

How to describe a new fungal species

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Abstract: The formal requirements and best practices for the publication of descriptions of new fungal species are discussed. Expectations for DNA sequences and cultures are considered. A model manuscript offers one possible approach to writing such a paper.

Key words:

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Latin diagnoses
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INTRODUCTION

Every fungal species is unique. Therefore, every description of a fungal species is also unique. The morphological, physiological, ecological, and molecular diversity in fungi means that descriptions and illustrations differ from one taxonomic group to another. There are no formal standards for the description and illustration of species, but there are some formal (or 'legal') requirements for proposing names that are imposed by the International Code of Botanical Nomenclature (ICBN; McNeill *et al.* 2006). Furthermore, community standards of scientific rigor are enforced by editors and reviewers.

For the beginner, it is useful to have models to assist with the preparation of descriptions and illustrations. In this paper, formal requirements and best practices that should be considered for any description are outlined, and a model manuscript for describing a new species is provided. Several 'tricks of the trade' and cautionary notes are also included.

Additional hints can be found in the now somewhat dated Code of Practice developed by the ICTF (Sigler & Hawksworth 1987), and the guidebook for mycologists by Hawksworth (1974). Although not exclusively concerned with fungi, the book by Winston (1999) also provides a valuable perspective.

FORMAL REQUIREMENTS

The International Code of Botanical Nomenclature (ICBN) governs the naming of fungi. This is a complex document, but you should read the relevant articles of the Code for exact wording of the regulations. The ICBN is updated every six years, after each International Botanical Congress, and is available on the World Wide Web (see references). The most recently published code must be followed, and previous Codes are considered obsolete. Although there have been discussions about a possible independent Mycological Code, or a BioCode covering all organisms, these are still in the dialogue stage. The Phylocode (Cantino & de Queiroz 2010) promotes phylogenetically based non-Linnaean nomenclature and is not relevant for the description of new species as presented here.

In taxonomic language, species must be 'effectively', 'legitimately' and 'validly' published. These three words have special meanings in taxonomic terminology (as do 'illegitimate' and 'invalid'), and they should not be used in other ways in taxonomic manuscripts.

1. To be **effectively** published (Arts. 29–31), i.e. to be made available, a description of a new species must be published in a journal that can be read by the scientific community. Species published in newspaper articles, or mentioned in oral presentations at scientific meetings, for example, are not considered effectively published. At present,

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descriptions of new species cannot be published exclusively on electronic media such as CD-ROMs, DVDs or on the Internet. Effective publication is only accepted by the ICBN when at least two paper copies are archived in a scientific library or other depository; however, we feel that many more printed copies should be deposited, preferably on each continent. Several mycological journals now publish articles including new species online and deposit printed copies in permanent libraries to meet effective publication requirements; the date of publication of the paper copy remains the official date, not the often earlier date of publication online. Academic PhD or other theses presented to universities as part of degree requirements are not considered effective publications, even if copies are distributed to other universities, unless they have an ISBN number or clearly state that they are to be intended effective publications (Art. 30.5).

2. To be **legitimately** published (Art. 6), i.e. legally acceptable, a new species must have a unique binomial, i.e. it cannot have the same species epithet as another species validly published in the same genus.
3. To be **validly** published (Arts 32–45), a new species must be clearly designated as a new species, have a Latin diagnosis, and a single, clearly designated and permanently preserved 'type', which fixes the application of the name. Usually, the type is preserved in a public herbarium (Holmgren *et al.* 1990) that will make the material available to interested scientists, has an on-line database of holdings, and that will assign a unique accession number, which you will then quote to clearly identify the type specimen. If there are duplicates of the type specimen, or cultures derived from it, these must be explicitly distinguished from the holotype; the others are referred to as 'isotypes' or as 'ex-type cultures'. To safeguard against loss and to facilitate access by other mycologists, isotypes should be deposited in several herbaria, on different continents if possible.

There are many nuances to the concept of a type (Arts 7–10). For a new species, you will normally propose a 'holotype'. The holotype is usually a dried, physiologically inert specimen (or a dried culture) that includes all diagnostic morphological characters of the species. For microscopic fungi, several separate individuals can be present as long as they are part of one sample collection, i.e. made at one time in a precise locality. Living cultures are now allowed as holotypes (Art. 8.4), but only if they are preserved in a metabolically inactive state (i.e. by lyophilization or in liquid nitrogen), ideally in an internationally recognized culture collection (see

World Federation for Culture Collections, s.d.). This practice is not widely used in mycology except for yeasts. Cultures can be dried for use as type specimens (Constantinescu 1983); take care to dry an uncontaminated, optimally developed culture, not an old one that has started to degenerate. If you wish to designate a microscope slide as a type, or to include one with the type, it is worth the effort to make a permanent preparation using the method described by Kohlmeyer & Kohlmeyer (1972).

INFORMAL REQUIREMENTS

To successfully describe a new species, the author must convince readers (especially reviewers and editors) that:

1. The species is really undescribed.
2. The species is being described in the most appropriate genus, and if molecular data are available, the genus including the new species remains monophyletic.
3. The species is described, illustrated or otherwise characterized adequately so that it can be recognized again by subsequent workers.
4. A sufficient number of cultures or specimens were examined. Ideally, new species should be described based on more than one specimen or culture, and some journals demand this. With limited material but clear taxonomic novelty, the author may be able to write a convincing argument for the proposal of a new species that is acceptable to editors and reviewers.

Manuscripts that do not satisfy these criteria should not be published until they can be met. Normally, peer reviewers and editors assess whether these criteria are satisfied.

In recent decades, partly as a result of the spirit of the UN Convention on Biological Diversity (CBD), taxonomists are encouraged, and sometimes legally required by national laws, to deposit type specimens in public reference collections in the country where the specimens were originally collected. If cultures were isolated, there may be a similar requirement or expectation from the originating country. Cultures of new species should be deposited in two or three internationally recognized public culture collections, which agree to make them available to other researchers. This latter practice is a condition for valid publication of new bacterial species (Lapage *et al.* 1992), and is enforced as an editorial policy by some journals that publish new fungal species.

It is critical that type specimens and cultures are available to other taxonomists who want to study and compare them with other material. The ICBN

recommends (Rec. 7A), but cannot enforce, that type specimens be deposited in public institutions with a policy to allow scientific researchers to examine material. A frequent problem is the unavailability of type or other specimens from under-resourced collections, or collections not curated by a mycologist. Some historical collections may never be sent on loan because of their fragility and extreme importance. Some nations forbid specimens or cultures from being sent abroad, under their interpretations of the CBD. A parallel situation is the reluctance of some industrial researchers (e.g. pharmaceutical companies) to allow access to cultures that they own. Balancing the question of open access to specimens or cultures against the legal or proprietary interests attached to that material is complicated, but must be considered when depositing type specimens. The scientific process demands reproducibility, and if this cannot be assured, responsible journals will not allow publication. The risk for the authors of species that cannot be re-examined or studied by other taxonomists is that the species will not be accepted by future scientists, and that the efforts and work of the authors of such species will be wasted and ignored.

Almost all mycological journals now require that names and certain nomenclatural information for all newly proposed fungal taxa, including new combinations, be deposited in MycoBank (Crous *et al.* 2004), and that the MycoBank accession number be included as part of the description. While the minimum requirements are the deposit of the Latin diagnosis and information on the type specimen, it is good practice to include as much information as possible, including illustrations, the English description, and links to molecular data, because this critical information will then be freely available to all scientists.

REQUIREMENTS FOR CULTURES AND MOLECULAR DATA

At present, there are no formal requirements that you must have cultures or DNA sequences of a fungus before you can describe a new species. Nevertheless, DNA sequences and cultures significantly enhance the value of a species description and you should make every effort to generate these resources.

Mycologists describing new species should indicate whether they have tried to obtain cultures and what methods were attempted. Not all species can be cultured using currently available methods, but for most groups, culturing should be relatively straightforward after consulting the literature on related species. Cultures are essential for some groups where the modern morphological taxonomy is based entirely on *in vitro* characters, especially hyphomycetes such as *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Penicillium* and *Trichoderma*; new species in these

genera should not be described in the absence of cultures or sequences. For other ascomycetes, single-spore cultures may yield unexpected anamorphs that will allow the description of a more complete life cycle.

DNA sequences can be usually obtained from all but the most recalcitrant materials (such as fossils). There is a growing expectation that descriptions of all new species should be accompanied by molecular data, driven in part by the need for DNA sequence data to integrate new species into molecular phylogenies. The growth of molecular ecology, which relies on databases of reference sequences for identification of environmental sequences, has also highlighted the importance of sequencing all newly described species. Therefore, an increasing number of journals, editors or reviewers insist on cultures or DNA sequences before a manuscript is accepted for publication. If you do not have cultures or DNA sequences, your new species can only be published in a journal with different policies. We encourage mycologists who lack resources for culturing or DNA sequencing to collaborate with colleagues who can assist with this, often in return for co-authorship.