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### A KEY TO DIATOM NOMENCLATURE

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## A KEY TO DIATOM NOMENCLATURE

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Common nomenclatural problems in diatom research are presented based on our insights. Described here is what is new in the most recent International Code on Botanical Nomenclature – the Vienna Code – since Ross’ papers on Nomenclature for Diatomists: the terms epitype and original material, second step lectotypification, treatment of fossil diatoms, and diatom indexing center. A validity check for new names and new combinations is offered in the format of a key. In addition, nomenclature, taxonomy and identification are differentiated and discussed.

### INTRODUCTION

Since Ross’ comprehensive paper on “Nomenclature for Diatomists” (1993), which was based on the Berlin Code (Greuter *et al.* 1988), one and a half decades have passed which have seen three new editions of the Code: the Tokyo Code (Greuter *et al.* 1994), the Saint Louis Code (Greuter *et al.* 2000a) and the Vienna Code (McNeill *et al.* 2006). There have been some changes in the Code that are of relevance to the Ross contents like renumbering of articles (a major change from the Berlin to the Tokyo Code), and new articles concerning typification, the introduction of the term epitype (Greuter *et al.* 2000a, McNeill *et al.* 2006, Art. 9.7), the clear definition of the term original material (Greuter *et al.* 2000a, McNeill *et al.* 2006, Art. 9.2 Note 2), the different treatment of fossil diatoms (McNeill *et al.* 2006, Art. 11.8, 13.3), and the [diatom] indexing center (Greuter *et al.* 2000a, McNeill *et al.* 2006, Rec.30A.2.). This paper supplies this additional or changed information bringing Ross’ invaluable paper up to date with the latest Code (Vienna Code, McNeill *et al.* 2006).

Nomenclature is looked at from a practical perspective based on our experience in applying the Code to new and old names in typifying, for example, Ehrenberg’s names and in modeling and running a micro algal database for the AlgaTerra Project (Jahn & Kusber 2008, Jahn *et al.* 2004, Kusber *et al.* 2003). Precise nomenclatural understanding, reproducible taxon concepts and clear cut definitions for biodiversity informatics are essential for modeling databases which are to serve our future diatom research.

Ross (1993, 1994) provided the rules of nomenclature for diatomists; we hope to show in this paper how diatomists can work with it in practice. Since we realized that checking the validity of a name or of a new combination often involves a stepwise yes/no situation a key was developed.

### **The trinity: taxonomy, nomenclature, and identification**

In their opinion paper Kociolek & Stoermer (2001) pointed out the need to link taxonomic information with (aut)ecological data in order to get the most precise and reliable information about species, including their habitat and their distribution. On the other hand, as much as

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ecological, morphological and molecular data needs to be taken into account for understanding the taxonomy of organisms, there is urgent need to clearly differentiate between nomenclature and taxonomy. In the common understanding, these two, plus the terms classification and identification, are often amalgamated laying the foundation for a number of confusions and further amalgamations that make the naming and identification of species and taxonomic concepts, historical biogeography and phylogeny so difficult (Edlund & Jahn 2001).

Especially in the English speaking countries the term “taxonomy” is often used when identification is meant. For the identification of species, available keys of comprehensive floras and/or papers are used. The basis for the identification is the species delimitation or the taxonomic concept; this is a hypothesis each researcher has in mind when identifying taxa. But taxonomic concepts change with time, from the first describer who gave a name to a new taxon through later interpretations and summarizing floras which fashion the taxonomic concept of a certain time. For example: After the Danish Scientist Otto Friedrich Müller had described the first diatom in 1782, which he later named *Vibrio paxillifer* (Müller 1786) and Gmelin *Bacillaria paradoxa* (Gmelin 1788), many new species were described as part of the genus *Bacillaria*. Almost all of these were later transferred to other genera like *Nitzschia*, *Navicula*, etc. (see list in VanLandingham 1967–1979, Jahn & Schmid 2007) because of better microscopes and changed taxonomic concepts of genera. Half a century later, C.G. Ehrenberg, because of his – at that time – new method of using the microscope as a scientific instrument, described many more new taxa (about 2000) than his predecessors had differentiated and named. But in turn, his drawings at only 300x magnification forced his successors to interpret his taxonomic concept over the following decades and centuries; i.e. his *Navicula rhomboides* was reinterpreted by Rabenhorst to be a *Frustulia* (Lange-Bertalot & Jahn 2000); his *Gomphonema vibrio* was reinterpreted by Grunow (Jahn & Geissler 1993). Another century later, Otto Müller had a detailed knowledge of *Surirella* taxa; the first samples from Africa allowed him to describe many species and infraspecific taxa which were later sunk into synonymy by Friedrich Hustedt (Jahn 2002, Cocquyt & Jahn 2005, 2007) because of the then prevailing concept of diatom cosmopolitanism.

In clarifying Kociolek & Stoermer (2001) we would therefore like to call their “consistent taxonomy” instead ‘the taxonomic concept of the diatom identifying researcher’ and their “correct taxonomy” instead the ‘correct identification’; this might not even imply using the correct name since the name is a nomenclatural problem/action. Every identification should be based on reproducible taxonomic concepts (see below). In order to be reproducible each researcher should state as explicitly as possible which taxonomic concepts he is working with and showing illustrations as well as citing the reference of identification. We strongly support the pledge by Kociolek & Stoermer (2001) for depositing samples into museum collections in order to be available for later research on biodiversity of certain areas especially when taxonomic concepts have changed.

We do not entirely agree with the statement of Kociolek & Stoermer (2001) “... that a formal epithet is a hypothesis concerning the descent of an organism”. Certainly, the delimitation of genera and species are arbitrary concepts, invented a century before the theory of a common descent – evolution – was crafted, but the epithet in itself is just a name tag tied to a specimen; it is not the taxon (see also Ross 1993). Therefore the name tag does not hinder us from changing our taxonomic concepts. Nomenclature is a set of rules for the naming of organisms applicable to earlier as well as current names. On the level of a taxon it provides us with a simple rule how to use a name. The name that is given to a new taxon (species and below) is really given to one specimen (an individual or a slide) which is called the nomenclatural type.

### **Nomenclatural types: definition, designation, and practice**

The name is tied to a specimen or in other words: the type is that specimen which bears the name tag. The name has of itself no taxonomic concept since it is only a tag on a specimen. The first describer supplies this name also with a taxonomic concept, the diagnosis, which delimitates it from similar taxa (note: only the diagnosis needs to be in Latin). By applying this name to its own specimen, the next user of this name is interpreting the original taxonomic concept. Example: Ehrenberg's *Navicula rhomboides* was interpreted and redrawn by Rabenhorst to look like a *Frustulia rhomboides*; and although Rabenhorst's taxonomic concept misinterpreted Ehrenberg's, his second hand concept was used for the next 150 years (see Lange-Bertalot & Jahn 2000). Today, in modern diatom research, it is important and should be required to investigate the type of the name before the name is recombined with a new genus or raised in rank from variety to species (note: a name has priority only on the rank that it was described at (McNeill *et al.* 2006, Art. 11.2)).

### **Types of types: holo-, iso-, neo-, lecto-, and epitypes**

The current Code requires the designation of a holotype by the describing author otherwise the name is invalid. This clear labeling of the specimen to which the name is tied was introduced stepwise: indication of the type since 1958, using the term "type" since 1990, and designating it explicitly since 2001 (see McNeill *et al.* 2006, Art. 37.1, 37.6). When no holotype has been designated and for retroactive designations of types, the Code allows us to chose a specimen from its original material such as pictures, isotypes (duplicates) or syntypes. The only prerequisite is, that this material must have been in the hands of the describer at the time of description. This chosen specimen is called a lectotype and must be designated as such since 2001. Only when no original material is available may a neotype be chosen. But, when any original material is available (Art. 9.2. Note 2), which may even be an unpublished illustration, this has to be used as lectotype and a neotype may not be designated; this is different from Ross' paper of 1993 when the term original material was not defined in the ICBN (Greuter *et al.* 2000a, McNeill *et al.* 2006, Art. 9.2 Note 2). Example: Cox (2003) designated a neotype for *Placoneis placentula* (Ehrenberg) Mereschkowski because no Ehrenberg specimen could be found. The original drawing by Ehrenberg is, however, available and was therefore chosen as lectotype by Jahn (2004) with Cox's neotype rededicated as epitype.

Besides the new and clear definition of "original material", the term epitype is new since the St.-Louis Code. This is a tool to choose an interpretative type when the original type does not supply the information needed (McNeill *et al.* 2006, Art. 9.7), i.e. an illustration cannot be examined by LM or SEM, a diatom valve cannot supply molecular data. An epitype should be chosen carefully and should be as similar to the author's original designation as possible, such as being from similar habitat and same type locality. It has to state exactly to which type it applies which means that typification has to have taken place (see Jahn *et al.* 2008).

### **Synonymy: a problem of nomenclature or taxonomy?**

In diatom practice the term synonym is often used without differentiating between nomenclatural facts and taxonomical opinions.

Nomenclatural synonyms are two names that have the same type; they are therefore also called homotypic synonyms. These synonyms are marked by a "≡" in the ICBN (McNeill *et al.* 2006). Example: Gmelin's name *Bacillaria paradoxa* (1788) is based on the same type as O.F. Müller's name *Vibro paxillifer* (1786). Müller had described this taxon already in 1782 but without a formal name; Gmelin apparently was not aware of Müller's paper of 1786 and gave it a different formal name. Both names are therefore homotypic or nomenclatural synonyms with Müller's species epithet having priority but to be recombined with the new genus name introduced by Gmelin. This was later recognized and done by Hendey in 1951 (see details in Jahn & Schmid 2007).

Taxonomical synonyms concern two names and two types which are considered to belong to the same taxon; they are therefore also called heterotypic synonyms. These synonyms are marked by a "=" in the ICBN (McNeill *et al.* 2006). This is proposed by publication and should be referenced (who created? place published?). Since this reflects opinions or current taxon concepts, these synonyms are not "lost" but can be revived when concepts change and better methods for character determinations become available. Example: Hustedt (in Huber-Pestalozzi 1942) synonymized *Surirella malombae* O.Müll. with *Surirella nyassae* O.Müll. because he thought that these two African taxa were only the extreme ends of a form spectrum. By studying Müller's original material with the SEM, Cocquyt & Jahn (2007) re-instated *S. malombae* and even described a further taxon of similar outline.

There is a third type of synonym which can be called a concept synonym; it is marked by a "-". This concerns invalid names, misapplied names and taxonomic synonyms which do not include the type of the name. Example: For decades *Aulacoseira valida* (Grunow) Krammer – with the rows of areolae curving dextrorse – has been misidentified as *A. italica* (Ehrenberg) Simonsen – with the rows of areolae curving sinistrose (Crawford *et al.* 2003: 13–14).

### **Naming and typifying diatoms: potential and real conflicts with the Code**

Problems arise from the fact that the Code is made primarily for people who name macroscopic plants; where a specimen (= individual) is glued on to a herbarium sheet and designated as the type. Comparable to a herbarium sheet a microscopic slide is understood as a specimen, even though it might contain many micro algal individuals and admixtures of other taxa (see McNeill *et al.* 2006, Art. 8.2, 9.12). Therefore, it could be seen to be in conflict with the Code when an individual valve is designated as type. To avoid this conflict, it is good practice to mark the specimen on the type slide, and to state in the diagnosis which image in the publication is representing the holotype (e.g. Lange-Bertalot 2001, Jahn & Kusber 2005, 2006). Some people call this picture an iconotype (e.g. Reichardt 2006) but this term is not legal in the Code (Greuter *et al.* 2000b). In order to unambiguously identify an individual as type as discussed in Mann (2001: 236), the new Code has introduced second-step lectotypification (McNeill *et al.* 2006, Art. 9.15 Ex. 8).

Many problems in new combinations, new species or typifications arise because simple requirements of the most recent Code are not fulfilled by the authors. For example, lectotypes are missing the term "designated here" or "hic designatus" (McNeill *et al.* 2006, Art. 7.11), the basionym is lacking full and direct citation (McNeill *et al.* 2006, Art. 33.4), the differential diagnosis is not in Latin (McNeill *et al.* 2006, Art. 36.2) or more than one gathering is cited by the authors without making clear which is the holotype (McNeill *et al.* 2006, Art. 37.1).

### **Talking diatoms: what is in a name?**

Conceptual problems often arise when names are tied to observational, ecological and floristic data from literature and the diatomologist does not clarify which level of taxon is meant by this name (cf. synonymy in Geissler & Kies 2003). From the nomenclatural point of view it is clear what a name implies: the name tag of the lowest taxon possible. Patrick & Reimer (1975) have been very consistent on this: every taxon was cited with its nominate variety; i.e. *Cymbella aspera* (Ehrenberg) H. Peragallo var. *aspera*. Normally, the nominate variety (or subspecies, or form) is not cited unless a new variety is introduced or used but this can be misleading since some researchers understand a species name to include "all its varieties". In both cases the taxon has the same name but one implies a broad concept while the other a narrower concept. What is needed is a clear indication in observational data which concept is meant. By citing the reference of the identification, the concept of the identifying diatomologist is clarified; e.g. *Cymbella helvetica* Kützing (including *Cymbella compacta* Østrup) sec. Krammer & Lange-Bertalot (1986: 324) versus *Cymbella helvetica* Kützing sec. Krammer (2002: 154) and *Cymbella compacta* Østrup sec. Krammer (2002: 150).

### Which names are relevant for the Code?

The Code applies to scientific names composed of one part (genus rank and higher), of two parts (genus name plus species epitheton = species name), or three parts (species name plus final epitheton on infraspecific rank). Names that consist of four or even more parts are not relevant for nomenclature but may be relevant for classification. If these names appear published, the epithets between the species name and the final epitheton are dropped. For example, Müller (1903) described two infraspecific taxa of *Cymatopleura solea* [var. *subconstricta*] f. *minor* and *Cymatopleura solea* [var. *clavata*] f. *minor*. Although both strings of names imply different taxa by classification, nomenclaturally they are homonyms, hence one has to be considered illegitimate (Jahn 2002).

Last but not least: only taxa which are clearly differentiated from other taxa, can be treated by the Code. This is not trivial since non acceptance of a new name by the author, such as a provisional name makes his new diatom name invalid. For example: *Amphiprora incerta* Bílý (1929) was published with a picture and a Latin diagnosis but the description was accompanied by the sentence “diagnosu a provisoní jméno” (Bílý 1929: 10), hence the name was invalidly published.

### Diatom indexing centers (state of the art)

A very important step forward was the idea of indexing centers for plant names in the Tokyo Code (Greuter *et al.* 1994, Art. 32.1) and a trial version of a database was set up (Raab-Straube & Berendsohn 1999). For different reasons, the obligatory registration of new names was withdrawn in the St. Louis Code (Greuter *et al.* 2000a, b) but a recommendation to deposit copies of the publication in a name-indexing centre appropriate to the taxonomic group was added (McNeill *et al.* 2006, Recommendation 30A.2).

Currently, the zoological community is realizing the need of indexing new names and is setting up their own database (Polaszek *et al.* 2005). In diatom research, not only the Index Nominum Algarum which has been compiled since 1948, includes diatoms and has been continuously made available online (Silva 1997-) but especially the Catalogue of Diatom Names by the California Academy of Sciences (Fourtanier & Kociolek 1999, 2007; <http://research.calacademy.org/research/diatoms/names/>) offers genera, species, literature online. Genus names for all plants are also available in the Index Nominum Genericorum (Farr *et al.* 1979), available online (Farr & Zijlstra 1996-). AlgaeBase (Guiry & Guiry 2008) is the name provider for the Global Biodiversity Information Facility (GBIF, GBIF 2008) via the Catalogue of Life (Bisby *et al.* 2008) and has recently expanded its focus from the sea-weeds to micro algae including diatoms. The AlgaTerra Information System is indexing new names and types of micro algae including diatoms and is serving GBIF as types provider (Jahn & Kusber 2008). Many more regional and national databases geared to different needs have been put online. Since there is no detailed co-ordination between all players there are still information gaps and duplication between databases thus producing a delayed data flow.

The urgent need for international co-ordination and most importantly for international registration of new names can be studied, for example, in the fate of taxa from the genus *Karayevia* Round et Bukhtiyarova ex Round which was first published invalidly by Round & Bukhtiyarova (1996), then validated by Round (1998). More new names were added by Bukhtiyarova (1999) but the unavailability of this publication resulted in a delayed scientific discussion (see Lange-Bertalot 2004).

**Key to the validity of diatom names<sup>1,2</sup> according to the Vienna Code (2006)**

	Art.	
1a		2
1b	34.1	Invalid
2a		3
2b	29	Invalid
3a		4
3b		5
4a	43.1	Invalid
4b		6
5a	43.1	Invalid
5b		6
6a		7
6b		20
7a		Invalid, Nomen nudum
7b		8
7c		9
8a		valid
8b	44.2	invalid

<sup>1</sup> This key focuses on species and infraspecific names.

<sup>2</sup> It is recommended to treat all diatoms which might occur in the recent and where the stratigraphy is doubtful as non fossil diatoms (see text).

<sup>3</sup> Such as subspecies, variety, forma.

<sup>4</sup> Note: also the new genus name needs to be tied to a validly published species name one of which should be the type of the name of the genus (Art. 10.1).

		Art.	
9a	Publication until 1952		valid
9b	Publication since 1953		10
10a	Rank <sup>5</sup> not clearly indicated	35.1	invalid
10b	Rank clearly indicated		11
11a	Publication until 1957		valid
11b	Publication since 1958		12
12a	Description lacks a figure	39.1	invalid
12b	Description includes a figure		13
13a	Description other than Latin	36.2	invalid
13b	Description in Latin		14
14a	Type not indicated (e.g. more than one sample mentioned)	37.1	invalid
14b	Type indicated		15
15a	Publication until 1989		valid
15b	Publication since 1990		16
16a	Determination of the type does not include the term “typus”		invalid
16b	Determination of the type includes the term “[holo]typus” or its equivalent in a modern language	37.6	17
17a	Herbarium, collection, or institution not specified		invalid
17b	Herbarium, collection, or institution specified	37.7	18
18a	Publication until 2006		valid
18b	Publication since 2007		19

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<sup>5</sup> Rank defines the position of the taxon such as genus, species, variety.



		Art.	
19a	Holotype of a newly described diatom is a picture <sup>6</sup>	37.4	invalid
19b	Holotype of a newly described diatom is a specimen (slide or stub)		valid
20a	(6b) Diatom name is a replacement name (nom. nov.)		21
20b	Diatom name is a new combination (comb. nov., stat. nov.)		22
21a	New name for an existing name that is not a later homonym		Illegitimate, superfluous name
21b	New name for a later homonym <sup>7</sup> in the same genus <sup>8</sup>		22
22a	Basionym or replaced synonym is indirectly referenced only	33.2	23
22b	Basionym or replaced synonym is clearly indicated <sup>9</sup> and a full and direct reference given to its author and place of valid publication with page or plate reference and date <sup>10</sup>	33.4	24
23a	Publication until 1952		valid
23b	Publication since 1953		invalid
24a	Publication until 2006		valid
24b	Publication since 2007		25
25a	Basionym or replaced synonym is not cited explicitly <sup>9</sup>	33.4	invalid
25b	Basionym or replaced synonym is cited explicitly <sup>11</sup>		valid

<sup>6</sup> Illustrations as types are only applicable to micro algae which can not be preserved permanently (McNeill *et al.* 2006, Art. 37.5).

<sup>7</sup> A later homonym is an illegitimate name; if substituted with a new name it is called replaced synonym.

<sup>8</sup> When transferring an illegitimate name to a different genus it is recommended to use the epithet of the illegitimate (original) name as epithet within the new genus but to publish it as a replacement name.

<sup>9</sup> Scientific name on which the new name is based is not spelled out but just referred to.

<sup>10</sup> Some errors in these citations are acceptable but not omissions (Art. 33.5).

<sup>11</sup> Including scientific name, author, journal, page, figure, year. Example taken from Cocquyt & Jahn (2005): Basionym: *Surirella bifrons* var. *tumida* O. Müller in Bot. Jahrb. Syst. 34: 27, t. 1, fig. 2. 1903.

### Treatment of fossil diatoms

In contrast to all other plant groups, since the St. Louis Code (Greuter *et al.* 2000a) the treatment of fossil and recent diatom names is almost the same; both have the same priority (McNeill *et al.* 2006, Art. 11.8). In addition, a name is treated as non-fossil unless a stratigraphic relation of the original site can be shown; “In cases of doubtful stratigraphic relations, provisions for non-fossil taxa apply.” (McNeill *et al.* 2006, Art. 13.3). This means that new diatoms from undefined sediments should be treated as recent. To test whether historical names of fossil diatoms are valid, different dates and rules apply (see McNeill *et al.* 2006, Art. 36.3, 38.1, 38.2; Preamble 7 plus note).

### The key

This key is not an authorized version of the Code. It is just a tool to help in determining the validity of names on the species and infraspecific level. It does not relieve you from the responsibility of consulting the Code which is available on-line (<http://ibot.sav.sk/icbn/main.htm>). The Code also contains a list of conserved names (McNeill *et al.* 2006, Appendix III A1. & IV A.).

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