

Commentary

The names of phyla and classes of blue–green algae (cyanobacteria, cyanophytes) and a typified name: Cyanobacteriophyta Oren, Mareš et Rippka

BORIS ALEKSOVSKI¹, SVETISLAV KRSTIĆ¹ & MICHAEL D. GUIRY^{2,*}

¹*Institute of Biology, Faculty of Natural Sciences and Mathematics–Skopje, Ss. Cyril and Methodius University in Skopje, North Macedonia*

²*AlgaeBase, Ryan Institute, University of Galway, University Road, Galway, H91 TK33, Ireland; *Corresponding author e-mail: michael.guiry@algaebase.org*

Abstract: The naming of organisms long known as “blue–green algae” or “cyanophytes”, and more recently as “cyanobacteria”, is currently governed by both the rules of the International Code of Nomenclature for algae, fungi, and plants (ICN) and the International Code of Nomenclature of Prokaryotes (ICNP) and a reciprocal principle of code coordination has been agreed so that names validated in either code are treated as valid in the other code. Under the ICN, both descriptive and typified names above the level of family are permitted, and the principle of priority does not apply but there is a recommendation that priority be applied to typified names. The current names in use, along with the typified or descriptive phylum/division names, and class names applied to cyanophytes, are discussed, and recommendations for their use are provided. We recommend adoption of the typified phylum name *Cyanobacteriophyta* Oren, Mareš et Rippka, 2022 in papers employing the ICN and *Chroococcophyceae* Hollerbach, Kosinskaya et Poljansky, 1953 as a class name that includes all cyanobacteria as currently conceived but with the caveat that further class names may come into use in the future.

Key words: Blue–green algae, *Chroococcophyceae*, code coordination, cyanobacteria, , Cyanobacteriophyta, Cyanoprokaryota, nomenclature

INTRODUCTION

Under the provisions of the International Code of Nomenclature for algae, fungi, and plants (ICN, TURLAND et al. 2018), the names of taxa above the rank of family may be automatically typified names formed in the same way as family names or descriptive names (ICN Art. 16), and the principle of priority does not apply to such names (ICN Art. 10).

Phylum (also known as division; ICN Art. 3) and class names for the blue–green algae, currently most widely known as the “cyanobacteria”, have been a source of difficulty for many years. Historically, due to their oxygenic photosynthetic nature, these organisms were treated as algae and studied primarily by botanists, which is still the case, the Preamble of the ICN currently stating that the provisions of the ICN applies to all organisms traditionally treated as algae, “...including the blue–green algae (*Cyanobacteria*)...”.

The International Code of Nomenclature of

Prokaryotes (ICNP) or “Prokaryotic Code”, formerly the International Code of Nomenclature of Bacteria or “Bacteriological Code”, governs the scientific names for Bacteria and Archaea including the cyanobacteria. In 2021, agreement was reached (Oren et al. 2021) that valid publication under the ICN would be treated as valid publication under the ICNP (see KOMÁREK 2011 for an account of the long history). For the blue–green algae, a prokaryotic grouping, names validated under ICNP are valid under the ICN (Preamble, Item 8, Art 45.1, but see Art. 54.1). Following the Principle of Coordination, the ICNP reciprocated ICN Art 45.1 so that names of cyanobacterial taxa validly published under the provisions of the ICN are automatically validly published under the provisions of the ICNP. A major difference between the two Codes should be noted, however: the ICNP requires publication in a particular journal and the deposition of living type cultures in two different countries whereas the ICN does not accept cultures as types except when a portion of a culture is preserved in a metabolically

inactive state (ICN Arts 8.4, 40.3).

The coexistence of two nomenclatural codes has led to inconsistencies in naming, classification, and the validity of published names (OREN & TINDALL 2005; OREN et al. 2009).

A plethora of valid and invalid, typified and descriptive names have been applied to the prokaryotic blue–green algae/cyanobacteria, mostly under the ICN, of which the most relevant are discussed in detail below. A summary of relevant class names is given in Table 1, mostly gleaned from Silva (1980). In many cases, historical class and phylum names are cited by authors that are not nomenclaturally valid.

For the sake of clarity, an explanation of the terms used for names herein may be useful.

A **colloquial, trivial or vernacular name** is an informal term applied to a grouping: for example “chlorophytes” for green algae, “rhodophytes” for red algae, and “cyanophytes” for blue–green algae. Such names have no standing under the ICN.

A **descriptive name** is a formal name of a taxon above the rank of family not formed from a generic name (Art. 16.1). A descriptive name is usually not typified but may be.

A **typified name** is a name based upon a generic name and is automatically typified (Art. 16.1).

Descriptive and typified names based on a genus name are treated as nouns in the plural and are written with an initial capital letter. It should also be noted that under the ICN, the term “name” should not be applied to invalid designations (Turland 2019: 18). Such designations have no standing under the ICN and the term “nomen” or “nomen nudum” is applied to them.

There is no requirement for priority under the ICN above the level of family, and the use of typified or descriptive names is permitted (ICN Art. 16), but Recommendation 16A is “In choosing among typified names for a taxon above the rank of family, authors should generally follow the principle of priority.”

In the following treatment, colloquial, trivial or vernacular names are written with lower–case initial letters whilst descriptive or typified names in both codes are capitalised.

Class Cyanophyceae HAUCK 1884

Cyanophyceae as a descriptive class name has been attributed to several nomenclatural authorities including HAUCK (1884: 487; 1885: xii¹), BENNETT & MURRAY (1889: 408, 426, “class” of the subdivision Protophyta), WEST (1904: 306), and SCHAFFNER (1909: 446, as a class). SILVA (1980: 49) seemingly considered that Cyanophyceae Schaffner 1909 was the earliest available name but did not mention Cyanophyceae Bennett et Murray or Cyanophyceae

Hauck. HAUCK’s *Die Meeresalgen Deutschlands und Österreichs* was issued in four parts from 1882–1885. In HAUCK (1885: xii), four “Reihe” are included, each of which contain taxa at the “Ordnung” level, which contain taxa at the “Familie” level. Thus HAUCK’s “Reihe” can be considered the equivalent of classes in the modern sense and the Cyanophyceae as a descriptive name should be credited to HAUCK as he provided a description in German (HAUCK 1884: 487), acceptable for validity at the time. While Art. 17.2 specifies that ‘Names intended as names of orders but published with their rank denoted by a term such as “cohors”, “nixus”, “alliance”, or “Reihe” instead of “order”, are treated as having been published as names of orders.’, it is clear from the context of Hauck’s treatment that he did not intend the name “Cyanophyceae” as an order.

Phylum Cyanophyta Geitler 1925

GEITLER (1925a: 172) introduced the descriptive name Cyanophyta as a “Stamm” [literally, trunk] for the Cyanophyceae Hauck 1884 and the Chlorobacteriaceae Geitler et Pascher 1925 [in PASCHER 1925b]. Geitler clearly excluded the Schizomycetes Nägeli 1857, which he included in his Schizophyta. Cyanophyta Geitler is a valid name, and since it included a circumscription of two classes, it can be regarded as a valid descriptive phylum name of blue–green algae. Inexplicably, in the *Die Süßwasser–Flora Deutschlands*, GEITLER (1925b, title page, 1) did not employ the name Cyanophyta simply using “Cyanophyceae” without referring to any phylogenetic level. The designation “Cyanophyta” had earlier been used by HAECKEL (1894: 101) as a class of Archeophyta Haeckel, a Stamm or “Phylen” [sic, presumably phylum] of Protophyta (HAECKEL 1894: 90), but as an alternative name for the “Classe Chromacea”, and thus at a different level to that of Geitler. Early use of the designation “Cyanophyta” might be connected to SACHS (1874: 248) as “Cyanophyceen”; nevertheless, this early designation was introduced without any description, rendering the name invalid at that time.

Class Nostocophyceae T.Christensen 1978

The typified name Nostocophyceae (Type: *Nostoc* Vaucher ex Bornet et Flahault 1886) was introduced by CHRISTENSEN (1978: 65), citing as class synonyms the earlier descriptive names Myxophyceae Stizenberger 1860, Cyanophyceen [sic] SACHS, 1874, and Schizophyceae Cohn 1880. The name “Myxophyceae” was introduced by STIZENBERGER (1860: 17, 18) as an “Ordnung” of Algae and included families such as “Fam. Chroococcaceae”. It is debatable as to whether Stizenberger’s “Ordnungen” are equivalent to modern classes, as one of the “Ordnung” he included was the Rhodophyceae. Similarly, the name “Die Cyanophyceen” was included by SACHS (1874: 251) as a name of “Klasse 1 Protophyten” so that its status as a class name is doubtful. The class name “Schizophyceae” is frequently attributed to “Cohn

¹ The introductory material for HAUCK’s *Die Meeresalgen Deutschlands und Österreichs* was printed in 1885 and is usually bound at the beginning of the whole work.

Table 1. Class names and designations applied to cyanobacteria and their status. The descriptive name Cyanophyceae is attributed by SILVA (1980: 49) to SCHAFFNER (1909: 446); see text. Pleurocapsophyceae Starmach is invalid as it was not accompanied by the Latin diagnosis required in 1966, and does not appear to have been validated since. Hormogoniophyceae Starmach should perhaps be considered an orth. mut. of Hormogoneae HOLLERBACH et al. (1953) and therefore valid. Chamaesiphonophyceae HOLLERBACH et al. (as ‘Класс Chamaseiphoneae’ is typified by Chamaesiphon A. Braun in RABENHORST (1864)). Chroococcophyceae Hollerbach et al. is typified by *Chroococcus* Nägeli 1849. The non-photosynthetic Vampirovibrionophyceae Strunecký et Mareš 2023 (STRU NECKÝ et al. 2023 ‘Vampirovibriophyceae’) proposed for a non-photosynthetic parasite of *Chlorella*, *Vampirovibrio chlorellavorus* (Gromov et Mamkayeva) Gromov et Mamkayeva and is considered to be a sister to the cyanobacteria.

Name/Designation	Authority	Descriptive/Typified	Status	Reference
Chamaesiphonophyceae	Hollerbach et al. 1953	Typified	Valid	SILVA (1980)
Chromacea	Haeckel 1894	Descriptive	Valid	SILVA (1980)
Chroococcophyceae	Hollerbach et al. 1953	Typified	Valid	SILVA (1980)
Cyanophyceae	Hauck 1884	Descriptive	Valid	Herein
Cyanoschiceae	Rothmaler 1951	Descriptive	Valid	SILVA (1980)
Hormogoneae	Hollerbach et al. 1953	Descriptive	Valid	SILVA (1980)
Hormogoniophyceae	Starmach 1966	Descriptive	Valid?	SILVA (1980)
Myxophyceae	G.S.West 1904	Descriptive	Valid	SILVA (1980)
Nostocophyceae	T.Christensen 1978	Typified	Valid	SILVA (1980)
Phycocchromophyceae	Rabenhorst 1864	Descriptive	Valid	SILVA (1980)
Pleurocapsophyceae	Starmach 1966	Typified	Invalid	SILVA (1980)
Schizophyceae	Knoblauch 1890	Descriptive	Valid	SILVA (1980)

1879” or “Cohn 1880”, both referring to COHN (1880)² in which he included the “Ordnung I. Schizosporeae” in the “Reihe I. Carposporeae” and in the Schizosporeae included “a. Schizophyceae” and “b. Schizomycetes” but a class name “Schizophyceae” cannot be clearly attributed to Cohn.

Vernacular names “Cyanobacteria” or “cyanobacteria”

Currently, “phylum Cyanophyta” is not widely used and has largely been replaced by the term “Cyanobacteria” or “cyanobacteria” by authors intending to emphasise their bacterial relationships. The descriptive name “Cyanobacteria” was only recently validated (without a type) under the ICN (GARCIA-PICHEL et al. 2019), and some authors (e.g. KOMÁREK 2020, 2023) seemingly deliberately employed the name as “cyanobacteria” with a lower-case initial letter, presumably highlighting its use as a trivial or vernacular name, but one that is widely recognised. The conceptual framework for the eventual adoption of the term “cyanobacteria” originated from the formal definition of a bacterium by STANIER & VAN NIEL (1962), who firmly stated that “...one could not

formulate a definition of bacteria which would exclude these [blue-green] algae.”

The descriptive designation Cyanobacteria for the blue-green algae seemingly was first introduced by the eminent and insightful microbiologist Roger Y. Stanier (1916–1982) in the 8th edition of Bergey’s Manual of Determinative Bacteriology (BUCHANAN & GIBBONS 1974: 22), who treated the kingdom Procaryotae Murray 1968 (an invalid name under the ICNP) as including two divisions: Cyanobacteria and Bacteria. According to OREN et al. (2022: 1) the designation Cyanobacteria is not valid under the rules of the ICNB/ICNP and “Proposals to establish the phylum Cyanobacteria Woese et al. 1985 ... or Cyanobacteria (ex Stanier 1974) Cavalier-Smith 2002 ... were made before the rank of phylum was included in the rules of the ICNB/ICNP.” Moreover, the ICNP requires a validly published type genus (such as *Cyanobacterium*) for a name at a higher rank, which did not exist at that time. As a result, the name Cyanobacteria did not fulfil the formal requirements for a formally valid taxonomic name in bacterial nomenclature.

Prior to 2021, the highest rank covered by the ICNP was “class.” The taxonomic ranks above class—including “Phylum” or “Division”—were not recognized and thus were not governed by the ICNP rules. They lacked official standing and were used informally and

² This paper appeared in Jahres-Bericht Schlesischen Gesellschaft für vaterländische Cultur für 1879 (Bd. 57). The title page of the volume clearly states “1880”.

mostly inconsistently by microbiologists. Therefore, the designation “Division Cyanobacteria” as used in the early editions of Bergey’s Manual and elsewhere has no nomenclatural standing.

WHITTAKER & MARGULIS (1978: 12) employed the alternative, descriptive designation “Cyanobacteria” without attribution as a phylum of blue–green algae, but no description or reference to a previously published name was provided.

The descriptive designation Cyanobacteria was applied by JEFFREY (1982: 410) to a subdivision of the division Phytotrophobacteria JEFFREY (1982: 410) which comprises subdivisions Cyanobacteria, Prochlorobacteria, Prochromobacteria. This designation was not valid as it was not accompanied by a Latin description (ICN Art. 44.1).

CAVALIER–SMITH (1998: 216, 218) reintroduced the name Cyanobacteria to a phylum of the superphylum Pimelobacteria Cavalier–Smith. He attributed the name to “Stanier 1973”, but he did not cite such a reference in his bibliography, although Stanier’s entry in Bergey’s Manual of Determinative Bacteriology ed. 8 (STANIER 1974) was probably intended. Although many considered this as validation of the name, the designation Cyanobacteria Stanier ex Cavalier–Smith 1998 is also invalid. The name was introduced before the rank of phylum was included in the rules of the ICNB/ICNP, and at that time no validly published genus named *Cyanobacterium* existed; moreover, Cavalier–Smith’s usage was not accompanied by a description.

In a subsequent taxonomic revision, CAVALIER–SMITH (2002) refined bacterial classification focusing on the negibacterial root, and he reclassified Cyanobacteria as “revived name” with the rank of “Division” (Division 1. Cyanobacteria (Stanier 1974) nom. rev.), also invalid under both Codes for the reasons discussed above.

Vernacular name “Cyanoprokaryota”

The designation “Cyanoprokaryota” emerged as an informal consensus name during the discussions at the 8th Symposium of the Association for Cyanophyte Research (IAC Kastanienbaum, Switzerland, 1979) and the 9th IAC Symposium (1983, Kastanienbaum and Dubendorf), with the main themes “Cyanophyta vs. cyanobacteria, principles and problems in taxonomic treatment of natural populations vs. axenic cultures”, and “Recommendations for a unified approach to the taxonomy of cyanophytes”, respectively. Despite many scientists agreeing on this term, it appears that it was never formally proposed or described nomenclaturally.

Initiated in the frame of the IAC Symposia, the designation “Cyanoprokaryota” was intended to be introduced as equivalent to the phylum Cyanobacteria in the: “Proposal for Guide to the Nomenclature and Formal Taxonomic Treatment of Oxyphototrophic Prokaryotes (Cyanoprokaryotes)” by KOMÁREK & GOLUBIĆ (1990). As special nomenclatural rules for cyanophytes/cyanobacteria were not acceptable at that time, the proposal of this

“Cyano–Guide” by KOMÁREK & GOLUBIĆ (1990) should have represented nomenclatural prescriptions of both the Botanical and Bacteriological Codes (see KOMÁREK 2011). The main part of that proposed “Guide” was prepared in the period 1983–1990 but was never published.

Thus, the descriptive designation “Cyanoprokaryota” although widely used, and influenced particularly by the title Süßwasserflora von Mitteleuropa series (Cyanoprokaryota, Bd. 19/1–3; KOMÁREK & ANAGNOSTIDIS 1998; KOMÁREK & ANAGNOSTIDIS, 2005; KOMÁREK 2013), is not valid as it was not provided with a description, and it was employed only as colloquial and vernacular term.

Phylum Cyanobacteriota Oren, Mareš et Rippka 2022

In 2015, the International Committee on Systematics of Prokaryotes (ICSP) finally decided to recognise the rank of phylum under the rules of ICNP (OREN ET AL., 2015), with phylum names agreed to bear the suffix “–ota”. This allowed publication of a valid, legitimate phylum name for the cyanophytes under the ICNP. OREN, MAREŠ & RIPPKA (2022) made such a proposal to validate the typified phylum name Cyanobacteriota with the type genus *Cyanobacterium* Rippka et Cohen–Bazire 2022.

Under the principle of Code Coordination, the name Cyanobacteriota is also valid under the ICN, but with the suffix “–phyta” (ICN Art. 16.3) so that the correct, typified name under the ICN is:

Cyanobacteriophyta Oren, Mareš et Rippka 2022 (“Cyanobacteriota”), orth. mut.

Type genus: *Cyanobacterium* Rippka et Cohen–Bazire 2022

The phylum Cyanobacteriophyta consists of prokaryotic organisms in the domain Bacteria capable of oxygenic photosynthesis with water as an electron donor and to reduce carbon dioxide as a source of carbon.

Those publishing under the ICN are required by ICN Art. 16.3 to use the orthography “Cyanobacteriophyta” for typified names whilst those publishing under the ICNP are required to use the orthography “Cyanobacteriota”. For the avoidance of confusion, we recommend that those working on cyanobacteria should work with the ICN.

CONCLUSION

In view of the absence of any requirement for priority under the ICN, and the allowed use of typified or descriptive names (ICN Art. 16), and following Recommendation 16A, phyco- logists have a choice for their use of descriptive and typified names for phyla and classes of blue–green algae as follows:

Descriptive phylum name: Cyanophyta Geitler 1925

Typified phylum name: Cyanobacteriophyta Oren, Mareš et Rippka 2022

Descriptive class name: Cyanophyceae Hauck 1884

Typified class name: Chroococcophyceae Hollerbach, Kossinskaja et Poljansky 1953

It should be emphasised that a type is not required for descriptive names to be valid. Cyanobacteriophyta is the equivalent of the invalid descriptive designations “Cyanobacteria” and “Cyanoprokaryota.”

RECOMMENDATIONS

As nearly all typified phylum/division names of plants employ the suffix “-phyta” we recommend the use of the phylum name Cyanobacteriophyta Oren, Mareš et Rippka 2022 in papers employing the ICN and Chroococcophyceae Hollerbach, Kosinskaya et Poljansky as a class name that includes all cyanobacteria as currently conceived. It should be noted that HOFFMANN, KOMÁREK & KAŠTOVSKÝ (2005, table 3) introduced four subclass taxa for Cyanophyceae: “Gloeobacteriophycidae”, “Synechococcophycidae”, “Oscillatoriohycidae”, and “Nostocophycidae”. These are invalid designations as they were clearly stated to be provisional (Art. 35.1) but it is not inconceivable that these may be found to represent classes. There are a number of valid class names available for use (Table 1).

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