Proposal to consistently apply the International Code of Nomenclature of Prokaryotes (ICNP) to names of the oxygenic photosynthetic bacteria (cyanobacteria), including those validly published under the International Code of Botanical Nomenclature (ICBN)/International Code of Nomenclature for algae, fungi and plants (ICN), and proposal to change Principle 2 of the ICNP

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This taxonomic note was motivated by the recent proposal [Oren & Garrity (2014) Int J Syst Evol Microbiol 64, 309–310] to exclude the oxygenic photosynthetic bacteria (cyanobacteria) from the wording of General Consideration 5 of the International Code of Nomenclature of Prokaryotes (ICNP), which entails unilateral coverage of these prokaryotes by the International Code of Nomenclature for algae, fungi, and plants (ICN; formerly the International Code of Botanical Nomenclature, ICBN). On the basis of key viewpoints, approaches and rules in the systematics, taxonomy and nomenclature of prokaryotes it is reciprocally proposed to apply the ICNP to names of cyanobacteria including those validly published under the ICBN/ICN. For this purpose, a change to Principle 2 of the ICNP is proposed to enable validation of cyanobacterial names published under the ICBN/ICN rules.

Progress towards the dual coverage of *Cyanophyceae* (the algal class name coined by J. Sachs in 1874)/*Cyanophyta* (the algal division name coined by F. Steinecke in 1931)/oxygenic photosynthetic bacteria/cyanobacteria (trivial terms introduced by R. Stanier in 1974) by the International Code of Botanical Nomenclature (ICBN) and the International Code of Nomenclature of Bacteria (ICNB) has fundamental implications for the International Code of Nomenclature of Prokaryotes (ICNP) put forward in 1999 (Labeda, 2000; De Vos & Trüper, 2000). Indeed, Oren & Garrity (2014) sought to cut the Gordian knot: they proposed to modify General Consideration 5 of the ICNP in such a way that the ICNP no longer covers the nomenclature of cyanobacteria. Approval of this proposal by the International Committee on Systematics of Prokaryotes (ICSP) would result in the cyanobacteria falling under the unilateral coverage of the ICN except for several species validly published in 1989–2008 according to ICNB/ICNP provisions (Oren, 2004).

In this connection, the original wording of General Consideration 5 of the ICNB (Lapage et al., 1992) should be noted: ‘This *Code of Nomenclature of Bacteria* applies to all bacteria’. A proposed additional note to General Consideration 5 (Tindall, 1999) states that: ‘The term “bacteria” covers those organisms variously recognized as prokaryotes, *Bacteria, Archaea, Eubacteria* and *Archaeabacteria*. Due consideration has been given to including cyanobacteria, which are traditionally covered by the International Code of Botanical Nomenclature, and has been discussed elsewhere.’ Another modified wording of General Consideration 5 as included in the ICNP (Labeda, 2000; De Vos & Trüper, 2000) also should be noted: ‘This *Code of Nomenclature of Prokaryotes* applies to all prokaryotes’. The supplementary note to General Consideration 5 of the ICNP states, in particular: ‘Prokaryotes covers those organisms that are variously recognized as e.g. ... *Bacteria*. It is noteworthy that although the terms ‘bacteria’ and ‘prokaryotes’ were adopted in the ICNB and later the ICNP only by making mention of them, their biological essence has been comprehensively confirmed in myriads of publications since the appearance of the global cytology concept by Stanier & Van Niel (1962) and the global phylogeny concept by Woese & Fox (1977).

It is well known that living organisms are treated, from viewpoint of their genotype and phenotype specificity, as evolutionary biological elements (biosystematics). For this purpose, classification units are delimited (taxonomy) and these are named according to codified rules (nomenclature). A preferred delimitation of taxa is based on phylogeny reconstruction (Wayne et al., 1987; Klenk & Göker, 2010). Consequently, the nomenclature, especially of higher taxonomic ranks, should be governed by separate codes (Blackwell, 2008; Komárek, 2011). Specifically, the phylogeny-based systematics of bacteria is adopted in the second edition of Bergey's Manual of Systematic Bacteriology (2001–2012; vols. 1–5) and the bacterial nomenclature is covered by the ICNP. Therefore, in correspondence with the above-mentioned wordings of General Consideration 5, cyanobacteria should be treated under the ICNP (Imhoff & Madigan, 2004).

Since the 1870s, cyanobacteria have been interpreted as binary dividing plants of the class Schizophyceae (the class name coined by F. Cohn in 1875) or classified as blue-green algae (Cyanophyta/Cyanophyceae); consequently, their nomenclature was initially regulated by the ICBN. Subsequently, owing to the first recognition of the bacterial nature of Schizophyceae/Cyanophyta/Cyanophyceae (Stanier & Van Niel, 1941), their nomenclature— as that of cyanobacteria— was proposed to be governed by the ICNB rules (Stanier et al., 1978). Guided by this proposal, the Judicial Commission of the International Committee on Systematics of Bacteria (ICSB) proposed usage of a permissible dual nomenclature system (the ICBN/ICNB) for Cyanophyta/Cyanophyceae/ cyanobacteria. However, this proposal was never formally endorsed by the ICSB/ICSP. The main obstacle is the mutually incompatible provisions of the Botanical and Bacteriological Codes; in particular, the rules concerning valid publication of names differ. Details are omitted here since they are comprehensively discussed elsewhere (Oren, 2004; Oren & Tindall, 2005; Komárek, 2011; Oren, 2011a, b).

The choice of a nomenclatural code to govern cyanobacteria has three possible options excluding the proposed BioCode and Cyanocode (Oren, 2004; Blackwell, 2008; Komárek, 2011). Namely, these bacteria may be regulated (i) under the ICN; (ii) under the ICNP; or (iii) under both the ICN and the ICNP. In the first case, according to the proposal by Oren & Garrity (2014), cyanobacteria are annexed by botany. Thus, organisms belonging to one phylogeny-based system will be described under the nomenclatural principles adopted for a separate phylogeny-based system. Moreover, the bacterial system is deprived of its most significant element taking into account the global role of cyanobacteria in cell evolution, as well as their diversity, abundance, distribution and ecology. To prevent the inconsistency, and in contrast to the proposal by Oren & Garrity (2014), it is proposed to apply the ICNP to cyanobacterial names including those validly published under the ICBN.

Operationally, cyanobacteria have already begun to be described under the ICNB/ICNP. Since 1989, there have been precedents of valid publication of novel genera and species (Oren, 2004; 2011a, b). At the same time, nomenclatural obstacles remained, especially for taxa validly published under the ICBN. Thus, the wording of General Consideration 5 of the ICNB (Lapage et al., 1992) states: ‘... The nomenclature of certain other microbial groups is provided for by other Codes: fungi and algae by the Botanical Code ...’. In addition, the wording of Principle 2 (ibid.) is: ‘The nomenclature of bacteria is independent of botanical nomenclature, except for algae and fungi ...’ (a supplementary note provides the following definition: ‘... “independent” means that the same name may be validly used for a taxon of bacteria as well as a taxon of plants and animals with the exceptions noted above’). The wording of Rule 10a, Recommendation 10a (ibid.) is: ‘The following Recommendations apply when forming new generic ... names. 3. Avoid introducing into bacteriology as generic names such names as are in use in botany or zoology, in particular well-known names. Finally, the wording of Rule 51b (ibid.) is: ‘Among the reasons for which a name may be illegitimate ... are the following. ... 4. If it is a junior homonym (the author’s remark: later homonym, in newer usage) of a name of a taxon of ... algae ...’. All these provisions unequivocally implied that cyanobacteria were considered to be algae, and thus their exclusion from the ICBN seemed consistent.

However, the proposed wording of General Consideration 5 of the ICNP (De Vos & Trüper, 2000) states: ‘... The nomenclature of eukaryotic microbial groups is provided for by other codes: ... algae by the International Code of Botanical Nomenclature ...’. The wording of the proposed change to Principle 2 (ibid.) is: ‘The nomenclature of Prokaryotes is not independent of botanical and zoological nomenclature. When naming new taxa in the rank of genus ..., due consideration is to be given to avoiding names which are regulated by ... the International Code of Botanical Nomenclature.’ In this case, exclusion of cyanobacteria from the ICNP is counter-logical because they are not eukaryotic microbes and, correspondingly, algae.

Taking into account the above considerations and code formulae, it is proposed to change the wording of Principle 2 of the ICNP as follows:

The nomenclature of prokaryotes is not independent of zoological nomenclature, as well as nomenclature of algae, fungi and plants. The only exception applies to names of the oxygenic photosynthetic bacteria (cyanobacteria) validly published, as names of algae, under the International Code of Botanical Nomenclature/International Code of Nomenclature for algae, fungi and plants.

Supplementary note: ‘independent’ means that the same name may be validly used for a taxon of bacteria as well as a taxon of algae, fungi, plants and animals.

The proposed change of the wording of Principle 2 of the ICNP tries to break, by way of exception, a deadlock in cyanobacterial nomenclature. This makes an opportunity to validate under the ICNP the names of cyanobacteria validly published under the ICBN/ICN.
The problem of genera names is in context with the problem of combinations at the rank of species or subspecies. Noteworthy, in the classification of cyanobacteria elaborated by Rippka et al. (1979) and, with certain modifications adopted in Bergey’s Manual of Systematic Bacteriology (Castenholz, 2001), the usage of species epithets is avoided. Only four binary combinations were validated under the ICNP: Prochlorothrix hollandica, Halospiroolina tapetica, Planktotricoides raciborski and Rubidibacter lacunae (Oren, 2004; 2011a, b).

‘Operational’ (taxonomic and nomenclatural) speciation of cyanobacteria is clearly distinct from the problem of defining their species in accordance within the general species definition for prokaryotes (Staley, 2006). Importantly, a genotype-level interspecies threshold has got no consensus of opinion (Stackebrandt et al., 2002; Doolittle & Zhaxybayeva, 2009; Tindall et al., 2010; Kim et al., 2014). Nevertheless and similarly with other prokaryotes, the systematics of cyanobacteria are currently based on the polyphasic approach (Colwell, 1970; Tindall et al., 2010) although the metabolic uniformity of this group confines phenotypic characteristics to gross morphology and, in rare cases, ultrastructure. With this approach, a number of cultured strains could be reliably identified at the species level (Otsuka et al., 2001; Wright et al., 2001; Komárek, 2006; Palinska & Marquardt, 2008).

Proposal of an ‘operational’ speciation algorithm for cyanobacteria is beyond the scope of this taxonomic note. However, one can outline it stepwise: (i) the ‘form-genus’ name is chosen based on matching morphological descriptions of cyanobacteria in hand to those in the ‘Geitlerian’ system (Castenholz, 1992); (ii) under the ‘form-genus’ name, collection strains and database references are operationally treated (Castenholz, 2001); (iii) the type strain, as the best characterized one, especially in respect of phylogeny, is considered an operational ‘form-species’; (iv) a closely fitting match is scanned for among ‘good’, i.e. distinct and coherent botanical species, and the operational ‘form-species’ assimilates the corresponding epithet. Noteworthy, the samples used in former times for botanical diagnoses should not be necessarily related to morphologically matching contemporary strains. In limited cases, this may be verified by employing molecular biological methods to historical herbaria (Palinska & Surosz, 2014). Anyway, given the proposed assimilation of genera names from the ICBN/ICN, the ICNP formula for validation of combinations including species and subspecies should be sought later. At the same time, a more radical algorithm is admissible: species epithets of cyanobacteria are abandoned, and strain numbers replace the corresponding portion of the binominal (Castenholz, 1992). However, voluminous deviation from the nomenclature of Linnaeus is hardly productive.

There are important matters pertaining to cyanobacteria that have already been pursued and should be gradually resolved in the future: (i) development of collections of pure cultures; (ii) choice of type strains; (iii) removal of misidentifications (Tindall et al., 2010; Komárek, 2011; Gupta et al., 2013). These tasks are currently supported, in informational respect, by the list of bacterial names with standing in nomenclature (Euzéby, 1997; Parte, 2014). However, the forthcoming goal is the creation of the ‘Approved Lists of Cyanobacterial Names’ based on valid publications in the IJSEM according to the ICNB/ICNP rules. Among the main impediments, besides the current veto on names with standing in the ICN, is a general shortage of pure cultures deposited in (at least two) authoritative collections. The above nomenclatural actions are endangered with emendation obstacles (Tindall, 1999). Complex authorship and naming trajectories is exemplified by Anabaina Bory (de Saint-Vincent) 1822/Anabaena Bornet et Flahault 1886 (Blackwell, 2008). Duplicate taxa are also undesirable, as well as proposals of new cyanobacterial names (Roldán et al., 2013) published in IJSEM under the provisions of the ICN. However, as pointed out by Imhoff & Madigan (2004): ‘There was no doubt and general agreement that cyanobacteria have to be treated according to the Bacteriological Code, but that this treatment should, in addition, be in accordance to the Botanical Code, whenever possible.’

In conclusion, this proposal calls for the nomenclatural treatment of cyanobacteria along with other bacteria. Alternatively, they are sentenced to be tendentiously separate from other representatives of their group. In other words, either the ICNP rules remain fast, or the bacterial system is violated and a long-lasting lacuna in bacterial nomenclature settled. Unilateral coverage of cyanobacteria by the ICN would also negatively influence their research, especially taking into account that this Code has no demand for live collections, pure cultures and type species.

It should be reminded that bacteria had once been placed in the plant division Schizophyta (1875; F. Cohn) along with the fungi of the class Schizomycetes (1857; C. Nägeli), and cyanobacteria in particular treated as the Cyanophyta Cyanophyceae algae. At the same time former ‘ray fungi’ (type genus, Actinomyces Harz 1877) now encompass a wide range of bacteria belonging to the phylum Actinobacteria (Ludwig et al., 2012), and there has been no call for unilateral coverage of these prokaryotes by the ICN.

A résumé of the author’s arguments is as follows. Firstly and most importantly, a proposal to consistently apply the ICNP to cyanobacteria conforms formally and logically to the wording and supplementary note of General Consideration 5. Secondly, it is proposed to legitimize, by way of exception, the usage of Cyanophyta/Cyanophyceae names in order to enable descriptions of cyanobacteria under the ICNP. With valid publications accumulated, a list of ‘Approved Names of Cyanobacteria’ would be compiled. Thirdly, code restrictions impede the four-decades-long operational usage of Cyanophyceae/Cyanophyta names by the global community of (cyanobacteria) biologists. Habitual presence of ‘botanical’ names in literature on cyanobacteria...
and databases is hardly possible to eradicate. In fact, an alternative option to reconsider cyanobacterial genera under the names coined de novo would have grave or even chaotic informational consequences.

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References


