NEW TAXONOMIES OF FOOD BORNE FUNGI

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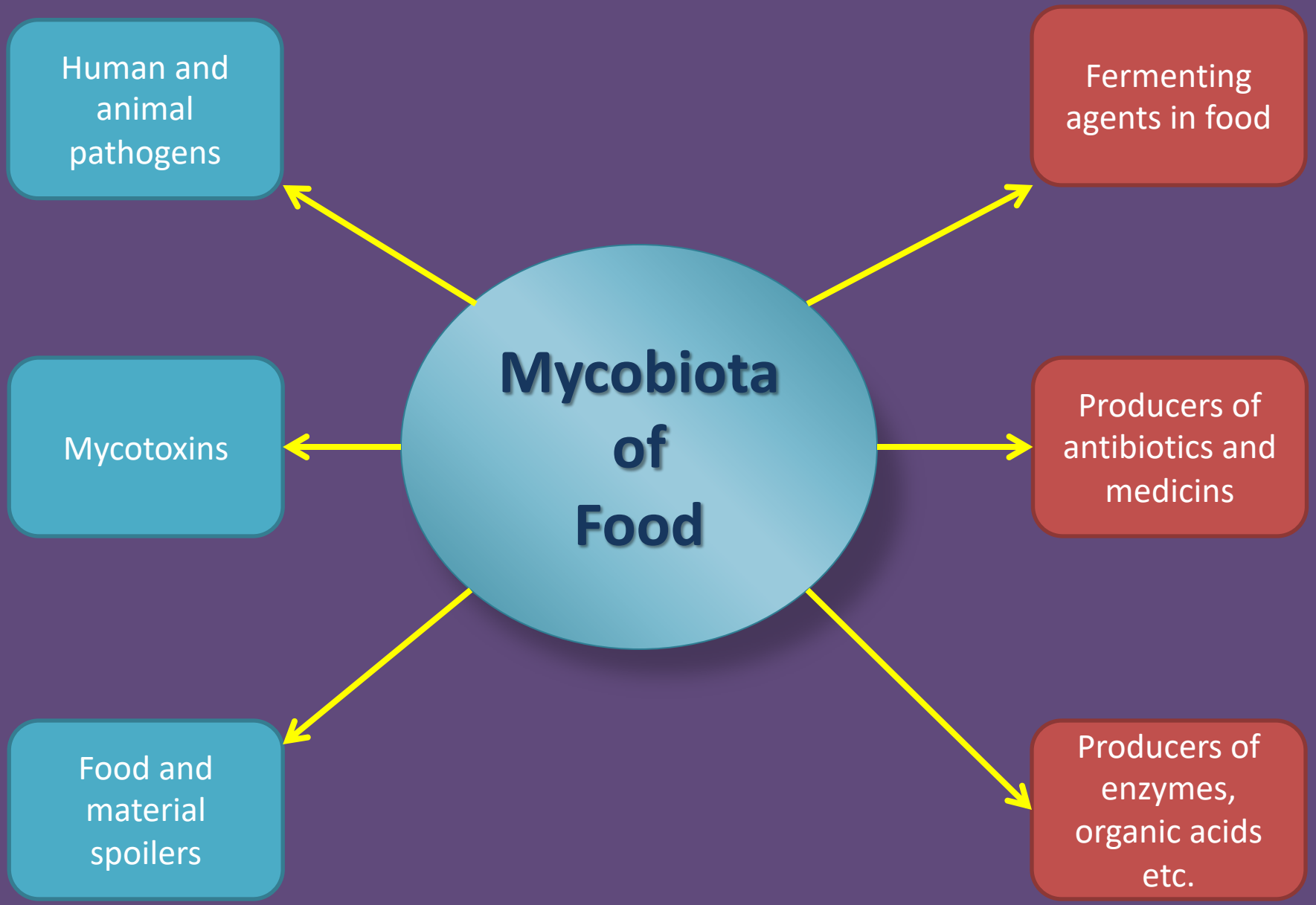
Session 5. Microbes in quality and safety of food



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- Food is a specific substrate for specific fungi
- About 120-150 species
- Taxonomy and the biodiversity used to be based on phenotypic characters
- The introduction of the polyphasic taxonomic concept has changed the species delimitation
- There is a trend to use the phylogenetic species concept

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New taxonomic schemes

- The use of molecular data have resulted in a better understanding of the genera
- Polyphasic taxonomy which also includes chemical data is useful for food mycology because the extrolite profiles are often specific for the species
- The single nomenclature has a great impact for naming of the genera and species

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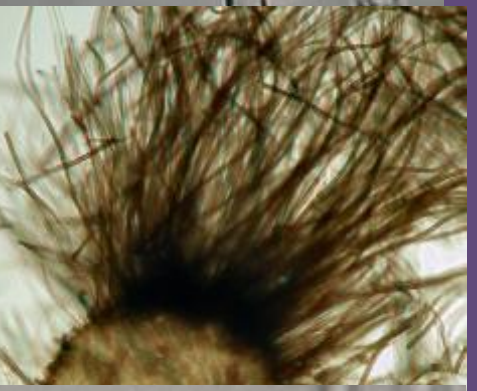
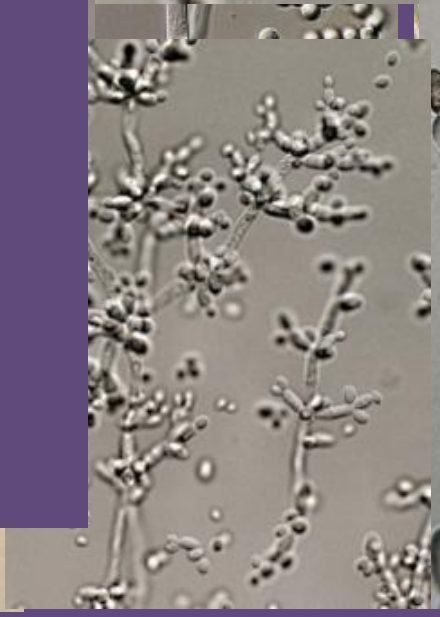
The biodiversity of fungi on food

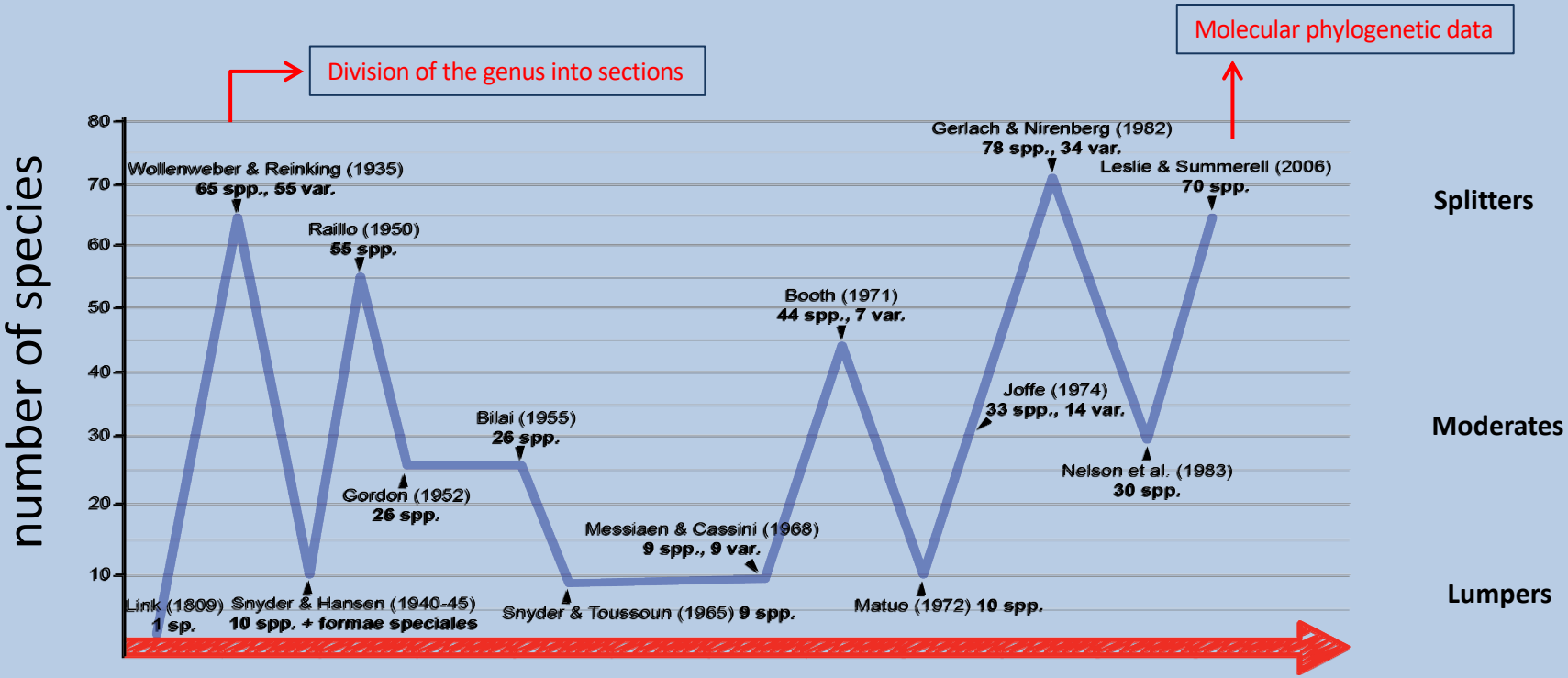


Important genera

- *Aspergillus*
- *Penicillium*
- *Fusarium*
- *Cladosporium*
- *Alternaria*



Fusarium taxonomic and nomenclature problems



Phylogenetic species concept ⟹ Number of species > 800

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Aspergillus, Penicillium and Talaromyces

- These are important genera have been studied for centuries
- Phenotypical characters were used
- The pioneers were Charles Thom and Kenneth Raper and most of their taxonomy is still valid
- Since two decades the polyphasic taxonomy started combining phenotypical, physiological, chemical and genotypical characters

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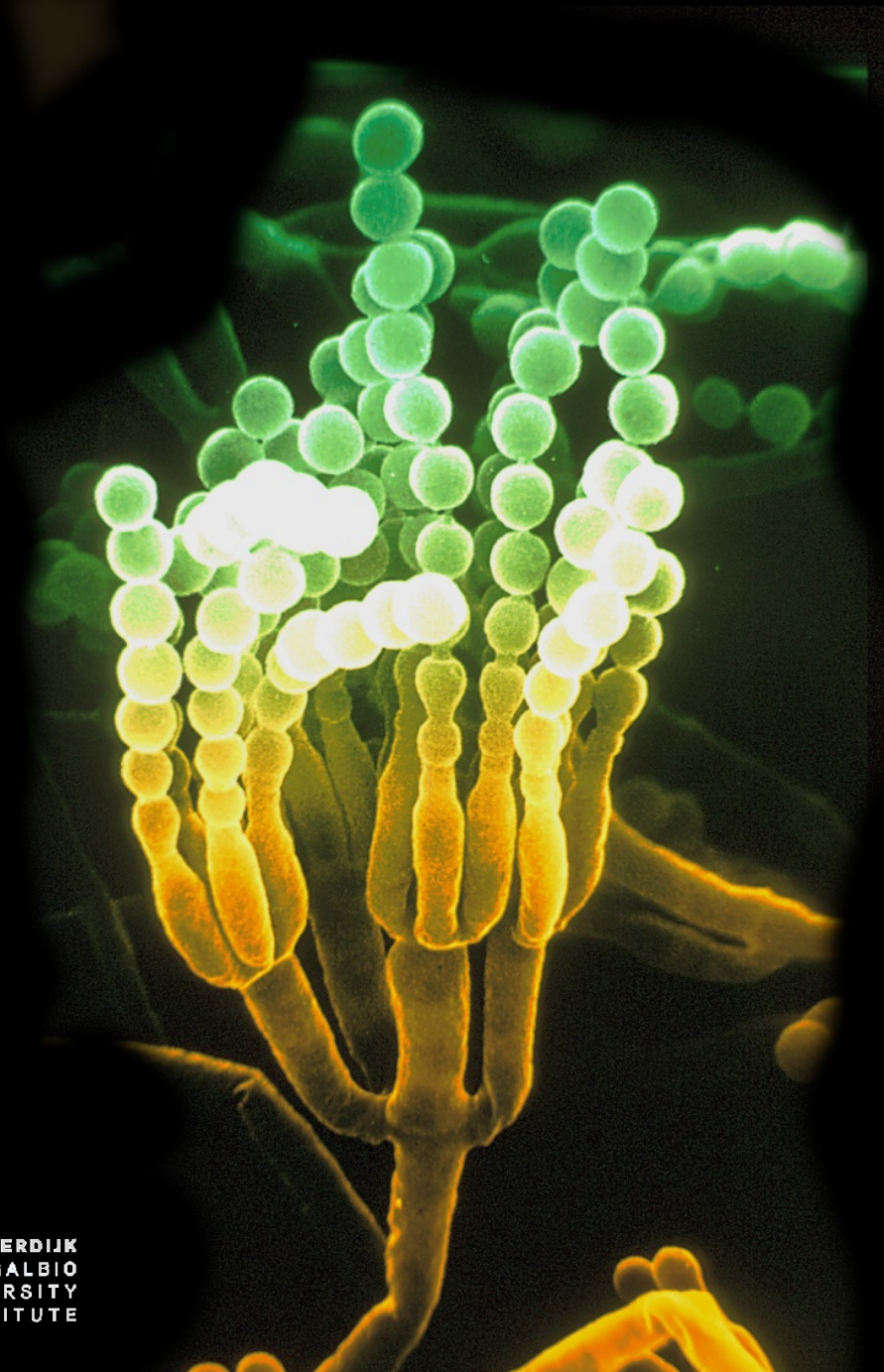
NEW TAXONOMIES OF PENICILLIUM

- Current species concept in *Penicillium* show that each species has its specific metabolites e.g. mycotoxins
- More than 430 are now described and accepted
- Correct species identification will provide information on the mycotoxin production
- Molecular typing is not always supported by phenotypic differences



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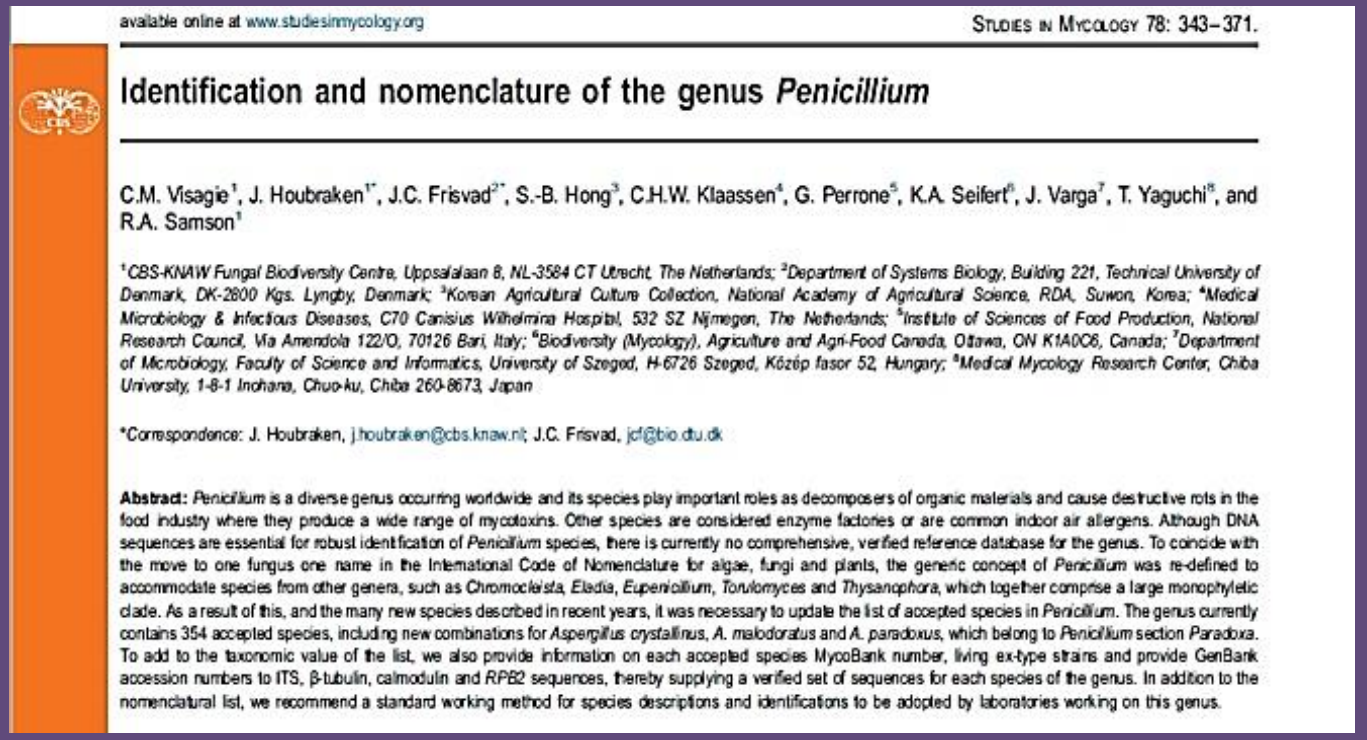
New taxonomies of Penicillium

- Visagie et al. (2014) with good overview
- Phylogenetic analysis shows that *Penicillium* in monopheletic
- Phenotypic identification is possible for the majority of species
- For identification beta tubulin can be used a second barcode
- Many new species are or will be described



available online at www.studiesinmycology.org

STUDIES IN MYCOLOGY 78: 343–371.

Identification and nomenclature of the genus *Penicillium*

C.M. Visagie[1], J. Houbraken[1*], J.C. Frisvad[2*], S.-B. Hong[3], C.H.W. Klaassen[4], G. Perrone[5], K.A. Seifert[6], J. Varga[7], T. Yaguchi[8], and R.A. Samson[1]

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Abstract: *Penicillium* is a diverse genus occurring worldwide and its species play important roles as decomposers of organic materials and cause destructive rots in the food industry where they produce a wide range of mycotoxins. Other species are considered enzyme factories or are common indoor air allergens. Although DNA sequences are essential for robust identification of *Penicillium* species, there is currently no comprehensive, verified reference database for the genus. To coincide with the move to one fungus one name in the International Code of Nomenclature for algae, fungi and plants, the generic concept of *Penicillium* was re-defined to accommodate species from other genera, such as *Chromocleista*, *Eladia*, *Eupenicillium*, *Torulomyces* and *Thysanophora*, which together comprise a large monophyletic clade. As a result of this, and the many new species described in recent years, it was necessary to update the list of accepted species in *Penicillium*. The genus currently contains 354 accepted species, including new combinations for *Aspergillus crystallinus*, *A. malodoratus* and *A. paradoxus*, which belong to *Penicillium* section *Paradoxa*. To add to the taxonomic value of the list, we also provide information on each accepted species MycoBank number, living ex-type strains and provide GenBank accession numbers to ITS, β-tubulin, calmodulin and *RPB2* sequences, thereby supplying a verified set of sequences for each species of the genus. In addition to the nomenclatural list, we recommend a standard working method for species descriptions and identifications to be adopted by laboratories working on this genus.

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NEW TAXONOMIES OF ASPERGILLUS

- Current species concepts in *Aspergillus* show that each species has its specific metabolites e.g. mycotoxins
- More than 420 are now described and accepted
- Correct species identification will provide information on the mycotoxin production
- Molecular typing is not always supported by phenotypic differences

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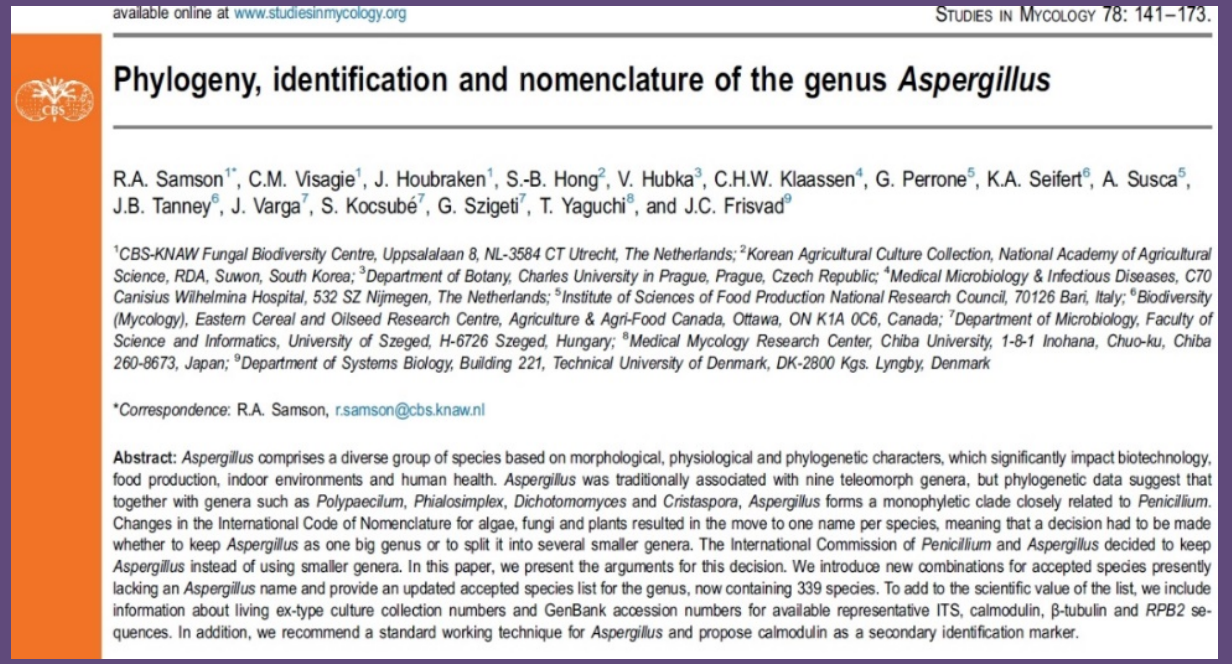
Benchmarks in Aspergillus taxonomy

- List of all known and accepted species of *Aspergillus*
- Recommendations for identification including first and second barcode
- *Aspergillus* is monopheletic
- The name *Aspergillus* is maintained for all subgenera and sections
- The extrolites including mycotoxins are specific for each species and well-documented



available online at www.studiesinmycology.org

STUDIES IN MYCOLOGY 78: 141–173.

Phylogeny, identification and nomenclature of the genus *Aspergillus*

R.A. Samson[1*], C.M. Visagie[1], J. Houbraken[1], S.-B. Hong[2], V. Hubka[3], C.H.W. Klaassen[4], G. Perrone[5], K.A. Seifert[6], A. Susca[5], J.B. Tanney[6], J. Varga[7], S. Kocsubé[7], G. Szigeti[7], T. Yaguchi[8], and J.C. Frisvad[9]

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Abstract: *Aspergillus* comprises a diverse group of species based on morphological, physiological and phylogenetic characters, which significantly impact biotechnology, food production, indoor environments and human health. *Aspergillus* was traditionally associated with nine teleomorph genera, but phylogenetic data suggest that together with genera such as *Polypaecilum*, *Phialosimplex*, *Dichotomomyces* and *Cristaspora*, *Aspergillus* forms a monophyletic clade closely related to *Penicillium*. Changes in the International Code of Nomenclature for algae, fungi and plants resulted in the move to one name per species, meaning that a decision had to be made whether to keep *Aspergillus* as one big genus or to split it into several smaller genera. The International Commission of *Penicillium* and *Aspergillus* decided to keep *Aspergillus* instead of using smaller genera. In this paper, we present the arguments for this decision. We introduce new combinations for accepted species presently lacking an *Aspergillus* name and provide an updated accepted species list for the genus, now containing 339 species. To add to the scientific value of the list, we include information about living ex-type culture collection numbers and GenBank accession numbers for available representative ITS, calmodulin, β-tubulin and *RPB2* sequences. In addition, we recommend a standard working technique for *Aspergillus* and propose calmodulin as a secondary identification marker.

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Species	Aflatoxin $B_{1\&2}$	Aflatoxin $G_{1\&2}$	Aflatrem[1]	Cyclopiazonic acid	3-nitropropionic acid[2]	Tenuazonic acid	Ochratoxin A
Aspergillus aflatoxiformans	+	+	+	+	-	-	-
A. alliaceus	-	-	-	-	-	-	+
A. arachidicola	+	+	-	-	-	-	-
A. aspearensis	-	-	-	-	-	-	-
A. austwickii	+	+	+	+	-	-	-
A. avenaceus	-	-	-	-	+	-	-
A. bertholletius	-[3]	-	-	+	-	+	-
A. caelatus	-	-	-	-	-	+	-
A. cerealis	+	+	+	+	-	-	-
A. coremiiformis	-	-	-	-	-	-	-
A. flavus	+	(+)[4]	+	+	+	-	-
A. hancockii[5]	-	-	-	-	-	-	-
A. lanosus	-	-	-	-	-	-	-
A. leporis	-	-	-	-	-	-	-
A. luteovirescens	+	+	-	-	-	+	-
A. minisclerotigenes	+	+	+	+	-	-	-
A. mottae	+	+	-	+	-	-	-
A. neoalliaceus	-	-	-	-	-	-	+
A. nomius	+	+	-	-	-	+	-
A. novoparasiticus	+[6]	+[6]	-	-	-	-	-
A. oryzae	-	-	-	+	+	-	-
A. parasiticus	+	+	-	-	-	-	-
A. pipericola	+	+	+	+	-	-	-
A. pseudocaelatus	+	+	-	+	-	+	-
A. pseudonomius	+	+	-	-	-	+	-
A. pseudotamarii	+	-	-	+	-	+	-
A. sergii	+	+	+	+	-	-	-
A. sojae	-	-	-	-	-	-	-
A. subflavus	-	-	-	-	-	-	-
A. tamarii	-	-	-	+	+	+	-
A. togoensis	+	-	-	-	-	-	-
A. transmontanensis	+	+	-	-	-	-	-
A. vandermerwei	-	-	-	-	-	-	+

available online at www.studiesinmycology.org

STUDIES IN MYCOLOGY 93: 1–63 (2019).

Taxonomy of *Aspergillus* section *Flavi* and their production of aflatoxins, ochratoxins and other mycotoxins

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*Correspondence: J.C. Frisvad, jcf@bio.dtu.dk; J. Houbraken, j.houbraken@westerdijkinstitute.nl

Abstract: Aflatoxins and ochratoxins are among the most important mycotoxins of all and producers of both types of mycotoxins are present in *Aspergillus* section *Flavi*, albeit never in the same species. Some of the most efficient producers of aflatoxins and ochratoxins have not been described yet. Using a polyphasic approach combining phenotype, physiology, sequence and extrolite data, we describe here eight new species in section *Flavi*. Phylogenetically, section *Flavi* is split in eight clades and the section currently contains 33 species. Two species only produce aflatoxin B_1 and B_2 (*A. pseudotamarii* and *A. togoensis*), and 14 species are able to produce aflatoxin B_1, B_2, G_1 and G_2: three newly described species *A. aflatoxiformans*, *A. austwickii* and *A. cerealis* in addition to *A. arachidicola*, *A. minisclerotigenes*, *A. mottae*, *A. luteovirescens* (formerly *A. bombycis*), *A. nomius*, *A. novoparasiticus*, *A. parasiticus*, *A. pseudocaelatus*, *A. pseudonomius*, *A. sergii* and *A. transmontanensis*. It is generally accepted that *A. flavus* is unable to produce type G aflatoxins, but here we report on Korean strains that also produce aflatoxin G_1 and G_2. One strain of *A. bertholletius* can produce the immediate aflatoxin precursor 3-O-methylsterigmatocystin, and one strain of *Aspergillus sojae* and two strains of *Aspergillus alliaceus* produced versicolorins. Strains of the domesticated forms of *A. flavus* and *A. parasiticus*, *A. oryzae* and *A. sojae*, respectively, lost their ability to produce aflatoxins, and from the remaining phylogenetically closely related species (belonging to the *A. flavus*-, *A. tamarii*-, *A. bertholletius*- and *A. nomius*-clades), only *A. caelatus*, *A. subflavus* and *A. tamarii* are unable to produce aflatoxins. With exception of *A. togoensis* in the *A. coremiiformis*-clade, all species in the phylogenetically more distant clades (*A. alliaceus*-, *A. coremiiformis*-, *A. leporis*- and *A. avenaceus*-clade) are unable to produce aflatoxins. Three out of the four species in the *A. alliaceus*-clade can produce the mycotoxin ochratoxin A: *A. alliaceus s. str.* and two new species described here as *A. neoalliaceus* and *A. vandermerwei*. Eight species produced the mycotoxin tenuazonic acid: *A. bertholletius*, *A. caelatus*, *A. luteovirescens*, *A. nomius*, *A. pseudocaelatus*, *A. pseudonomius*, *A. pseudotamarii* and *A. tamarii* while the related mycotoxin cyclopiazonic acid was produced by 13 species:

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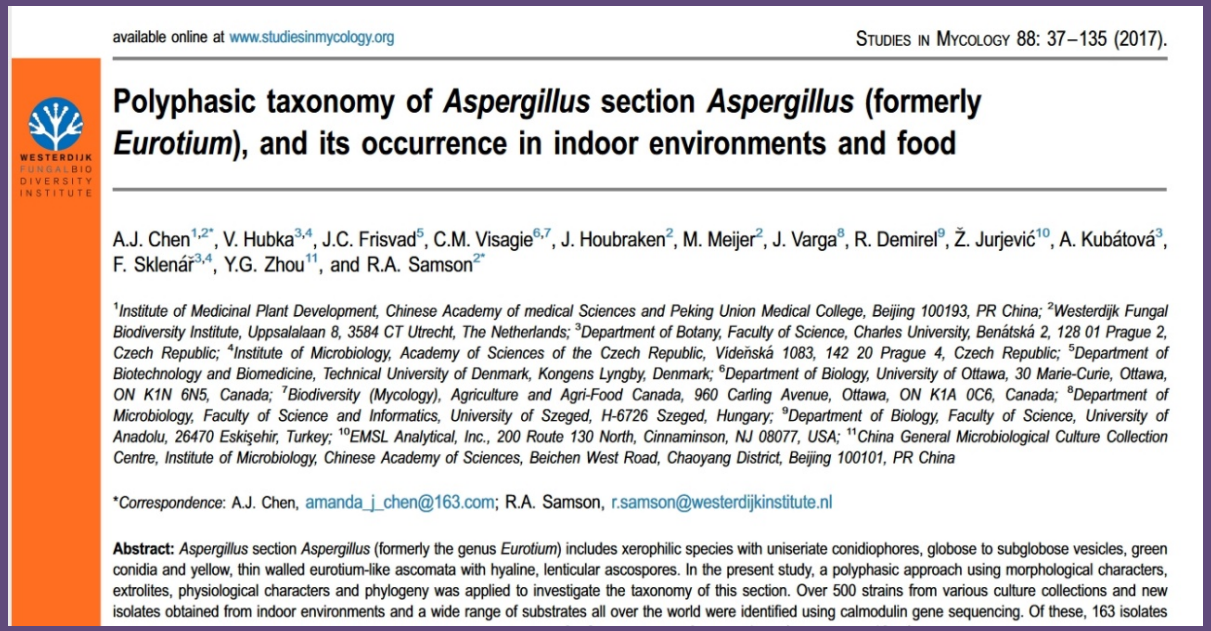
New Aspergillus studies

- **Polyphasic taxonomy of *Aspergillus* section *Aspergillus* (formerly *Eurotium*), and its occurrence in indoor environments and food**
- Amanda Chen et al. Studies in Mycology 88: 37–135 (2017)



available online at www.studiesinmycology.org

STUDIES IN MYCOLOGY 88: 37–135 (2017).

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Polyphasic taxonomy of *Aspergillus* section *Aspergillus* (formerly *Eurotium*), and its occurrence in indoor environments and food

A.J. Chen[1,2*], V. Hubka[3,4], J.C. Frisvad[5], C.M. Visagie[6,7], J. Houbraken[2], M. Meijer[2], J. Varga[8], R. Demirel[9], Ž. Jurjević[10], A. Kubátová[3], F. Sklenář[3,4], Y.G. Zhou[11], and R.A. Samson[2*]

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Abstract: *Aspergillus* section *Aspergillus* (formerly the genus *Eurotium*) includes xerophilic species with uniseriate conidiophores, globose to subglobose vesicles, green conidia and yellow, thin walled eurotium-like ascomata with hyaline, lenticular ascospores. In the present study, a polyphasic approach using morphological characters, extrolites, physiological characters and phylogeny was applied to investigate the taxonomy of this section. Over 500 strains from various culture collections and new isolates obtained from indoor environments and a wide range of substrates all over the world were identified using calmodulin gene sequencing. Of these, 163 isolates

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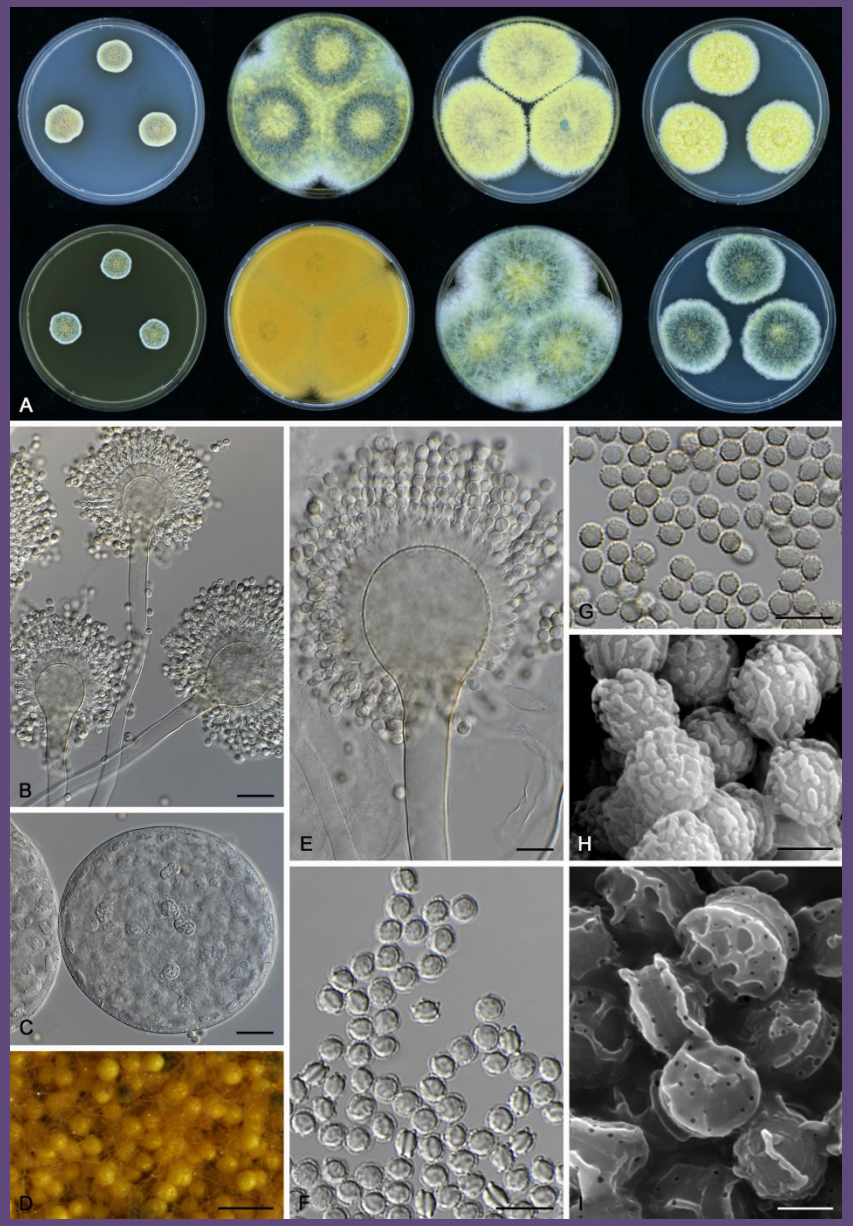
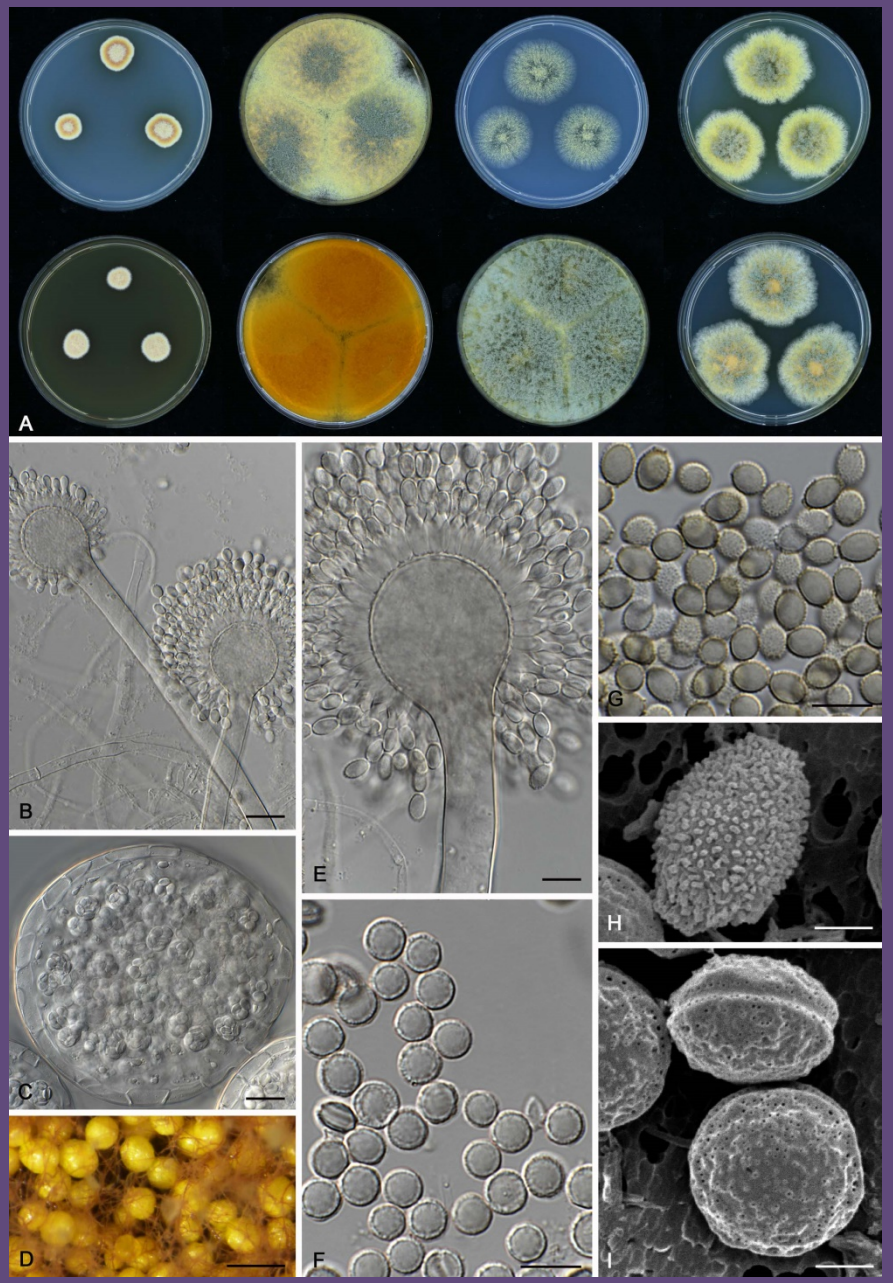


Aspergillus porosus



Aspergillus zutongqii

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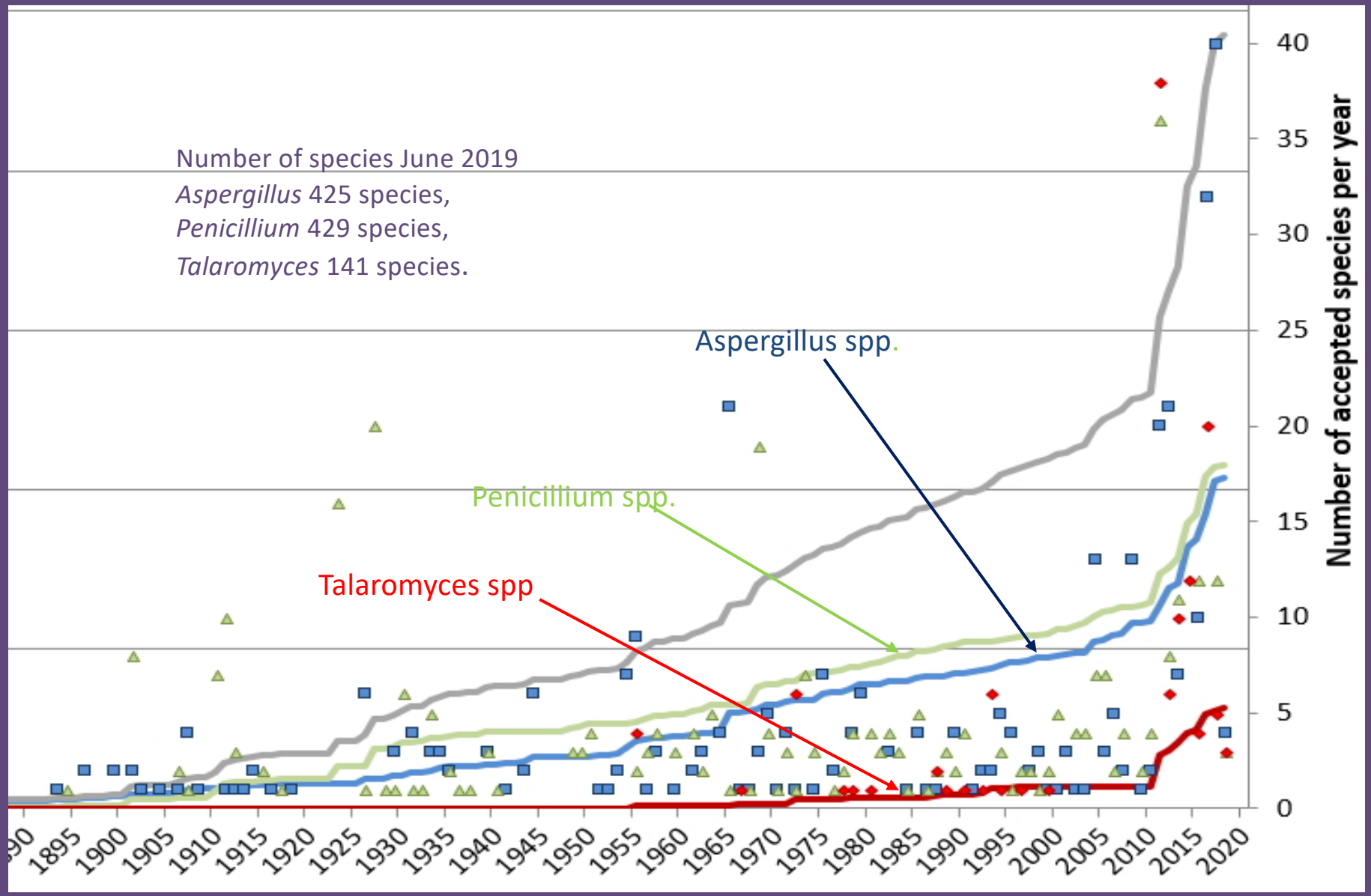

Courtesy of Jos Houbraken

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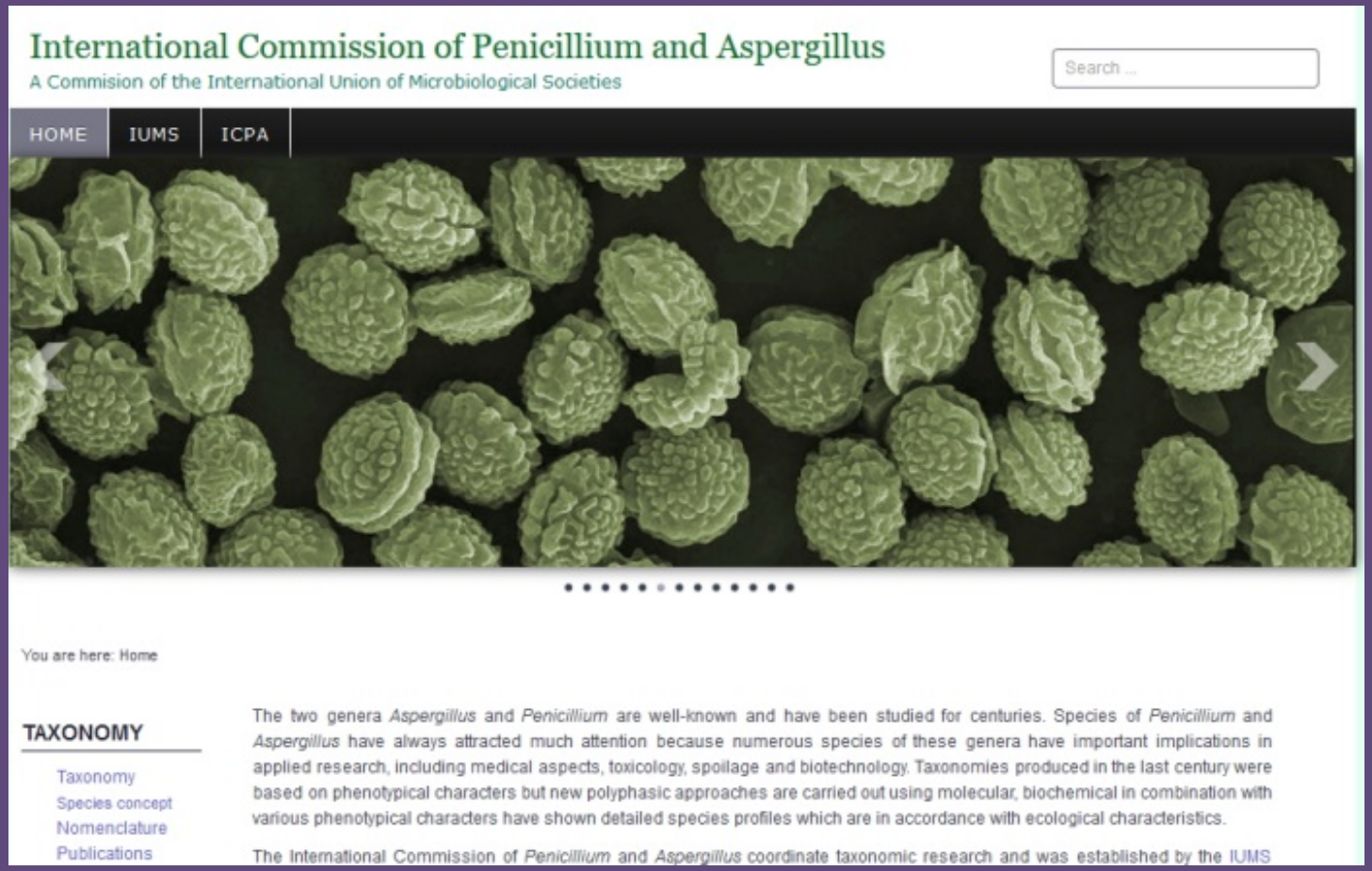

- Databases including correct species name, author(s), type culture and sequences are available for each species of the three genera
- Visit www.aspergilluspenicillium.org

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Food borne mycobiota - taxonomy 2019

- Biodiversity in the genera is high and the number of species will probably increase
- Species identification often provides also information about mycotoxins
- There are a few databases which can serve as reference material and identification
- Although the molecular tools are valuable phenotypic characters should be emphasized

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Food borne mycobiota - taxonomy 2019

- Phylogenetic species concept is sometimes problematic for phenotypic identification
- Many genera contain cryptic species
- Are taxonomic changes updated in the databases of the culture collections?
- Is there a continuation of taxonomic research?

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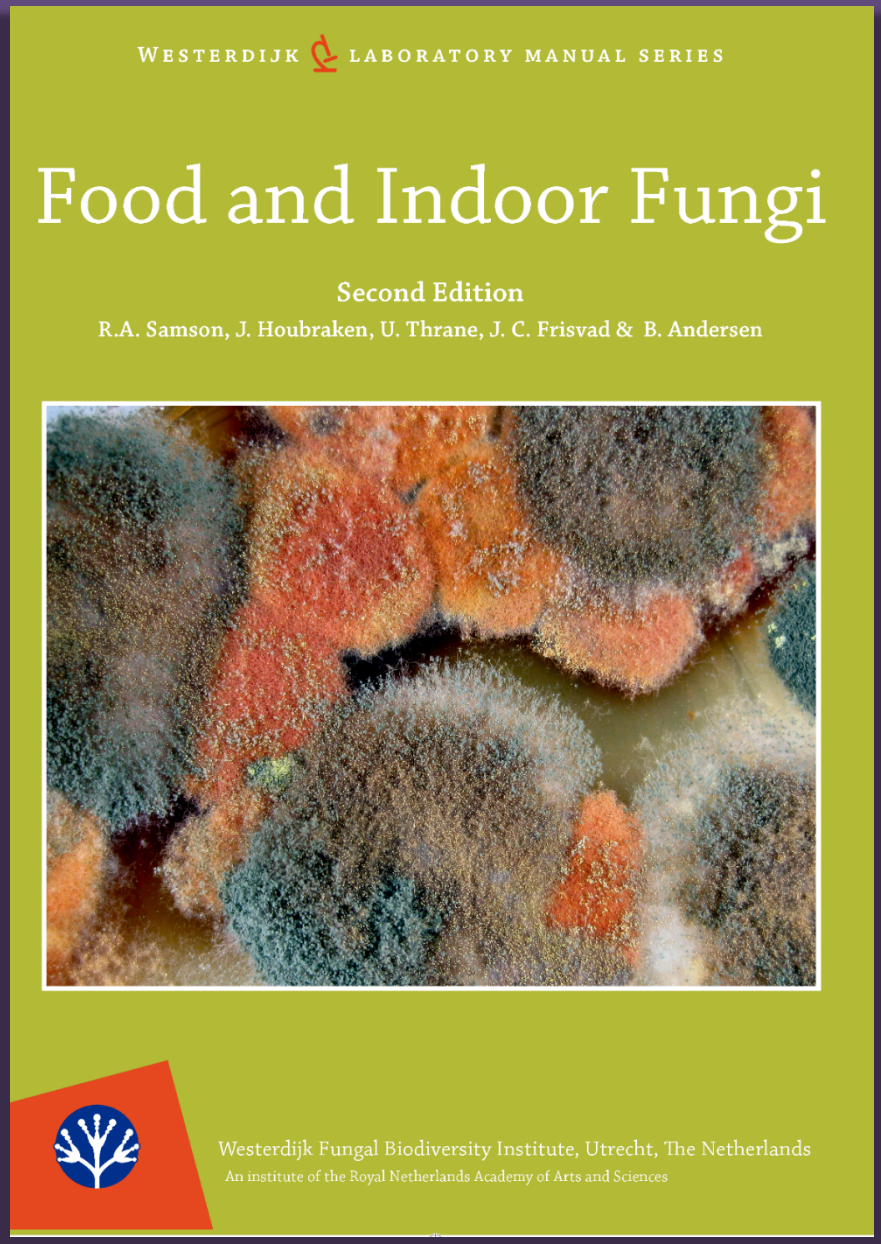

Food and Indoor Fungi (second edition) will be in print at the end of June and available in July - August

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