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1 Naming names: The etymology of fungal entomopathogens

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Abstract

This chapter introduces the reader to the etymology of the generic names given to 26 fungal entomopathogens. Possessing some knowledge on how a name originates sometimes provides us with information on a fungal characteristic that might help us identify the organism, e.g., Conidiobolus, Cordyceps, Pandora, Regiocrella, Orthomyces, etc. In other cases, the name won't tell us what the fungus looks like, but serves to honor those for whom the fungus was named, e.g., Aschersonia, Batkoa, Beauveria, Nomuraea, Strongwellsea, etc.

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1. Introduction

One interesting aspect in the business of science is the naming of taxonomic species: the reasons why organisms are baptized with a certain name, which might or might not change as science progresses. Related to this topic, the scientific illustrator Louis C. C. Krieger (1873-1940) [1] self-published an eight-page long article in 1924, entitled "The millennium of systematic mycology: a phantasy" where the main character is a "... systematic mycologist, who, from too much "digging" in the mighty "scrapheap" of synonymy, fell into a deep coma." As he lies in this state, he dreams about being in Heaven, and unable to leave behind his collecting habits, picks up an amanita and upon examining it finds a small capsule hidden within it. The capsule reveals a herbarium label containing the scientific name *Amanita coelicola*, but lacks the name of the person that described it, or as he writes: "I cannot, in truth, conceive of a binomial without this indispensable appendage." Befuddled, he notices another inhabitant in the forest, and upon reaching him, discovers he is "none other than one of the immortals of mycology" who explains to him that this being Heaven, the names are final and are not subject to the foibles and mistakes of humans down on earth. The mycologist finally wakes up, his almost complete monograph on the genus *Inocybe* waiting for him on his desk.

This interesting story brings to the forefront the naming of fungi, why they are named a certain way, and the people that made those decisions. My goal is to introduce the reader to the etymology of the generic names given to 26 fungal entomopathogens. This I do in part to honor some of our scientific ancestors, mostly now forgotten, and without exception all from the Old World, as well as a few scientists that are still quite active in the field. Possessing some knowledge on how a name originates sometimes provides us with information on a fungal characteristic that might help us identify the organism, e.g., *Conidiobolus, Cordyceps, Pandora, Regiocrella*, *Orthomyces*, etc. In other cases, the name won't tell us a thing of what the fungus looks like, but serves to honor those for whom the fungus was named, e.g., *Aschersonia*, *Batkoa*, *Beauveria*, *Nomuraea*, *Strongwellsea*, etc. One particularly interesting case in this paper is Batko's naming of *Entomophaga*.

1.1. The international code

The rules for naming new species are spelled out in the International Code of Botanical Nomenclature, which unfortunately, does not require that the descriptions of new genus/species include the etymology. At the XVI International Botanical Congress meeting held in St Louis in 1999, Recommendation 60H.1[1] states that "The etymology of new names or of epithets in new names should

[1] http://www.bgbm.org/iapt/nomenclature/code/default.htm

be given, especially when their meaning is not obvious." Unfortunately, this is just a recommendation and is non-mandatory. This decision is shortsighted, because the description is the ideal place to include this etymological information.

1.2. Understanding the etymology

Some books are particularly useful in trying to understand the etymology of fungal names. First of all, a Latin dictionary is essential, as well as a Greek dictionary. An indispensable work is the Italian mycologist Pier Andrea Saccardo's (1845-1921) *Sylloge fungorum omnium hucusque cognitorum* ("Index of all Fungi, As Currently Understood") - better known as Saccardo's "Sylloge fungorum." The first volume was published in 1882 and the last (# 25) in 1937, with still one more volume (#26), published in 1972. The entire work includes approximately 160,000 pages. Another useful reference – although in Spanish - is the Mexicans Miguel Ulloa and Teofilo Herrera's "Etimología e Iconografía de Géneros de Hongos" published in 1994 by the Universidad Nacional Autónoma de México.

2. The naming of names: Etymology

2.1. *Acremonium* Link (Ascomycota: Hypocreales: Incertae Sedis)

Named in 1809 by the German scientist Johann Heinrich Friedrich Link (1769-1851) [2], who described the spores as solitary ("Sporidia solitaria..."). According to Saccardo, the etymology is based on "acros" meaning "topmost" or "extreme" and "monos" meaning "one" thus describing single-celled solitary conidia that can be produced in chains or heads [3]. Ulloa and Herrera [4] erroneously state that solitary conidia are not produced, and base the etymology on the Greek word "akremon" which means "thicket" or "dense growth", combined with the Latin diminutive suffix "ium" which, according to them describes the conidial formation at the end of the conidiophores. This explanation doesn't make sense if the original name – which has always been valid - was based on specimens with solitary conidia.

2.2. *Aschersonia* Montagne (Ascomycota: Hypocreales: Clavicipitaceae)

Named in 1848 by the French surgeon Jean Pierre Francois Camille Montagne (1784 -1866) [5] in honor of the German physician and botanist Ferdinand Moritz Ascherson (1798-1879), author of *De fungis venenatis* (1828; "On Venomous Fungi") and *Über die Fructifikationsorgane der höheren Pilze*" (1836; "On the Reproductive Organs of the Higher Fungi.").

The first species, *A. taitensis*, was named from a specimen collected from a leaf in Tahiti.

2.3. *Batkoa* Humber (Zygomycota: Entomophthorales: Entomophthoraceae)

Named by the USA mycologist Richard A. Humber in 1989 [6] to honor the Polish mycologist Andrzej Batko (1933-1997).

2.4. *Beauveria* Vuillemin (Ascomycota: Hypocreales: Clavicipitaceae)

Named in 1912 by the French physician Jean Paul Vuillemin (1861-1932) [7] in honor of the French scientist Jean Beauverie (1874-1938).

2.5. *Conidiobolus* Brefeld (Zygomycota: Entomophthorales: Ancylistaceae)

Described in 1884 by the German botanist Julius Oscar Brefeld (1839 - 1925) [8], from the Greek "konis" (from which the word "conidia" derives) meaning "dust" and the Latin "bolus" which means "throwing" or "hurling," thus describing the forcible discharge mechanism for the conidia.

2.6. *Cordyceps* Fries (Ascomycota: Hypocreales: Clavicipitaceae)

Named in 1818 by the Swedish botanist Elias Magnus Fries (1794 - 1878) [9]. From the Greek word "cordyle" which means "club-like" combined with the Latin "ceps" which is derived from the Latin *capitis* (head), thus describing the shape of the stroma, i.e., club-shaped.

2.7. *Entomophaga* Batko (Zygomycota: Entomophthorales: Entomophthoraceae)

Even though the Greek "entomon" means "insect" and "phaga" means "to eat," the genus was created in 1964 by the Polish mycologist Andrzej Batko (1933 - 1997) [10]: "... to commemorate the international journal "Entomophaga" devoted to problems of biological control of insect pests." The journal ceased publication in 1998 and was replaced by *BioControl*.

2.8. *Entomophthora* Fresenius (Zygomycota: Entomophthorales: Entomophthoraceae)

Named in 1856 by the German physician J. B. Georg W. Fresenius (1808 - 1866) [11]. From the Greek "entomon" which means "insect," and "phthora" which means "destroyer." The word "entomon" also means "cut up into sections" to describe the segments seen in insects.

2.9. *Erynia* Nowakowski (Zygomycota: Entomophthorales: Entomophthoraceae)

Genus created by the Polish scientist Leon Nowakowski in 1881 [12]. From the Greek mythological creatures known as the Erinyes or as the Romans called them, Furies, described as spirits that claimed vengeance against a crime. One can see an insect pest feeding on a plant as a specific crime for which the fungus would kill the insect, thus exacting vengeance.

2.10. *Eryniopsis* Humber (Zygomycota: Entomophthorales: Entomophthoraceae)

Named by Humber in 1984 [13] based on its similarity to members of the genus *Erynia*, and combined with the Greek work "opsis" which denotes "aspect" or "appearance."

2.11. *Furia* (Batko) Humber (Zygomycota: Entomophthorales: Entomophthoraceae)

Originally erected in 1966 by A. Batko [14] as a subgenus of *Zoophthora*, the name originates from the Latin "furia" "... to stress the destructive effect of the epizootia of this type species of the subgenus in populations of Lepidoptera caterpillars" [14]. Humber [6] raised *Furia* to the generic level.

2.12. *Hirsutella* Patouillard (Ascomycota: Hypocreales: Clavicipitaceae)

Named in 1892 by the French pharmacist Narcisse Theophile Patouillard (1854-1926) [15] after examining a fungus attacking an adult Coleoptera from Ecuador. From the Greek "hirsutus" which means "hairy" combined with the Latin diminutive suffix "ella" to describe the narrow and extended neck of the conidiogenous cell. Patouillard (1892) included this genus in the Hymenomycetes (Basidiomycota) based on what he thought were spores on basidia. Speare [16] showed that *Hirsutella* does not produce true basidia.

2.13. *Lecanicillium* W. Gams & Zare (Ascomycota: Hypocreales: Clavicipitaceae)

The name originates from *Verticillium lecanii* by taking "lecani" and combining it with "cillium" [17].

2.14. *Massospora* Peck (Zygomycota: Entomophthorales: Entomophthoraceae)

Named in 1895 by the botanist Charles Horton Peck (1833-1917) [18] using the Greek word "masso" which means "to grind" and "spora" or "spore"

thus describing the complete disintegration of the insect's internal tissues eventually leading to a "pulverulent mass of spores within" [18] that can be seen after the terminal parts of the abdomen fall off. This genus has only been reported on periodical cicadas.

2.15. *Metarhizium* Sorokin (Ascomycota: Hypocreales: Nectriaceae)

A genus erected in 1883 by Nikolay Vasilevich Sorokin (1846-1909) [19], a Professor of Botany at the University of Kazan in Russia (where Leo Tolstoy and Vladimir Lenin studied) based on a specimen classified by Elie Metchnikoff [20] as *Entomophthora anisopliae*, which he found infecting the beetle *Anisoplia austriaca* (Coleoptera: Scarabaeidae). From the Greek "meta" meaning "change" combined with the Greek word "rhiza" meaning "root" and the Latin diminutive suffix "ium." Sorokin referred to the mycelium as the root part of the fungus (in contrast to the spores). He observed differences in hyphal growth inside the insect depending on whether there was (1) spore germination and immediate penetration through the cuticle or (2) hyphal growth outside the insect followed by eventual penetration of the cuticle.

2.16. *Neozygites* Witlaczil (Zygomycota: Entomophthorales: Neozygitaceae)

Genus created in 1885 by Emanuel Witlaczil [21], from the Greek word "neo" meaning "new" or "unusual" combined with the Greek word "zygon" meaning "yoke", and the Greek suffix "ites." Describes the visual image of a yoke when a secondary conidium (capilliconidium) is produced on top of the capillary conidiophores.

2.17. *Nomuraea* Maublanc (Ascomycota: Hypocreales: Clavicipitaceae)

A genus established in 1903 by the French naturalist André Maublanc (1880-1958) [22] based on an infected *Pionea forficalis* (Lepidoptera: Pyralidae) that the Japanese scientist H. Nomura had sent from Tokyo.

2.18. *Orthomyces* Steinkraus, Humber & Oliver (Zygomycota: Entomophthorales: Entomophthoraceae)

A genus erected in 1998 by three USA scientists (D. C. Steinkraus, R. A. Humber, and J. B. Oliver) [23] from the Greek "ortho" which means "straight" and the Greek "mykes" which means "fungus," thus describing "… the short secondary capillary conidiophores bearing secondary conidia in the axis of the conidiophore which may, in turn, emerge axially through the papilla of the primary conidia" [23].

2.19. *Paecilomyces* Bainier (Ascomycota: Hypocreales: Clavicipitaceae)

Described by the French scientist Georges Bainier [24] from the Greek word "poikilos" which means "diverse" or "varied" and "mýkes" ("myces" in Latin) which means fungus, to describe the diverse fruiting structures observed in the genus. Several species in the genus *Paecilomyces*, including all entomopathogenic species, have been found to be monophyletic (*Isaria* clade) and have been transferred to the genus *Isaria* [25-26].

2.20. *Pandora* Humber (Zygomycota: Entomophthorales: Entomophthoraceae)

Originally created by A. Batko [14] as a subgenus of *Zoophthora*. Humber [6] raised it to the genus level. From the Latin "pando" which means "to become curved" or "to sag" and the generic suffix "ra" thus describing conidia, which are "... often with weakly outlined bilateral symmetry: on one side (abdominal) slightly flattened, on opposite (dorsal) side more convex, on the third (lateral) side somewhat curved towards the abdominal side and slightly asymmetrical..." [14].

2.21. *Regiocrella* Chaverri & Hodge (Ascomycota: Hypocreales: Clavicipitaceae)

A recently created genus, resembling *Hypocrella*, described by the Costa Rican mycologist Priscila Chaverri and the USA mycologist Kathie T. Hodge for two fungal species attacking scale insects [27]. From the Latin word "regius" to describe the stromata with orange perithecia resembling a golden crown, combined with the Latin "cre" which means "fleshy" and the Latin diminutive suffix "ella."

2.22. *Stilbella* Lindau (Ascomycota: Hypocreales: Incertae sedis)

Named in 1900 by the German naturalist Gustav Lindau (1866-1923) [28] to include some genera included by Fries in the genus *Stilbum* that properly belonged in the Hyphomycetes [29]. A combination of the genus *Stilbum* combined with the Latin diminutive suffix "ella."

2.23. *Strongwellsea* Batko & Weiser (Zygomycota: Entomophthorales: Entomophthoraceae)

Named by Batko and Weiser [30] to honor F. E. Strong, K. Wells, and J. W. Apple, who originally isolated the fungus from seed corn maggots (*Delia platura* (Meigen)) in Wisconsin, USA [31].

2.24. *Tarichium* Cohn (Zygomycota: Entomophthorales: Entomophthoraceae)

Genus created in 1870 by the German botanist Ferdinand Julius Cohn (1828-1898) [32], from a fungus attacking turnip moth larvae (*Agrotis segetum* (Denis & Schiffermüller)). Derived from the Latin "taricheia" which means "mummification" or "embalming" combined with the Latin diminutive suffix "ium" to describe the infected larvae, which end up becoming a hard mummy. The genus is used for members of the Entomophthorales known only (at the time of their collection and description) from their thick-walled resting spores [33].

2.25. *Torrubiella* Boudier (Ascomycota: Hypocreales: Clavicipitaceae)

Modified from the genus *Torrubia* Leveillé (now *Cordyceps*) combined with the Latin diminutive suffix "ella." Named in 1885 by the French pharmacist Émile Boudier (1828-1920) [34] to honor the Spanish priest and naturalist José Torrubia (1698-1761) [35], who in his "Aparato para la historia natural española" (1754) described dead wasps he observed in Havana with "little trees" growing out of them. According to Steinhaus [36], "In all probability these "trees" represent species of *Cordyceps*." Insects attacked by members of the Clavicipitaceae were known as "vegetable wasps," "entomogenous plants," or "plant worms."

2.26. *Zoophthora* Batko (Zygomycota: Entomophthorales: Entomophthoraceae)

Named by A. Batko [10] from the Greek "zoo" which means "animal" and "phthora" which means "destroyer."

3. Conclusion

Scientific names are the currency of biology, evoking the unique features and characteristics of a species. The classical system of naming fungi based on morphology, physiological traits, and/or reproductive compatibility has been complemented by the phylogenetic species concept, which provides an objective basis for defining species based on molecular phylogenetic evidence (for a better understanding of various species concepts see 37-38-39-40). The phylogenetic species concept allows differentiating between "species synonyms" and "species complexes" in which species boundaries are uncertain using classical methods. For example, a recent molecular phylogenetic analysis of *Beauveria bassiana* has revealed a multiplicity of cryptic phylogenetic species, which will eventually need to be described [41-42-43]

and whose name will likely be based on geography, ecological distribution, and morphological or physiological features. A strength of being able to resolve phylogenetic species is that this knowledge should make it much easier to determine what visible or physiological features are unique to a clade. In the same vein, the discovery by Blackwell and her colleagues of more than 300 new ascomycete yeast species in the guts of beetles [40, 44] will eventually become a formidable task when these need to be described and named. The significance of these newly discovered hyperdiverse yeasts can be better understood when we realize that the total number of species described so far in this group (Saccharomycetales) is approximately 800 species. The bottom line is that even though the challenges in discovering, differentiating, describing, and naming new species can be formidable, the ride, which has been good so far, will only get better.

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