed there are good taxonomic reasons to warrant more than one genus. Cross-referencing will help to keep track of difficult taxa.

10. In dubio contra reum

Eventually, if after careful weighting of the characters used you feel that you may be dealing in fact with two different genera and nobody but you can positively see why, refrain from describing a new genus. You will gain the gratitude of many ecologists and avoid lengthy discussions with other taxonomists. And, of course, you will have the chance to describe the new genus in an additional publication, as soon as you will gather additional evidence for your hypothesis!

Acknowledgments

This paper is the result of many discussions with colleagues working in fungal taxonomy and ecology. Dr Gary J. Samuels (Beltsville, USA) made many helpful suggestions and comments to improve it and pointed out to me, among other things, the example of *Ceratocystis* and *Ophiostoma*. He also suggested the neologisms "Teleists, Anaists, and Holists". I have no plans, however, to introduce them in mycology. I am also very much indebted to Drs L. E. Petrini and T. N. Sieber (Zürich, Switzerland) for their criticisms.

References

- Aa, H. A. van der, M.E. Noordeloos & J. de Gruyter (1990). Species concepts in some larger genera of the Coelomycetes. pp 3 - 19 in Gams, W., K. A. Seifert, H. van der Aa & R. A. Samson (eds.). Developments in the taxonomy of anamorphic fungi. Stud. Mycol. 32.
- Arx, J. A. von & E. Müller (1975). A re-evaluation of the bitunicate Ascomycetes with keys to families and genera. Stud. Mycol. 9: 1 - 159.
- Barr, M. E. (1979). Preliminary studies on the Dothideales in temperate North America. Contr. Univ. Michigan Herbarium 9: 523 - 638.
- Barr, M. E. (1990). Prodrum to nonlichenized, pyrenomycetous members of class Hymenoascomycetes. Mycotaxon 39: 43 - 184.
- Booth, C. (1971). The Genus *Fusarium*. C.A.B., C.M.I., Kew, Surrey, 237 pp..
- Chesselet, M.-F. (ed.) (1990). *In situ* Hybridization Histochemistry. CRC Press, Boca Raton, Ann Arbor, Boston, 211 pp.
- Domsch, K. H., W. Gams & T.-H. Anderson (1980). Compendium of Soil Fungi. Academic Press, London & New York, 859+405 pp.
- Ellis, M. B. (1971). Dematiaceous Hyphomycetes. C.A.B., C.M.I., Kew, Surrey, 608 pp.
- Ellis, M. B. (1976). More Dematiaceous Hyphomycetes. C.A.B., C.M.I., Kew, Surrey, 507 pp.
- Gams, W. (1971). *Cephalosporium*-artige Schimmelpilze (Hyphomycetes). Fischer Verlag, Stuttgart, 262 pp.
- Gams, W., K. A. Seifert, H. van der Aa & R. A. Samson (eds.) (1990). Developments in the taxonomy of anamorphic fungi. Stud. Mycol. 32: 1 - 104.
- Hawksworth, D. L. & B. C. Lodha (1983). *Helicogermis* sp. nov., a new stromatic xylariaceous genus with a spiral germ slit from India. Trans. Br. mycol. Soc. 81: 91-96.
- Hoog, G. S. de (1974). The genera *Blastobotrys*, *Sporothrix*, *Calcarisporium* and *Calcarisporiella* gen. nov. Studies in Mycology 7: 1 - 84.
- Hoog, G. S. de & R. J. Scheffer (1984). *Ceratocystis* vs. *Ophiostoma*: a reappraisal. Mycologia 76: 292 - 299.
- Karsten, P. A. (1873). Pyrenomycetes novi, in Fennia et Lapponia rossica lecti. Notiser ur Sällskapet pro Fauna & Flora Fennica Förhandlingar 13: 245 - 248.
- Kohn, L. M. & R. P. Korf (1975). Variation in ascomycete iodine reaction: KOH pretreatment explored. Mycotaxon 3: 165 - 172.

- Kujala, V. (1953). *Ascocalyx abietina* ja sen kuromamuodot. Karstenia 2: 35 - 38.
- Leuchtmann, A. & K. Clay. (1990). Isozyme variation in the *Acremonium/Epichloë* fungal endophyte complex. Phytopathology 80: 1133-1139.
- Martin, P. (1967). Studies in the Xylariaceae. II. *Rosellinia* and the Primo Cinerea section of *Hypoxylon*. J. S. African Bot. 33: 315 - 328.
- Metzenberg, R.L. (1991). Benefactor's lecture: the impact of molecular biology on mycology. Mycol. Res. 95: 9 - 13.
- Meyer, W., A. Koch, C. Niemann, B. Beyermann, J. T. Epplen & T. Börner (1991). Differentiation of species and strains among filamentous fungi by DNA fingerprinting. Curr. Genet. 19: 239 - 242.
- Mills, D. & K. McCluskey (1990). Electrophoretic karyotypes of fungi: the new cytology. Mol. Plant-Microbe Interact. 3: 366 - 373.
- Mugnai, L., P. D. Bridge & H. C. Evans. (1989). A chemotaxonomic evaluation of the genus *Beauveria*. Mycol. Res. 92: 199 - 209.
- Müller, E. (1958). Pilze aus dem Himalaya. II. Sydowia 12: 160 - 184.
- Müller, E. & C.E. Dorworth (1983). On the discomycetous genera *Ascocalyx* Naumov and *Gremmeniella* Morelet. Sydowia 36: 193 - 203.
- Müller, E., O. Petrini, P. J. Fisher, G. J. Samuels & A. Y. Rossman (1987). Taxonomy and anamorphs of the Herpotrichiellaceae with notes on generic synonymy. Trans. Br. mycol. Soc. 88: 63 - 74.
- Munk, A. (1953). The system of the Pyrenomycetes. Dansk Bot. Arkiv 15: 1 - 163.
- Nobles, M. K. (1958). Cultural characters as a guide to the taxonomy and phylogeny of the Polyporaceae. Can J. Bot. 36: 883 - 926.
- Parker, A. K. & J. Reid (1969). The genus *Rhabdocline* Syd. Can. J. Bot. 47: 1533 - 1545.
- Petrini, L. E. & E. Müller (1986). Haupt- und Nebenfruchtformen europäischer *Hypoxylon*-Arten (Xylariaceae, Sphaeriales) und verwandter Pilze. Mycol. Helvetica 1: 501 - 627.
- Petrini, L. E., O. Petrini & P.J. Fisher (1987). *Anthostomella calligoni*, an endophyte of *Suaeda fruticosa* in Dorset. Trans. Br. mycol. Soc. 89: 387 - 389.
- Petrini, O. (1982). Notes on some species of *Chloroscypha* endophytic in Cupressaceae of Europe and North America. Sydowia 35: 206 - 222.
- Petrini, O. (1986). Taxonomy of endophytic fungi of aerial plant tissues. pp. 175-187 in: Fokkema, N. J & J. van den Heuvel (eds.). Microbiology of the Phyllosphere. Cambridge University Press.

- Petrini, O. (1991). Fungal endophytes of tree leaves. pp 179-197. In Andrews, J. A. & S. Hirano (eds). *Microbial Ecology of Leaves*. Springer, New York.
- Petrini, O. & P. J. Fisher (1990). Occurrence of fungal endophytes in twigs of *Salix fragilis* and *Quercus robur*. *Mycol. Res.* 94: 1077-1080.
- Petrini, O., L. E. Petrini, G. Laflamme & G. B. Ouellette (1989). Taxonomic position of *Gremmeniella abietina* and related species: a reappraisal. *Can. J. Bot.* 67: 2805 - 2814.
- Petrini, O., C. V. Rusca & I. Szabó (1990). ASCUS: an error-tolerant mycological classification system. *Sydowia* 42: 273 - 285.
- Pouzar, Z. (1985). Reassessment of *Hypoxylon serpens*-complex I. *Ceská Mykol.* 39: 15 - 25.
- Rossmann, A. Y. (1979). *Calonectria* and its type species, *C. daldiniana*, a later synonym of *C. pyrochroa*. *Mycotaxon* 8: 321 - 328.
- Samuels, G. J. , A. Y. Rossmann, R. Lowe & C. T. Rogerson (1991). A synopsis of *Nectria* subg. *Dialonectria*. *Mycol. Papers*, 164: 1-48.
- Schol-Schwarz, M. B. (1970). Revision of the genus *Phialophora*. *Persoonia* 6: 59 - 94.
- Sieber-Canavesi, F., O. Petrini & T. N. Sieber (1991). Endophytic *Leptostroma* species on *Picea abies*, *Abies alba*, and *Abies balsamea*: a cultural, biochemical, and numerical study. *Mycologia* 83: 89-96.
- Stalpers, J. A. (1978). Identification of wood-inhabiting Aphyllophorales in pure culture. *Stud. Mycol.* 16: 248 pp.
- Sutton, B. C. (1980). *The Coelomycetes*. C.A.B., C.M.I., Kew, Surrey, U.K., 696 pp.
- Whalley, A. J. S. & M. A. Whalley (1977). Stromal pigments and taxonomy of *Hypoxylon*. *Mycopathologia* 61: 99-103.
- Williams, J. G. K., A. R. Kubelik, K. J. Livak, J. A. Rafalski & S. V. Tingey (1990). DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic Acid Res.* 18: 6531 - 6535.