Naming Cyanophyta/Cyanobacteria – a bacteriologist's view

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Abstract: This paper provides information on the origin and the etymology of the names of genera of Cyanophyta/Cyanobacteria in current use and on the way new names are formed under the provisions of the International Code of Botanical Nomenclature and the International Code of Nomenclature of Prokaryotes. Special emphasis is placed on the differences between the two Codes that should be taken into account when creating new names compatible both with the botanical and with the bacteriological nomenclature system, to support the ongoing efforts to harmonize the nomenclature of the Cyanophyta/Cyanobacteria under the two Codes.

Key words: Cyanobacteria, Cyanophyta, *Halothece*, International Code of Botanical Nomenclature, International Code of Nomenclature of Prokaryotes, *Nostoc*

Introduction

"The knowledge of classical Latin and Greek is permanently decreasing". Thus complained Hans Trüper (1999) in this exemplary essay on "How to name a prokaryote? Etymological considerations, proposals and practical advice in prokaryotic nomenclature". Issues relating to etymology, Latin, and Greek are equally relevant to the nomenclature of the Cyanophyta/Cyanobacteria which was not discussed in–depth by Trüper (1999, 2001).

With over 250 names of genera described (see http://www.cyanodb.cz/valid_genera), the cyanobacteria are a relatively large group of prokaryotes. For comparison, the current list of genera with standing in the prokaryote nomenclature (http://www.bacterio.cict.fr/number.html#total), a list that contains only very few cyanobacterial names, encompasses about 1900 names.

The history of some of the cyanobacterial names is much longer than the nomenclatural history of most other prokaryotes. When in 1875 Ferdinand Cohn classified bacteria in six genera, many cyanobacterial genera had already been named by botanists such as Hans Christian Lyngbye (1782–1837), Carl Adoph Agardh (1785–1859), and others. Some scientific names of cyanobacteria in current use even predate Linnaeus, as shown by the case of *Nostoc* discussed below.

This short essay was written with two purposes. The first is to provide those who work with Cyanophyta/Cyanobacteria some information about the origin and the etymology of their names. The question "What's in a name"[1] often allows interesting insights into the nature of these organisms. An understanding of the ways names were given in the past is also highly relevant when suitable names should found to describe newly discovered genera and species. Table 1 therefore presents a glossary that contains most of the elements found in the generic names of Cyanophyta/Cyanobacteria. Unfortunately the authors who proposed the names seldom provided their etymology. Therefore guesswork was sometimes needed, and comments and corrections relating to this list are welcome. Some elements used in the names are derived from Latin, but Greek words dominate. Botanists who described all those genera in the past have made a particularly creative use of the Greek dictionary. I hope that the glossary will be helpful to those who deal with cyanobacterial names, so that the dictum "It was Greek to me"[2] will not apply to students of cyanobacteria.

1 Shakespeare, Romeo and Juliet
2 Shakespeare, Julius Caesar

The second reason for presenting this information is the ongoing effort to harmonize the nomenclature of the Cyanophyta/Cyanobacteria under the two Codes: the International Code of Botanical Nomenclature (MCNEILL et al. 2007) – 'the Botanical Code', and the International Code of Nomenclature of Prokaryotes (formerly the International Code of Nomenclature of Bacteria) (LAPAGE et al. 1992) – 'the Bacteriological Code'. Although the provisions in both Codes for naming new genera and species are quite similar, minor differences exist, and these should be taken into account when creating new names compatible both to the 'botanical' and to the 'bacteriological' nomenclature system.

The rules of the Codes

Most genera and species of Cyanophyta/Cyanobacteria have been named under the rules of the Botanical Code; see also COMPÈRE (2005) for valuable comments on the way names are formed under the provisions of this Code. Only a few generic names have been published under the provisions of the Bacteriological Code. Examples are *Halospirulina*, *Planktotricoides*, *Prochlorothrix*, and *Rubidibacter* (OREN & TINDALL 2005; OREN et al. 2009).

When comparing the rules of nomenclature there are a number of interesting differences between both Codes:

1. According to Principle I of the Botanical Code, "Botanical nomenclature is independent of zoological and bacteriological nomenclature". However, the formerly similar Principle 2 of the Bacteriological Code was modified in 1999, and now states that "The nomenclature of Prokaryotes is not independent of botanical and zoological nomenclature" (DE VOS & TRÜPER 2000). Therefore it is still possible to use a generic name with standing in the prokaryote nomenclature to name a new genus of plants, including cyanobacteria, but the opposite is no longer allowed.
2. Under both Codes, scientific names of taxonomic groups are treated as Latin. Under the Bacteriological Code, a specific epithet must be treated in one of the three following ways: 1. As an adjective that must agree in gender with the generic name, 2. As a substantive (noun) in apposition in the nominative case, 3. As a substantive (noun) in the genitive case (Rule 12c). Under the Botanical Code, the rules are less strict: "The epithet in the name of a species may be taken from any source whatever, and may even be composed arbitrarily" (Art. 23.2). The Bacteriological Code does not enable the formation of a specific epithet such as used in *Microcystis ichthyoblabe* (from Greek ἰχθύς = fish; βλάβη = damage), but under the Botanical Code such an epithet can be validly published, even if Recommendation 23A.3(a) suggests "To use Latin terminations insofar as possible".
3. Under the Bacteriological Code, the derivation (etymology) of a new name must be given (Rule 27.2(b) as modified in 1999) (DE VOS & TRÜPER 2000). Under the Botanical Code, the specification of the etymology of the new name is a recommendation only: "The etymology of new names or of epithets in new names should be given, especially when their meaning is not obvious" (Recommendation 60H.1).
4. Use of hyphens in specific epithets is not allowed under the rules of the Bacteriological Code. "If an epithet has been hyphenated, its parts should be joined. The name retains its validity and standing in nomenclature" (Rule 12a). Under the Botanical Code, the use of the hyphen is allowed, both in generic names (Article 20.3) and in specific epithets (Article 23.1; see also Article 60.9). Therefore names containing a hyphen such as *Anabaena flos–aquae* and *Dolichospermum torques–reginae* [*torquis–reginae* would be grammatically preferable!] are allowed under the Botanical Code. Recommendation 23A.3(d) states that authors should avoid creating specific epithets formed of two or more hyphenated words, and recommendation 23A.3(b) warns against the creation of epithets that are very long and difficult to pronounce in Latin. Not all authors, however, have followed these recommendations, as the example of *Coelosphaerium evidenter–marginatum* shows (AZEVEDO & SANT'ANNA 1999).

Diacritical signs are not allowed in genus and species names under both Codes (Rule 64 of the Bacteriological Code; Art. 60.6 of the Botanical Code). The name *Chamaesiphon komárekii* (ROTT 2008) was thus created in violation of the regulations, and should be corrected to *Chamaesiphon komarekii*.

Overall the rules of the Botanical Code allow more ways to create new generic names and specific epithets than does the Bacteriogical Code. In view of the attempts to harmonize the nomenclature of the Cyanophyta/Cyanobacteria under both Codes, it is recommended that new names to be added in the future should be compatible with the provisions of both Codes.

The case of *Halothece californica*

In view of the above considerations, the case of the description of *Halothece californica* (Margheri et al. 2008) is to some extent a missed opportunity. The paper intended to provide a description of a new genus and species in a form that should be compatible first of all with the requirements of the Botanical Code, but with the Bacteriological Code as well. However, Principle 3 of Bacteriological Code states that "The scientific names of all taxa are Latin or latinized words treated as Latin regardless of their origin" (see also Rule 6), and Principle V of the Botanical Code was formulated similarly. Even if the Latin noun theca (a case, a box, a chest) was derived from the Greek noun θήκη, the Latin form should be used, and the correct genus name under both codes should therefore be *Halotheca* (etymology: ha.lo.the'ca; Gr. fem. n. *hals*, *halos*, salt; L. fem. n. *theca*, box [or Gr. fem. n. *thece*, to comply with Recommendation 6(3) of the Bacteriological Code and Recommendation 20A.1.(d) of the Botanical Code]; N.L. fem. n. *Halotheca*, salt box) (Oren 2009a). Moreover, according to current practice in prokaryote nomenclature, new 'geographical' names are formed with the ending *–ensis* (masc., fem.) or *–ense* (neut.) (Trüper 1999), and thus the preferred specific epithet is *californiensis* (ca.li.for.ni.en'sis; N.L. fem. adj. *californiensis*, pertaining to Baja California Sur, Mexico, where the nomenclatural type was isolated).

Genera of Cyanophyta/Cyanobacteria named to honor famous scientists

As customary also for other groups of plants, and in the bacteriological nomenclature as well, certain generic names and specific epithets in the cyanobacterial nomenclature honor colleagues, both in the past and in the present, who have made important contributions to our knowledge in the field. Thus we have genera such as *Borzia* and *Borzinema* (honoring Antonio Borzi, 1852–1921), *Geitleria* and *Geitlerinema* (Lothar Geitler, 1899–1990), *Gomontiella* (Maurice Gomont, 1839–1909), *Jaaginema* (Otto Jaag, 1900–1978), *Lemmermanniella* (Ernst Johann Lemmermann, 1867–1915), *Lyngbya* and *Leptolyngbya* (Hans Christian Lyngbye, 1782–1837), *Stanieria* (Roger Stanier, 1916–1982), and others.

Undoubtedly there are more distinguished colleagues who have contributed much to the taxonomy of the Cyanophyta/Cyanobacteria and deserve to be honored with a name of a cyanobacterial genus. However, this is not always simple. For example: in the cases of Friedrich Kützing (1807–1893) and Carl Adolph Agardh (1785–1859), *Kuetzingia* is already a rhodophyte genus, but "*Kuetzingiella*" can still be used; the name *Agardhia* apparently has been already used for more than one botanical taxon (see the Index Nominum Genericorum – A compilation of generic names published for organisms covered by the International Code of Botanical Nomenclature; http://botany.si.edu/ing/). The generic name *Komarekia* (an illegitimate substitute name for *Hofmania*) was given to a member of the Chlorophyceae to honor Jiři Komárek (Fott 1981), but "*Komarekiella*" may still be available.

To honor Ferdinand Cohn (1828–1898), who was the first to recognize the affiliation of the Cyanophyceae with the bacteria, with a new cyanobacterial genus name will be more complicated. *Cohnia* is already a genus of angiosperm plants, and *Cohnella* is an endospore–forming Gram–positive heterotrophic prokaryote. Principle I of the Botanical Code states that "Botanical nomenclature is independent of zoological and bacteriological nomenclature", so that formally the name *Cohnella* can still be proposed. However, this would create a homonym, which could lead to considerable confusion in the future. A remaining option is "*Ferdinandcohnia*" (compare *Elizabethkingia*, a genus name with standing in the prokaryote nomenclature). Finding a name for a cyanobacterial genus to honor the late Imre Friedmann (1921–2007) (Oren 2009b) will also be problematic. *Friedmannia* is already a member of the Chlorophyceae, and *Friedmanniella* is a heterotrophic prokaryote belonging to the Actinobacteria.

When creating names that should obtain standing both in the botanical and in the prokaryote nomenclature, it should be remembered that the

Botanical Code allows the creation of composite names such as *Borzinema*, *Geitleribactron* etc., but Appendix 9 of the Bacteriological Code (TRÜPER & EUZÉBY 2009) states only two ways to form a generic name from a personal name, either directly or as a diminutive; both are always in the feminine gender. Still, the Code does not forbid proposing compound nouns based on personal names, and two such names were added in 2009: *Gordonibacter* and *Rummelliibacillus*.

The slimy world of cyanobacterial nomenclature

Many cyanobacteria excrete polysaccharide slimes, and this property is expressed in many generic names and specific epithets. The element 'gloeo' or 'gloea' (Gr. γλοιός = gum, resin, oil) is found in the genus names *Gloeothece*, *Gloeotrichia*, *Chlorogloea*, and *Chondrogloea*. We further find *Blennothrix* (Gr. βλεννός = slime), *Lithomyxa* and *Myxosarcina* (Gr. μύξα = discharge from the nose), and *Hydrocoleum glutinosum* (L. glutinosus = viscous, sticky).

The most interesting 'slimy' generic name is undoubtedly *Nostoc*. The etymology of this name was disclosed in a delightful essay by POTTS (1997). The name predates the establishment of binomial nomenclature by LINNAEUS, and can be attributed to the 16th century Swiss scientist, alchemist and philosopher AUREOLUS PHILIPPUS THEOPHRASTUS BOMBASTUS VON HOHENHEIM (1493–1541), better known under the name PARACELSUS. The original spelling is Nostoch, and this word was most probably derived from a combination of the Old English 'Nosthryl' and the German 'Nasenloch', two words that mean exactly the same: nostril. The name *Nostoc* soon became generally accepted, and the genus *Nostoc* became the type of the family *Nostocaceae* (BORNET & FLAHAULT, 1886–1888). The name is a typical case of a generic name composed in an arbitrary manner (Article 20.1 of the Botanical Code).

We also find the name in the nomenclature of non–photosynthetic prokaryotes in *Leuconostoc* (with the etymology: Gr. adj. *leukos*, clear, light; N.L. neut. n. *Nostoc*, algal generic name; N.L. neut. n. *Leuconostoc*, colorless nostoc) (see http://www.bacterio.cict.fr/l/leuconostoc.html). The name was given to a genus of dextran–producing lactic acid bacteria in 1878, and was included in the Approved Lists of Bacterial Names (SKERMAN et al. 1980). Based on Rule 10a ("The name of a genus … is treated as a Latin substantive"), it is no longer possible to create a name such as *Nostoc* under the rules of the Bacteriological Code, unless a Latin ending will be added.

Based on Article 20.1 of the Botanical Code, there is no problem with the newly proposed generic name *Desmoc* (HROUZEK et al. 2010), a combination of Gr. δέσμος = band, binding material, and part of the last syllable of 'Nasenloch' used nearly five hundred years ago to coin the name *Nostoc*. However, to the opinion of the author the name does not sound very elegant. Moreover, in a time attempts are made to harmonize the treatment of the nomenclature of the Cyanophyta/Cyanobacteria under both Codes, it is to be recommended that newly formed generic names should meet the standards not only of the Botanical Code, but also of Rule 10a and the other provisions of the Bacteriological Code, and that information on the etymology of the newly proposed names should be provided as well.

Final comments

This short essay shows that there are quite a number of interesting, and generally little known, features in the nomenclature of the Cyanophyta/Cyanobacteria. Scientists who work with these prokaryotes rarely realize the source of the names of the organisms studied. Still, an understanding of the nomenclature (ideally backed up by some basic knowledge of Latin and Greek) can be helpful and provide an insight into the nature of the taxa. An in–depth understanding of the ways scientific names are formed and validly published is essential for those who wish to describe new genera and species.

Although the Botanical Code and the Bacteriological Code both use the binomial system that treats names of taxa as Latin words, there are minor differences between the two Codes. Attempts toward the harmonization of the treatment of Cyanophyta/Cyanobacteria under the two Codes are underway. Nomenclature matters are not the greatest problem here. Much more important are issues relating to the nature of the type material and to central registration and indexing of validly published names (OREN & TINDALL 2005; OREN et al. 2009). Based on Art. 45.4 of the Botanical Code, names of cyanobacteria validly published under the Rules of the Bacteriological

Code are considered to be validly published also based on the requirements of the Botanical Code. If in the future the International Committee on Systematics of Prokaryotes, the body governing the International Code of Nomenclature of Prokaryotes (the Bacteriological Code), will be able to reciprocate this Art. 45(4), it will appear that quite a few names in current use are not in agreement with the way names are formed under that Code. Therefore it is recommended, when creating names of new genera and species, to use names compatible with both Codes.

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Table 1. A (non–exhaustive) list of word elements found in genus names of Cyanophyta/Cyanobacteria, based on the list given in http://www.cyanodb.cz/valid_genera. (Gr.) = Greek; (L.) = Latin. Elements derived from names of persons are not listed.

A	
Actis (Gr.) ἀκτίς, ray, beam	Arbor (L.) arbor, tree
Aggregatum (L.) aggrego, join together	Arthro– (Gr.) ἀρθρον, a joint
Anabena (Gr.) ἀναβαίνω, to go up	Aster (Gr.) ἀστήρ, star
Aphano– (Gr.) ἀφανής, unseen	Aulo– (Gr.) αὐλός, flute
Aphanizo– (Gr.) ἀφανίζω, to hide, to make unseen	
B	
Bactron, Bacterium (Gr.) βάκτρον, staff, stick	Botrys (Gr.) βότρυς, bunch of grapes
Bacula (L.) bacula, small berry	Brachy– (Gr.) βραχύς, short
Blenno– (Gr.) βλεννός, slime	Byrsa (Gr.) βύρσα, hide, skin
C	
Calo (Gr.) κάλος, beautiful	Chondro– (Gr.) χονδρός, granular, coarse
Calyx (Gr.) κάλυξ, covering, shell, pod	Chroo– (Gr.) χροός, χρώς, skin, flesh
Camptylo– (Gr.) καμπύλος, bent, curved	Cladus (Gr.) κλάδος, branch
Capsa (L.) capsa, case, receptacle	Clast– (Gr.) κλαστός, broken in pieces
Carpella (Gr.) κάρπος, fruit	Coelo– (Gr.) κόιλος, empty
Caryo– (Gr.) κάρυον, a nut	Coleus, Coleum (Gr.) κολεόν, sheath
Catella (L.) catella, light chain	Coccus (Gr.) κόκκος, grain, seed
Catena (L.) catena, chain	Coryne (Gr.) κορύνη, club, staff
Cavum (L.) cavum, hole	Crinis (L.) crinis, lock of hair, tress
Chaete (Gr.) χαίτη, long hair	Croco– (Gr.) κρόκεος, saffron colored
Chamae– (Gr.) χαμαί, on the ground	Cuspi– (L.) cuspis, sharp point, tip
Chlamy– (Gr.) χλαμύς, mantle	Cyano– (Gr.) κυάνεος, dark blue
Chlor– (Gr.) χλωρός, light green	Cystis (Gr.) κύστις, bladder
D	
Dasy– (Gr.) δασύς, hairy	Dictyon (Gr.) δίκτυον, net
Derma (Gr.) δέρμα, hide	Dolicho– (Gr.) δολιχός, long
Desmium, Desmo– (Gr.) δέσμος, band, binding material	Dolio– (Gr.) δολιός, crafty, deceitful (?)
Dicho– (Gr.) δίχη, in two	
E	
Epi– (Gr.) ἐπί, upon, on	Ento– (Gr.) ἐντός, inside, within
Enchym (Gr.) ἐνχυμα, infusion	Eu– (Gr.) εὐ, well

F

Fasciculus (L.) fasciculus, bundle, parcel

G

Gemino– (L.) geminus, twin
Glauco– (Gr.) γλαυκός, blue–green
Gloeo–, Gloea– (Gr.) γλοιός, gum, resin, oil
Gompho– (Gr.) γόμφος, pin, nail
Granis (L.) granum, seed

H

Halo– (Gr.) ἁλς, ἁλος, salt
Hapalo– (Gr.) ἁπαλός, tender
Herpyzo– (Gr.) ἑρπύζω, to creep, to crawl
Hetero– (Gr.) ἑτερος, other
Homeo– (Gr.) ὁμοιος, like, resembling
Hormo–, Hormato– (Gr.) ὁρμος, chain, necklace
Hydro– (Gr.) ὑδωρ, water
Hypho– (Gr.) ὑφη, web

I

Is(o)– (Gr.) ἰσος, equal

K

Katagnymene (Gr.) κατάγνυμι, to break in pieces
Kybus (Gr.) κύβος, cube
Kyrtu– (Gr.) κυρτός, curved, arched

L

Lepto– (Gr.) λεπτός, fine, small
Limno– (Gr.) λίμνη, pool of water, lake
Lith(o)– (Gr.) λίθος, stone

M

Macro– (Gr.) μακρός, large
Mastigo– (Gr.) μαστιγόω, to whip, to flog
Merismo– (Gr.) μερισμός, partition, division
Micro– (Gr.) μίκρος, small
Moron (Gr.) μωρός, sluggish
Morpha (Gr.) μορφή, shape
Myxo–, Myxa (Gr.) μύξα, discharge from the nose

N

Nema (Gr.) νήμα, thread
Nephron (G.) νεφρός, kidney
Nodu– (L.) nodus, knot

O

Onko– (Gr.) ὀγκος, bulk, mass
Oscilla– (L.) oscillum, swing

P

Pannus (L.) pannus, piece of cloth, rag
Para– (Gr.) παρά, from beside, alongside
Pedia (Gr.) πεδίον, plain
Pelato– (Gr.) πελάτης, neighbor; coming closer
Phanon (Gr.) φανός, light, bright
Phorm– (Gr.) φορμός, basket, mat
Physa– (Gr.) φυσα, wind, air bubble
Placa (Gr.) πλάξ, πλακός, flat surface, plain
Plankto– from (Gr.) πλάνος, wandering
Plecto– (Gr.) πλεκτή, coil, twisted rope
Pleuro– (Gr.) πλευρά, rib, flank
Ploca (Gr.) πλοκή, web
Podo– (Gr.) πούς, ποδός, foot
Pogon (Gr.) πώγων, beard
Poly– (Gr.) πολύς, many
Proter– (Gr.) πρότερος, before, in front
Porphyro– (Gr.) πορφύριος, dark purple
Pseudo– (Gr.) ψεύδος, falsehood, lie
Pulvin– (L.) pulvinus, cushion, pillow
Ptyche (Gr.) πτυχή, πτύξ, leaf, plate, fold

R

Radio (L.) radio, to shine
Raphi– (Gr.) ῥαφή, needle
Restis (L.) restis, rope, cord
Rhabdo– (Gr.) ῥάβδος, stick
Rivularia (L.) rivulus, brook
Rubidi– (L.) rubidus, red

S

Saccus (L.) saccus, bag
Sarcina (L.) sarcina, bundle
Schizo– (Gr.) σχίζω, to split
Scyto– (Gr.) σκυτος, leather, hide
Siphon (Gr.) σίφων, tube, pipe
Siro– Sira (Gr.) σειρά, cord, chain
Spelae– (Gr.) σπήλαιον, grotto, cave
Sperm– (Gr.) σπέρμα, seed
Sphaer– (Gr.) σφαίρα, ball
Spir– (Gr.) σπείρα, (L.) spira, coil
Stauroma– (Gr.) σταύρωμα, palisade
Sticho– (Gr.) στίξ , στίχος, row, line
Stylon (Gr.) στύλος, pillar
Sym–, Syn– (Gr.) συν, along with, together with
Sympho– (Gr.) συμφύω, to grow together
Synecho– (Gr.) συνέχεια, continuity

T

Tapino– (Gr.) ταπεινός, small, modest, weak
Tetra– (Gr.) τετρα–, four
Thalpo– (Gr.) θάλπος, warmth, heat
Thamn– (Gr.) θάμνος, bush, shrub
Thece (Gr.) θήκη, (L.) theca, case, box, chest
Thermo– (Gr.) θερμός, hot, warm
Thio (Gr.) θειον, θέειον. sulfur
Thrix (Gr.) θρίξ, θρίχος, hair
Tholos (Gr.) θολός, mud, dirt
Tolypo (Gr.) τολύπη, a ball of wool
Tricho, Trico– (Gr.) θρίξ, θρίχος, hair
Trypo– (Gr.) τρύπη, hole
Tycho– from (?) (Gr.) τύχη, chance, fortune

X

Xeno– (Gr.) ξένος, guest, stranger

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