Based on a nomenclatural point of view, the name *Rhodococcus equi* is associated, as required by the Bacteriological Code, with a defined position, rank and circumscription. A search of the literature indicates that the name *Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977 has also been shown to be a synonym of *Corynebacterium equi* Magnusson 1923, *Corynebacterium hoagii* (Morse 1912) Eberson 1918 and *Nocardia restricta* (Turfitt 1944) McClung 1974. Application of the rules of the Bacteriological Code together with the currently inferred taxonomic concept associated with the species bearing the name *Rhodococcus equi* indicates that this is not the correct name of this taxon and the use of that name in the context of a circumscription that includes the type strain of the species *Corynebacterium hoagii* is contrary to the Rules of the Code.

A new starting date for bacterial nomenclature was created with the publication of the Approved Lists of Bacterial Names (Skerman *et al.*, 1980, 1989), which was associated with a new version of the International Code of Nomenclature of Bacteria (Lapage *et al.*, 1975) and the implementation of the current system of the valid publication of names of taxa at the rank from subspecies up to and including class. The purpose of the former was to solve problems of the past. The purpose of the latter was to prevent similar issues arising in the future. Unfortunately, the latter goal has not always been achieved, but recognition of the current problems, their origin and ways of dealing with them are an important step in further refining the current infrastructure.

The current case study deals with the application of the names:

*Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977

*Corynebacterium equi* Magnusson 1923

*Corynebacterium hoagii* (Morse 1912) Eberson 1918

*Nocardia restricta* (Turfitt 1944) McClung 1974

All four names were included on the Approved Lists of Bacterial Names (Skerman *et al.*, 1980, 1989), where it should be noted that at the time that list was published Goodfellow & Alderson (1977) had already indicated that *Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977 and *Corynebacterium equi* Magnusson 1923 were homotypic synonyms and that *Nocardia restricta* (Turfitt 1944) McClung 1974 was a heterotypic synonym. Sly *et al.* (1983) pointed out that the use of different ATCC accession numbers as the types of *Rhodococcus equi* (Magnusson 1923) Goodfellow and Alderson 1977 and *Corynebacterium equi* Magnusson 1923 was confusing and seemed to imply that these two taxa were heterotypic synonyms until one realized that both accessions were ultimately based on a single strain held in the NCTC and should be regarded as homotypic synonyms. The inclusion of these three known synonyms on the Approved Lists emphasizes that the list does not advocate a particular ‘approved’ taxonomy, but lists names that are to be considered validly published for which further evaluation with respect to their classification may be required to determine which name is to be used.

The International Code of Nomenclature of Bacteria (Lapage *et al.*, 1992) states:

**Principle 8**

Each order or taxon of a lower rank with a given circumscription, position, and rank can bear only one correct name, i.e. the earliest that is in accordance with the Rules of this Code.

**Rule 23a**

Each taxon above species, up to and including order, with a given circumscription, position, and rank can bear only one correct name, that is, the earliest that is in accordance with the Rules of this Code.

The name of a species is a binary combination of a generic name and specific epithet (see Rule 12a).
In a given position, a species can bear only one correct epithet, that is, the earliest that is in accordance with the Rules of this Code.

Note 1. In the case of a species, Rule 23a must be applied independently to the generic name and the specific epithet.

The term correct is a technical term and should not be interpreted to mean that a particular classification (taxonomy) is the one to choose, but rather if a particular classification is selected then the name that is to be used is also based on Principle 6:

The correct name of a taxon is based upon valid publication, legitimacy, and priority of publication.

Priority of publication for names, combinations and epithets published on the Approved Lists of Bacterial Names (Skerman et al., 1980, 1989) is determined by Rule 24b:

(1) If two names compete for priority and if both names date from 1 January 1980 on an Approved List, the priority shall be determined by the date of the effective publication of the name before 1 January 1980.

The issue of priority in the context of names that are treated as synonyms (i.e., the union of taxa of equal rank) is covered by Rule 41:

In the case of subspecies, species, subgenera, and genera, if two or more of those taxa of the same rank are united, the oldest legitimate name or epithet is retained.

In the current example the following interpretation applies:

If the type strain associated with the name Corynebacterium equi Magnusson 1923 is considered to be a member of the genus Corynebacterium and a distinct taxon from Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turfitt 1944) McClung 1974 then the correct name of the taxon is Corynebacterium equi Magnusson 1923, even though Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 is a homotypic synonym. All names remain validly published, all are legitimate but only one is the correct name.

Should the type strain associated with Corynebacterium equi Magnusson 1923 be considered to be a member of the genus Rhodococcus and a distinct taxon from Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turfitt 1944) McClung 1974 then the correct name of the taxon is Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977. In this case, Corynebacterium equi Magnusson 1923 is both a homotypic synonym and basionym of Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977. All names remain validly published, all are legitimate, but only one is the correct name.

Should in either of the above cases the type strain of Nocardia restricta (Turfitt 1944) McClung 1974 be considered to be a member of the same species as the taxon treated as either Corynebacterium equi Magnusson 1923 or Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 then the principle of priority indicates that the epithet (in the corresponding combinations) equi has priority over restricta should the latter be placed in either the genus Corynebacterium or the genus Rhodococcus. All names remain validly published, all are legitimate, but only one is the correct name.

In contrast, if the type strain of the species Corynebacterium hoagii (Morse 1912) Eberson 1918 is placed in the same species as the type strain of the species Corynebacterium equi Magnusson 1923 then the principle of priority applies independently to the epithets and the correct name of the taxon is Corynebacterium hoagii (Morse 1912) Eberson 1918. The type of that taxon is the type of the species Corynebacterium hoagii (Morse 1912) Eberson 1918. All names remain validly published, all are legitimate, but only one is the correct name.

The same principle applies to the case where, should the type strain of the species Corynebacterium hoagii (Morse 1912) Eberson 1918 be placed in the same species as the type strain of the species Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 (of which Corynebacterium equi Magnusson 1923 is both a homotypic synonym and a basionym), then the principle of priority determines that the correct name of the taxon is ‘Rhodococcus hoagii’ (Morse 1912) and is further attributed to the authors making that proposal. Corynebacterium hoagii (Morse 1912) Eberson 1918 is both a homotypic synonym and a basionym, with the type of this species also serving as the type of ‘Rhodococcus hoagii’ (Morse 1912) Anon. All names remain validly published, all are legitimate, but only one is the correct name. However, a correct name cannot be selected because the name ‘Rhodococcus hoagii’ (Morse 1912) Anon has not been proposed or validly published, although the continued use of Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 for that taxon is contrary to the Rules of the Code.

A careful check of the literature published over the past 35 years indicates that Corynebacterium equi Magnusson 1923 has been considered to be more appropriately placed in the genus Rhodococcus as Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977. Although Goodfellow & Alderson (1977) indicated that the type strain of Nocardia restricta (Turfitt 1944) McClung 1974 should be placed in the same species as the type strain of Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977, it was only subsequently shown that the type strain of Corynebacterium hoagii (Morse 1912) Eberson should also be placed in the same species. While the synonymy of Nocardia restricta (Turfitt 1944) McClung 1974 and Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 is not problematic, apart from the fact that it is not immediately obvious that this has been stated at
least five times (directly and indirectly), the synonymy of Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 and Corynebacterium hoagii (Morse 1912) Eberson 1918 and placement of the latter in the genus Rhodococcus requires that the combination 'Rhodococcus hoagii' (Morse 1912) be created. In the original publication by Suzuki et al. (1981) where the key arguments were based on DNA–DNA hybridization, the authors do not clearly state that these two names are to be treated as synonyms, nor have the consequences (the creation of a new combination) been followed. Goodfellow et al. (1982b) were evidently aware of the publication by Suzuki et al. (1981) and that it provided support for their data and conclusions, correctly stating:

‘... although C. hoagii (Morse, 1912) Eberson 1918 has priority over C. equi Magnusson 1923, the former epithet is rarely cited in the literature while the latter is well known, widely used (Barton & Hughes, 1980) and needs to be conserved.’

The conservation of a name is a nomenclatural act that can only be implemented by the Judicial Commission and to date no action has been either formally requested or undertaken.

This issue of synonymy of Corynebacterium hoagii and Rhodococcus equi was also raised in Collins et al. (1982a), but not in Collins et al. (1982b):

‘Representatives of the first three species mentioned above form a single DNA homology group (Suzuki et al., 1981) and it has been proposed, on the basis of chemical, numerical phenetic and genetical data, that C. hoagii be reduced to a synonymy of R. equi (Goodfellow et al., 1982a).’

Goodfellow et al. (1982a) also provide an emended description of the species Rhodococcus equi although no clear mention is made of synonymy with Corynebacterium hoagii, Nocardia restricta or Corynebacterium equi; the authors conclude:

‘The inclusion of the type strain C. hoagii in the R. equi phenon is also consistent with the results of earlier studies (Goodfellow et al., 1981). It is timely to reclassify R. equi in the light of data derived in this and some recent studies.’

This paper is also cross referenced by Goodfellow (1987) but no specific mention is made in the text of the fact that Rhodococcus equi, Corynebacterium hoagii and Nocardia restricta had been treated as synonymy despite an emended description that appears to infer inclusion of Corynebacterium hoagii as part of the species Rhodococcus equi.

It is interesting to note that in both Bergey’s Manual of Systematic Bacteriology, volume 2 and volume 4, and Bergey’s Manual of Systematic Bacteriology, 2nd edition, volume 5A, the synonymy of Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977, Corynebacterium equi Magnusson 1923, Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turfitt 1944) McClung 1974 have all been clearly stated (Goodfellow, 1986, 1989; Jones and Goodfellow, 2012). In the 1986 edition of Bergey’s Manual of Systematic Bacteriology (Collins & Cummins, 1986) notes have been added to the entry under Corynebacterium hoagii, stating that:

‘Numerical phenetic (Goodfellow et al., 1982), mycolic acid (Collins et al., 1982a), fatty acid (Collins et al., 1982b) and DNA homology (Suzuki et al., 1981) studies indicate C. hoagii and Rhodococcus equi represents a single species. It is considered in this volume under R. equi.’ Page 1275

This issue of synonymy of Corynebacterium hoagii and Rhodococcus equi was also raised in Collins et al. (1982a) and Goodfellow et al. (1982b) and DNA homology (Suzuki et al., 1981) studies indicate C. hoagii and Rhodococcus equi represents a single species. It is considered in this volume under R. equi.’

Editorial notes have also been added to the entry under Rhodococcus equi in both volume 2 and volume 4 of the relevant chapters in Bergey’s Manual of Systematic Bacteriology (Goodfellow, 1986, 1989) stating:

‘Editorial note: Corynebacterium hoagii is considered a synonym; for further information see genus Corynebacterium.’ Page 1478

‘Editorial note: Corynebacterium hoagii is considered a synonym; for further information see genus Corynebacterium in Volume 2.’ Page 2368

These latter two chapters also clearly document the opinion that Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977, Corynebacterium equi Magnusson 1923, Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turfitt 1944) McClung 1974 are synonyms. However, the consequences of that synonymy have not been implemented.

The more recent edition of Bergey’s Manual of Systematic Bacteriology (Jones & Goodfellow, 2012) also clearly states that Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977, Corynebacterium equi Magnusson 1923, Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turfitt 1944) McClung 1974 are synonyms, but continues to use the name Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 contrary to the Rules of the Code.

Recent publications have also shown that the type strain of Corynebacterium hoagii (CIP 81.17 or ATCC 7005) is to be placed in the same taxon as the type of Rhodococcus equi (Khamis et al., 2004; Ruimy et al., 1995), while Corynebacterium hoagii appears as a distinct taxon in Lee et al. (2009), perhaps because the authors were unaware of the synonymy. Barrow & Feltham (2004) clearly refer to the fact that Rhodococcus equi, Corynebacterium equi and Corynebacterium hoagii are treated as synonyms.

It is confusing to note that while Goodfellow et al. (1998) recognize the synonymy of Rhodococcus equi and Nocardia restricta, no mention is made of the synonymy with Corynebacterium hoagii.

Recent publications (Jones et al., 2013a, b) dealing with the proposal to remove Rhodococcus equi from the genus
Rhodococcus do not appear to have used any of the type strains of either Corynebacterium hoagii or Nocardia restricta and there is no direct reference in the section dealing with the proposal of the new species combination to the fact either that the basonym of either ‘Prescottia equi’ or ‘Prescottella equi’ is Corynebacterium equi Magnusson 1923, that Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977 is a homotypic synonym, or that Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turffitt, 1944) McClung 1974 are heterotypic synonyms. However, Jones et al. (2013a) clearly reference publications where Rhodococcus equi, Corynebacterium hoagii or Nocardia restricta are treated as synonyms such as Jones and Goodfellow (2012), Goodfellow et al. (1982a, b) and McMinn et al. (2000) that in turn references Goodfellow et al. (1982a), while the protologue associated with the genus name ‘Prescottia’, which is also the protologue for the genus name ‘Prescottella’, specifically references Collins et al. (1982a). Note that the 16S rRNA gene sequence nucleotide signatures listed in table 2 of Jones et al. (2013a) also apply to the type strain of Corynebacterium hoagii.

This highlights two problems. In the case of the genus name ‘Prescottia’ Jones et al. 2013, it is illegitimate because it is a later homonym of both an orchid genus name, Prescottia Lindley 1824, and the insect genus name Prescottia Ball 1932, which also means that if the genus name could not serve as a correct name then nor could the associated species combination. In the case of the genus name ‘Prescottella’, there would appear to be no objections on the basis of homonymy, but the issue arises that if Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977, Corynebacterium equi Magnusson 1923, Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turffitt 1944) McClung 1974 are treated as synonyms, then the type and only species in the genus must be given the name ‘Prescottella hoagii’ (Morse 1912). Anon, with the type of the species being by definition the same as the type strain of Corynebacterium hoagii, the basonym of the species name. In the absence of any act to conserve the epithet equi in Rhodococcus equi over the older epithet hoagii as in ‘Rhodococcus hoagii’, as alluded to by Goodfellow et al. (1982b), the name Rhodococcus equi is not the correct name of the taxon. It should also be remembered that due consideration should be given to the conservation of the epithet equi in Rhodococcus equi over the epithet hoagii (as in ‘Rhodococcus hoagii’) and that this does not automatically extend to a new genus (Rule 56b), nor does the conservation of the epithet equi in ‘Prescottella equi’ over hoagii as in ‘Prescottella hoagii’ extend back to cover the conservation of one epithet over the other in the genus Rhodococcus. It is also unclear whether the Judicial Commission can act to conserve an epithet in the absence of any formal proposal to create either ‘Rhodococcus hoagii’ or ‘Prescottella hoagii’ as this anticipates something that has not taken place (Willems & Collins, 1994; Labeda, 1997). The Code is clear with regards the creation of a new combination that is illegitimate, where Rule 51b states:

‘Among the reasons for which a name may be illegitimate are the following.

2. If the author did not adopt for a binary or ternary combination the earliest legitimate generic name, specific epithet, or subspecific epithet available for the taxon with its particular circumscription, position, and rank.’

In the absence of any action to implement the conservation of one epithet over another the proposal to create the name ‘Prescottella equi’ is contrary to the Rules, resulting in an illegitimate name, which per definition may not be used. The valid publication of a genus name also requires the associated valid publication of at least the legitimate name (combination) of the type species.

The second problem that extends beyond the issue of nomenclature is one that is often overlooked and is the link between names and the taxonomic concepts/opinions and classification being used. If as stated in Principle 6 ‘each order or taxon of a lower rank with a given circumscription, position, and rank can bear only one correct name’ then it should be possible to determine each of these three parameters in each and every publication that uses the scientific names of organisms. While it is normally possible to determine the rank based on the use of names and their defined endings from genus to order, or the use of combinations at the rank of species (binary combinations) and subspecies (ternary combinations), the position within higher taxa may or may not be stated/implied. The question of circumscription is often addressed vaguely and is certainly not covered by citing the authors of the name, especially when new taxa have been added, additional data added, and emendations or taxonomic rearrangements have been made. In this particular case there is well-documented evidence that Rhodococcus equi (Magnusson 1923) Goodfellow and Alderson 1977, Corynebacterium equi Magnusson 1923, Corynebacterium hoagii (Morse 1912) Eberson 1918 and Nocardia restricta (Turffitt 1944) McClung 1974 are to be treated as synonyms by Jones et al. (2013a, b), but this is certainly not clearly stated. Jones et al. (2013a) make reference to Goodfellow et al. (1982a, b) and Jones & Goodfellow (2012) where the issues of synonymy are documented, as well as to McMinn et al. (2000) that cross references Goodfellow et al. (1982a). This problem is not restricted to this publication and is fairly widespread.

A further degree of uncertainty is introduced by Jones et al. (2013b) where the authors have used as a model text published by Greene et al. (2009). The problem that arises is that this text creates a validly published combination, Frondihabitans australicus (Zhang et al. 2007) Greene et al. 2009 because the original combination Frondicola australicus Zhang et al. 2007 is based on an illegitimate genus name. However, in the case of ‘Prescottella equi’
despite the fact that an illegitimate combination 'Prescottia equi' (Magnusson 1923) Jones et al. 2013 has been created there exists a validly published, legitimate basionym, Corynebacterium equi Magnusson 1923, a fact that can only be extracted from past work and references made in the main text of the paper by Jones et al. (2013a). It also follows that the citation 'Prescottella equi' (Jones et al. 2013) Jones et al. 2013 would falsely attribute the epithet equi to Jones et al. 2013a (although in the absence of the valid publication of 'Prescottia equi' this adds a further twist to the tale) instead of to the epithet equi as originally published in Corynebacterium equi Magnusson 1923, i.e. 'Prescottella equi' (Magnusson 1923) Jones et al. 2013. A more appropriate model text would be that dealing with the creation of the names Goodfellowia Labeda et al. 2008 and Goodfellowia coeruleoviolacea (Preobrazhenskaya and Terekhova 1987) Labeda et al. 2008, where in addition to the problem of the illegitimate genus name and species combinations Goodfellowia Labeda and Kroppenstedt 2006 and Goodfellowia coeruleoviolacea (Preobrazhenskaya and Terekhova 1987) Labeda and Kroppenstedt 2006 there also exist validly published, legitimate synonyms, namely Actinomadura coeruleoviolacea Preobrazhenskaya and Terekhova 1987 and Saccharothrix coeruleoviolacea (Preobrazhenskaya and Terekhova 1987) Kroppenstedt et al. 1991 (see Labeda et al., 2008). Here the synonyms are clearly stated and the basionym is correctly identified, although this would not cover the aspects of heterotypic synonyms that arise in this case.

There are a number of reasons for publishing this information and include the fact that the synonymy of Rhodococcus equi and Corynebacterium hoagii is not clearly documented in the IJSEM. While there are a number of instances where this synonymy has been documented, the consequences that the combination 'Rhodococcus hoagii' is to be created has never been undertaken (ignoring the fact that the parent genus name Rhodococcus Zopf 1891 is illegitimate because it is a later homonym of an algal genus name Rhodococcus Hansgirg 1884), nor have any steps been taken to conserve the epithet equi over hoagii for the taxon (species) that includes the type strains of the species Rhodococcus equi and Corynebacterium hoagii. Wisdom and balance are needed to solve the current problems.

It also needs to be emphasized that not all collections/ databases that refer to the name Corynebacterium hoagii document the synonymy with Rhodococcus equi and this issue has also appeared in recent publications. While the name Rhodococcus equi is associated with an animal and opportunistic human pathogen, the continued use of the name Corynebacterium hoagii (Dent and Williams, 1987; Viti et al., 2003; Atlas, 2004; Frederick et al., 2013) remains a problem, especially when synonymy is not recognized, with the name Corynebacterium hoagii only being recorded as a human pathogen, whereas Rhodococcus equi (Corynebacterium equi, Nocardia restricta) is recorded as both a human and more importantly an animal pathogen [Committee on Biological Agents – Ausschuss für Biologische Arbeitsstoffe (ABAS), 2010]. The current state of affairs would appear to be due to two main causes. One is the failure to implement the rules of the Bacteriological Code, with respect either to priority or to the possibility of the Judicial Commission acting to conserve a name/combination/epithet once synonymy has been recognized and it is considered prudent to make an exception to the Rules. Although the failure to deal with the creation of a new combination is the cause of the current problem, the failure to properly document both synonymy of names (when new combinations do not need to be created) and also changes in the way taxonomic concepts are applied (in particular the circumscription and description associated with a name/names) are loopholes in most Codes of Nomenclature. The first issue has been partly addressed by the publication of the 'Lists of Changes in Taxonomic Opinion' (Euzéby et al., 2004). The second issue is often considered to be solely one of taxonomic opinion (classification), but unless that is clearly expressed/documented it is often impossible to determine the basis for that opinion in any given publication. Since changes to the Code now state that 'names have meaning only in the context in which they were formed and used' (Tindall et al., 2008), it should be evident that their formation and use are tied to descriptions, circumscriptions and classification that may change over time, for which Codes currently do not have efficient methods of tracking.

One final point worth considering is the way the Code is implemented. Young (2009) has clearly indicated that illegitimate names are often used as if they are correct names, which implies that actions contrary to the Rules of the Code are acceptable. The subcommittee on the taxonomy of Agrobacterium and Rhizobium has also questioned a published opinion of the Judicial Commission (Tindall et al., 2008) advocating the use of a name in a fashion that does not reflect the correct name (Lindström and Young, 2009), a course of action questioned by Young (2010). There would appear to be two ways of dealing with such issues. One is to continue without paying due attention to the workings of the Code, a course of action that will certainly lead to an erosion in the value of the Code and it eventually being ignored. A return to a pre-1980 state is pre-programmed. The other way is to adhere as closely as possible to the Code and make use of all modern electronic tools available to us as well as drawing on the guidance of experts in the field. The IJSEM would be the ideal vehicle for the latter course of action. The IJSEM is the official journal of the ICSP, but there appears at present to be no clear policy as to whether the IJSEM is in any way bound by the wording of the Code or any policies formulated by the ICSP, its Judicial Commission or the ICSP executive board. Clarity is clearly needed if one is to deal with the issues raised here.

General Consideration 1 of the Code states:

'The progress of bacteriology can be furthered by a precise system of nomenclature accepted by the majority of bacteriologists of all nations.'
Precision is not only required at the level of nomenclature and the time is long overdue to consider changing the role of the ICSP in the context of an International Standards Organization (Garrity and Oren, 2013). This would of course also require that the expertise and authority of that organization be recognized.

Disclaimer

The author of this paper, as current chairman of the Judicial Commission, does not intend to express a particular taxonomic opinion and the purpose is to solely deal factually with issues relating to nomenclature that are subject to different taxonomic opinions. Readers should not infer that a particular taxonomy is endorsed.

Declaration of a potential conflict of interest

The author is employed by an organization that commercially offers both taxonomic services as well as biological material to the scientific community. This may be perceived as a potential conflict of interest.

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